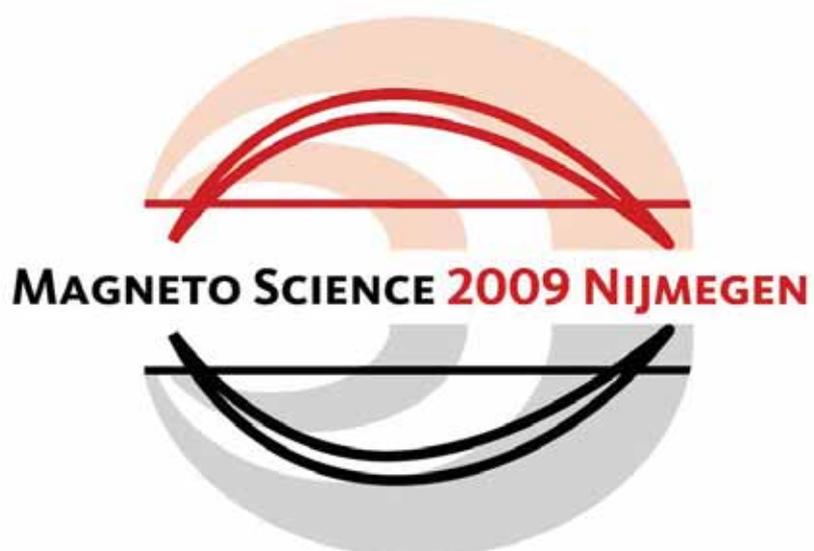


# Magneto Science 2009

3<sup>rd</sup> International Conference on Magneto Science

Magnetic Field Effects in Chemistry, Physics, Biology  
and Related Phenomena



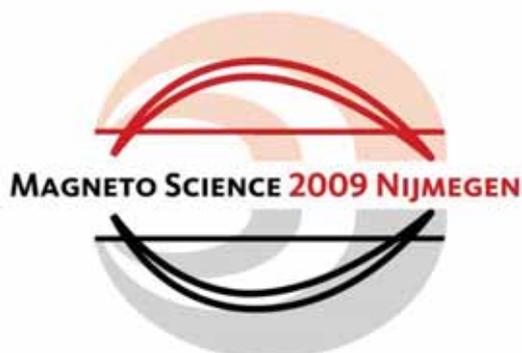
University Auditorium Radboud University Nijmegen  
Nijmegen, The Netherlands  
October 26-29, 2009

## Preface

On behalf of the organizing committee I would like to welcome all participants to the **3<sup>rd</sup> International Conference on Magneto Science**, held at the Radboud University Nijmegen, the Netherlands, from October 26<sup>th</sup> to 29<sup>th</sup> 2009.

Magneto Science 2009 is a continuation of a successful conference series in Japan. In 2005, the first International Symposium on Magneto Science was organized in Yokohama by Professor Masuhiro Yamaguchi. Two years later, in 2007, the International Conference on Magneto Science was held in Hiroshima with Professor Yoshifumi Tanimoto as chair of the organizing committee. In an attempt to further enhance the international character of this conference series, this year the Nijmegen High Field Magnet Laboratory (HFML) hosts the first Magneto Science conference outside Japan. We are extremely pleased to welcome all new, mostly European, researchers that have not attended the first two meetings, as well as our old friends from Japan, China and many other places around the world.

The aim of the meeting has not been changed: to bring together a large number of world-leading scientists in the field of Magneto Science; to provide a timely update of this relatively new research area; to generate new ideas; and to initiate new collaborations amongst the participants. The conference will cover a broad range of exciting topics: magnetic field effects on chemical, physical and biological phenomena, magnetic processing of materials, diamagnetic levitation, magnetic orientation, the magneto-Archimedes effect, spin chemistry, magneto-thermodynamic effects, magneto-electro-chemistry, micro-MHD effect, magnetic separation and purification, magneto-crystallization, magnetic field induced phase transitions, material properties in high magnetic fields, novel magnetic phenomena, magneto-biology and magneto-reception.



I wish you a very successful conference and a great time in Nijmegen

Nijmegen, October 2009

Peter Christianen  
Chair of the Organizing Committee

## Contents

Preface .....	1
Conference details .....	3
Instructions for Presentations.....	8
General Information.....	8
Conference Time Table.....	10
Scientific Program .....	11
Abstracts .....	27
Author Index .....	115
List of Participants.....	117

**Magneto Science 2009 is sponsored by:**



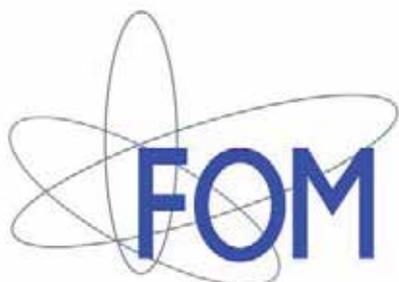
*Science in High Magnetic Fields*

High Field Magnet Laboratory

[www.hfml.science.ru.nl](http://www.hfml.science.ru.nl)



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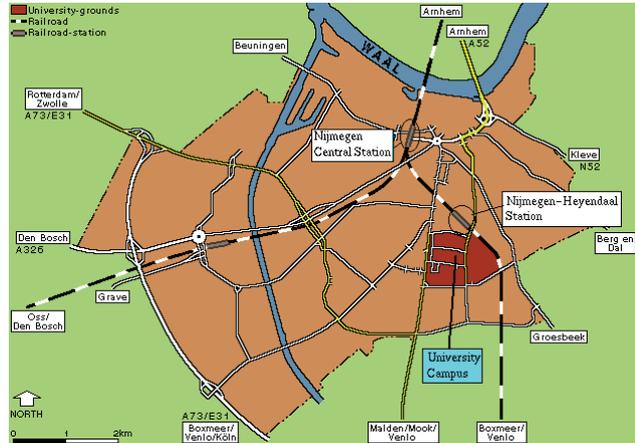
## Conference details

### Conference Venue

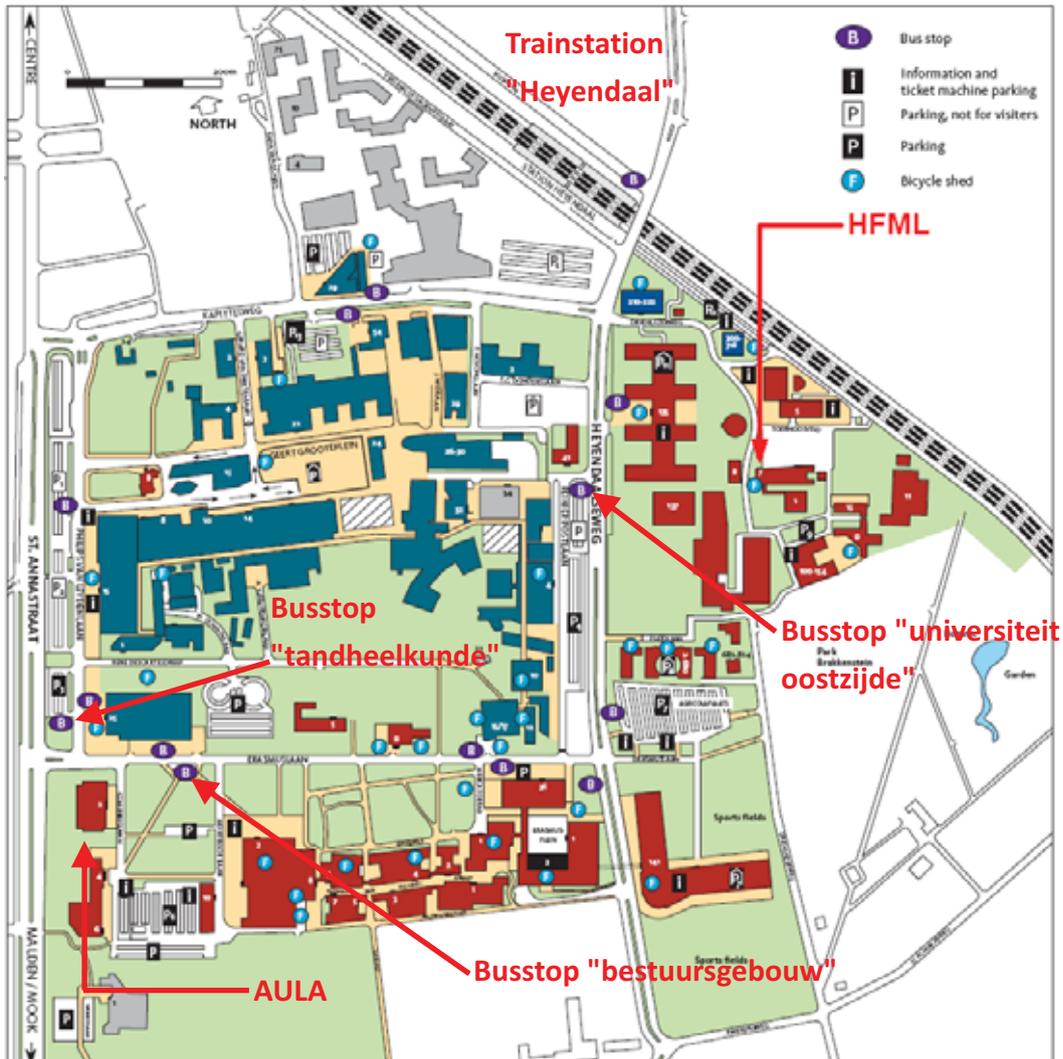
The conference will be held at the **University Auditorium (AULA)**, situated at the campus of the Radboud University Nijmegen at the following address:

Comeniuslaan 2  
6525 HP Nijmegen  
Phone: +31 (0)24 3612156  
Fax: +31 (0)24 3567956

Map of Nijmegen



Map of Campus:



### **Access to the AULA (see map of campus)**

From the Nijmegen **central railway station** (Mercure hotel, Apollo hotel) or **Nijmegen city center**, "plein 1944" (Atlanta Hotel):

- take bus Novio line 3 or 4 to "Wijchen", exit at bus stop "Bestuursgebouw" (Erasmuslaan), or
- take bus Novio line 6 to "Brabantse poort", exit at bus stop "Tandheelkunde" (Philips van Leydenlaan), or
- take bus Novio line 10 to "HAN" or "Heyendaal", exit at bus stop "Bestuursgebouw" (Erasmuslaan), or
- take bus Novio line 11 to "Beuningen", exit at bus stop "Bestuursgebouw" (Erasmuslaan), or
- take bus Hermes line 83 to "Gennepe" or "Venlo", exit at bus stop "Tandheelkunde" (Philips van Leydenlaan)"

From **mr. Franckenstraat** (Hotel Belvoir)

- take bus Novio line 3 or 4 to "Wijchen", exit at bus stop "Bestuursgebouw" (Erasmuslaan)

From the bus stop it is a few minutes walk to the AULA.

### **Access to the High Field Magnet Laboratory (HFML) (see map of campus)**

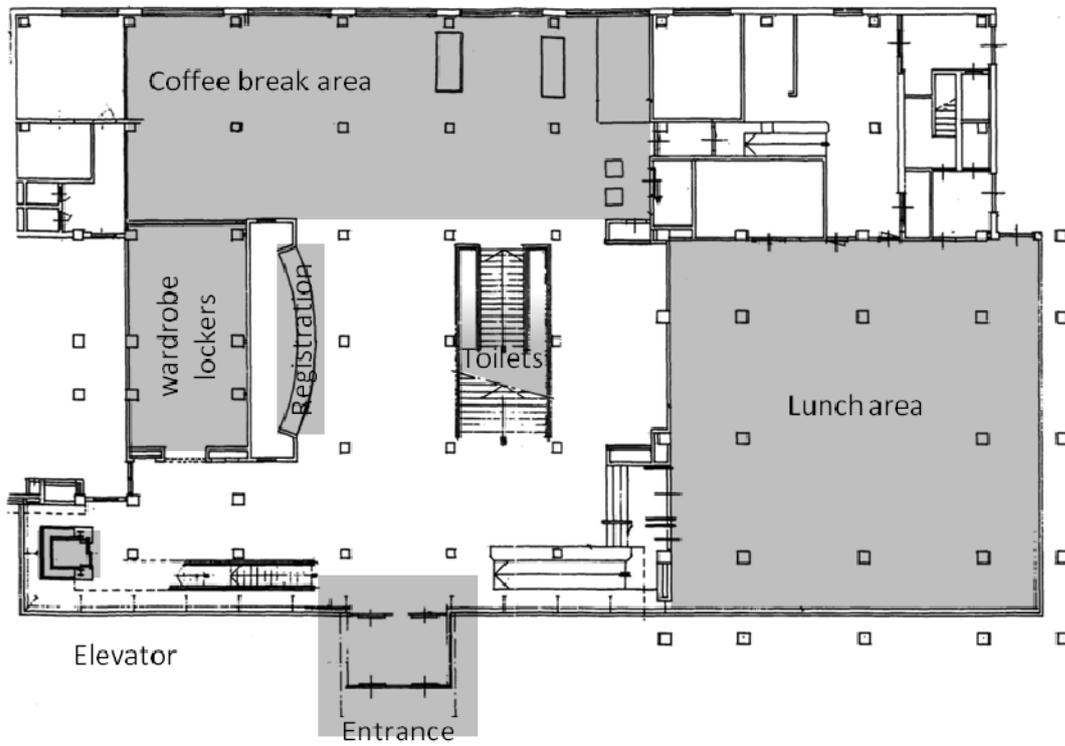
- Take bus Novio lines 3, 4, 10 or 11 (see above) that also stop at "Universiteit, Oostzijde", from which it is a few minutes walk to the HFML.
- Take the train from the central railway station to station "Heyendaal", from which it is a 5 minutes walk to the HFML.

### **Bus Tickets**

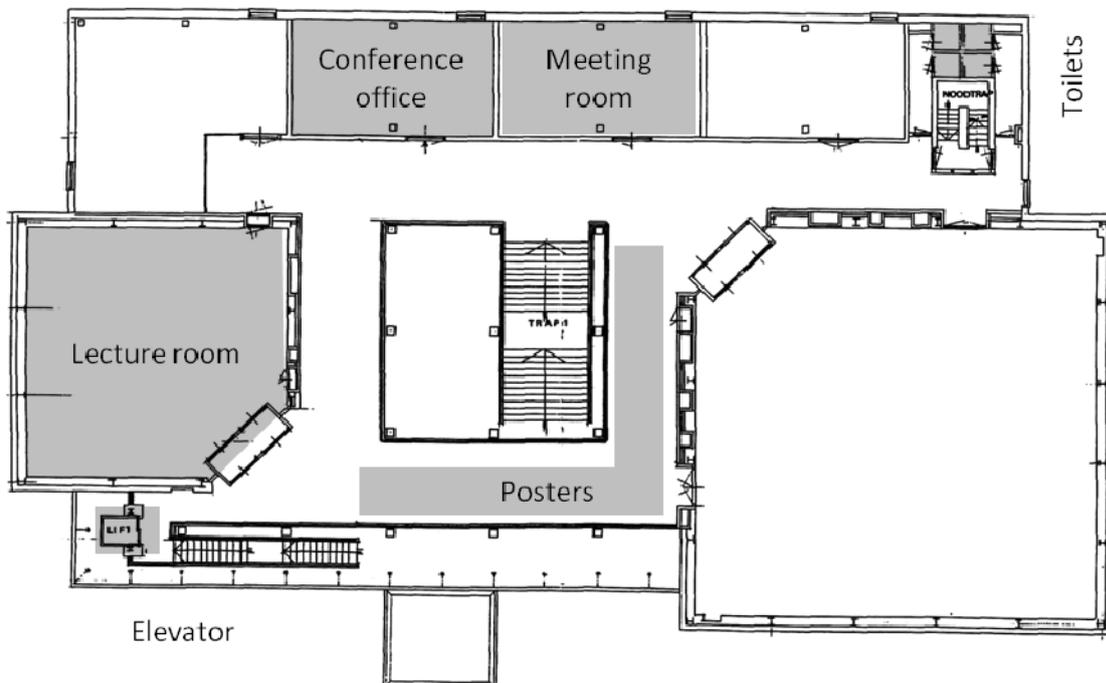
Bus tickets can be bought on the bus from the driver, but it's easier and cheaper to buy a "national strippenkaart" in advance. This blue 15 unit-ticket (for adults) costs about seven Euros. "Strippenkaarten" are sold at tobacconists and train and bus stations. A limited amount of "strippenkaarten" can be bought at the conference office/registration desk.

## Overview of the AULA

### Ground floor



### First floor



### **Conference Office**

The conference office is situated in the "Mohrman kamer" at the first floor of the AULA. It is open at conference days from 09:00-17:00 h (Monday, Tuesday, Thursday) or 09:00-13:00 h (Wednesday).

### **Registration**

The registration desk is open at:

- Sunday afternoon (October 25<sup>th</sup>) from 16:00-19:00 at the Welcome Party at the High Field Magnet Laboratory (HFML), Toernooiveld 7, 6525 ED Nijmegen.
- Monday morning (October 26<sup>th</sup>) from 08:45-10:00 before the first scientific session at the conference venue (AULA).
- Throughout the conference at the conference office.

Upon registration you will receive your conference bag, including your name badge, a conference booklet, tickets for the excursion/banquet, a map of Nijmegen and a receipt for the conference fee. Please wear your badge whenever you are at the conference site.

<b>Conference Fees:</b>	<b>Rate:</b>	<b>Includes:</b>
Before September 21 <sup>st</sup> 2009	€400, -	<ul style="list-style-type: none"><li>• Welcome reception @ HFML</li><li>• Access to scientific sessions</li><li>• Refreshments during the breaks</li><li>• Lunches</li><li>• Farewell party @ HFML</li></ul>
After September 21 <sup>st</sup> 2009	€450, -	
On-site registration (cash only)	€500, -	
Excursion and banquet	€100, -	
Accompanying person	€125, -	<ul style="list-style-type: none"><li>• Welcome reception @ HFML</li><li>• Refreshments during the breaks</li><li>• Lunches</li><li>• Farewell party @ HFML</li></ul>

### **Wireless Internet**

During the days of the conference wireless LAN internet is freely available throughout the AULA. With the login name and password you received, you can connect to the wireless network "ru-guest" in and nearby the AULA, and near the Linnaeus building which is close to the HFML. This is an open network: no encryption, no 802.1X, and, at first, no authentication. You should be able to connect to this network without any problem; your wireless adapter will then have the status "connected".

In order to continue, you should first use your internet browser to connect to any URL, and you will be redirected to the login page of "wireless guest access". Here you can login using

the supplied name and password. If successful, you will receive a logout page saying "Login successful". It is wise to leave this page open as long as you use the internet. You will not be redirected automatically to the URL you typed; instead, you should open a second browser window or tab to start your internet session. Be aware of the fact that the connection is not secure.

You are expected to logout at the end of your internet session. If you accidentally closed the logout page, you can surf to <https://1.1.1.1/logout.html> to log off. If you have any questions, please contact dr. Hans Engelkamp.

### **Lunch**

Lunches are included in the conference fee of participants and accompanying persons. Each conference day the lunch is served from 12:30-14:00 h in the "Anton van Duinkerkenzaal" at the ground floor of the AULA.

### **Welcome Party - Sunday October 25<sup>th</sup>: 16:00-19:00**

All participants and accompanying persons are cordially invited, on Sunday afternoon, to join the welcome party at the High Field Magnet Laboratory, Toernooiveld 7, 6525 ED Nijmegen. The party starts at 16:00 hours.

Food (buffet) and drinks will be served, the registration desk will be open and the high magnet field installation and the experimental facilities can be viewed via guided tours.

### **Excursion/Banquet**

The excursion consists of a trip to the Kröller–Müller Museum, located in the Hoge Veluwe National Park. A magnificent amalgamation of art, architecture and nature. Amidst unspoilt natural surroundings, the Kröller–Müller Museum's collection centres on the extensive collection of works by Vincent van Gogh and the world famous sculpture garden. The bus will leave the AULA at 14:00 h.

The conference dinner will take place at restaurant Wijnfort, located in Lent across the river Waal.

Tickets for the Excursion/Banquet can be purchased till Monday afternoon.

### **Farewell Party – Thursday October 29<sup>th</sup>: 18:00-21:00**

All participants and accompanying persons are cordially invited, on Thursday evening, to join the farewell party at the High Field Magnet Laboratory, Toernooiveld 7, 6525 ED Nijmegen. The party starts at 18:00 hours, immediately after the final scientific session.

Food (buffet) and drinks will be served and the magnet field installation and experimental facilities can be visited via guided tours.

## **Conference Proceedings**

There will be no conference proceedings.

## **Instructions for Presentations**

### **Oral presentations**

The scientific program consists of invited and contributed talks which will be presented in the "Senaatzaal" at the first floor of the AULA. Time slots are 30 minutes (25 min. + 5 min. discussion) for invited talks, and 20 minutes (15 min. + 5 min. discussion) for contributed talks. All speakers are kindly asked to keep strictly to the time allotted for their talk.

A beamer with 1024 x 768 screen resolution will be used. Speakers may use the supplied computer running Windows XP, Service Pack 3 (English Version) and Powerpoint 2007, or use their own computer. In all cases the speakers are requested to test their presentation in the lecture room well in advance of the start of their session. In case of any problem, please contact dr. Hans Engelkamp.

### **Poster presentations**

Poster sessions will take place on Tuesday (14:00 – 15:30, session I) and Wednesday (11:00 - 12:30, session II). The board size is 90 cm wide and 200 cm high. The poster sessions will take place around the Vide at the first floor of the AULA, just outside the lecture room. The posters can be mounted at the beginning of the day of the respective poster session and should be removed at the end of the poster session. Mounting material will be provided by the conference organization.

## **General Information**

### **Organizing Committee**

Peter Christianen (Chair)

Hans Engelkamp

Jan Kees Maan (Chair Program committee)

Ine Verhaegh – Conference Office

### **Conference Office**

HFML Secretariat

Phone: +31 (0)24 3652087

Toernooiveld 7

Fax: +31 (0) 24 3652440

6525 ED Nijmegen

Email: [magnetoscience@science.ru.nl](mailto:magnetoscience@science.ru.nl)

The Netherlands

Web: [www.hfml.science.ru.nl/magnetoscience2009](http://www.hfml.science.ru.nl/magnetoscience2009)

During the conference the conference office is situated in the "Mohrmann kamer" (1<sup>st</sup> floor AULA). Opening hours: 9:00-17:00 (Mon., Tues., Thurs.) and 09:00-13:00 (Wedn.).

### **Programme committee**

Eric Beaugnon – Grenoble, France  
Laurence Eaves – Nottingham, UK  
Peter J. Hore – Oxford, UK  
Tsunehisa Kimura – Kyoto, Japan  
Jan Kees Maan (Chair) – Nijmegen, The Netherlands  
Iwao Mogi – Sendai, Japan  
James Valles – Providence, USA

### **International Advisory Board ICMS**

Eric Beaugnon – Grenoble, France  
Andreas Bund – Dresden, Germany  
Peter J. Hore – Oxford, UK  
Tsunehisa Kimura – Kyoto, Japan  
Jan Kees Maan – Nijmegen, The Netherlands  
Sumio Ozeki – Matsumoto, Japan  
Zhongming Ren – Shanghai, China  
Justin Schwartz – Tallahassee, USA  
Peng Shang – Xian, China  
Dmitri V. Stass – Novosibirsk, Russia  
Yoshifumi Tanimoto – Osaka, Japan  
Hitoshi Wada – Kashiwa, Japan  
Masuhiro Yamaguchi (Chair) – Yokohama, Japan

## Overall Time Table

		<b>Auditorium Radboud University Nijmegen</b>				
	Sunday 25/10	Monday 26/10	Tuesday 27/10	Wednesday 28/10	Thursday 29/10	
09:00		Registration Opening <b>Magnetophoresis</b> <b>H. Watarai</b> N. Pamme	<b>Magnetic Processing II</b> <b>C. Esling</b> K. Koyama T. Gracin T.T.A. Lummen	<b>Spin Chemistry</b>  <b>P.J. Hore</b> S. Basu R. Morgunov D.V. Stass	<b>Biological Systems I</b> <b>H. Mouritsen</b> U. Shevchenko J. van Loon R. Herranz	
10:30		Coffee Break	Coffee Break	Coffee Break	Coffee Break	
11:00		<b>Magnetic Processing I</b> <b>N. van Dijk</b> Y Zhong Y. Mitsui E. Beaugnon	<b>Magnetic Levitation</b> <b>D.-C. Yin</b> C. Uyeda P. Shang <b>R.J.A. Hill</b>	<b>Poster Session II</b>	<b>Magnetic Orientation</b> <b>T. Kimura</b> M. Yamaguchi N. Ubrig <b>W. Bras</b>	
12:30		Lunch Break	Lunch Break	Lunch Break	Lunch Break	
14:00		<b>Magneto Electro-Chemistry</b> <b>J.-P. Chopart</b> G. Mutschke I. Mogi R. Aogaki	<b>Poster Session I</b>	Conference Excursion Kröller-Müller Museum	<b>Biological Systems II</b> <b>J.M. Valles</b> J. Torbet M. Iwasaka Y. Fujiwara	
15:30		Coffee Break	Coffee Break		Coffee Break	
16:00		Welcome Party @HFML Registration Buffet, Drinks HFML Labtours	<b>Magnetic Field Effects I</b> <b>S. Ozeki</b> Y.B. Borozdina R. Sueptitz J.M.D. Coey	<b>Magnetic Field Effects II</b> <b>N. Hirota</b> I. Yamamoto C. Uyeda T. Weier		<b>Magneto-Chemistry</b> <b>J.C. Gielen</b> L. Monsù Scolaro E. Kampert Y. Tanimoto
17:30						
18:00					Conference Banquet Wijnfort Lent	Farewell Party @HFML Buffet, Drinks HFML Labtours
19:00						
22:00						

## Scientific Program Magneto Science 2009

### October 25<sup>th</sup>. (Sunday)

16:00 – 19:00 Welcome party @ High Field Magnet Laboratory (HFML)  
Registration, drinks & buffet, HFML lab tour

### October 26<sup>th</sup>. (Monday)

08:45 – 09:30 Registration  
09:30 Conference Opening

#### Session 1                      Magnetophoresis                      Chair: M. Yamaguchi

09:40    1-1    **Dynamic force analysis of chemical bonding with electromagneto-buoyancy**, H. Watarai, T. Kato  
*Department of Chemistry, Graduate School of Science, Osaka University, Japan*

10:10    1-2    **Magnetic forces for the versatile manipulation of diamagnetic and paramagnetic particles in microfluidic devices**, S.A. Peyman, O. Margaron, A. Iles, N. Pamme  
*University of Hull, United Kingdom*

10:00                      Coffee break

#### Session 2                      Magnetic Processing I                      Chair: C. Esling

11:00    2-1    **Strong acceleration of the isothermal martensitic transformation kinetics in high magnetic fields**, N.H. van Dijk<sup>a</sup>, S. San Martin<sup>b</sup>, E. Jiménez-Melero<sup>a</sup>, E. Kampert<sup>c</sup>, U. Zeitler<sup>c</sup>, S. van der Zwaag<sup>d</sup>

<sup>a</sup>*Fundamental Aspects of Materials and Energy, Faculty of Applied Sciences, Delft University of Technology, the Netherlands*

<sup>b</sup>*MATERIALIA group, Departamento de Metalurgia Física, Centro Nacional de Investigaciones Metalúrgicas, Madrid, Spain*

<sup>c</sup>*High Field Magnet Laboratory, IMM, Radboud University Nijmegen, the Netherlands*

<sup>d</sup>*Fundamentals of Advanced Materials, Faculty of Aerospace Engineering, Delft University of Technology Delft, the Netherlands*

- 11:30 2-2 **Investigation on solidification of metals under a strong magnetic field**, Yunbo Zhong<sup>a</sup>, Zhongmin Ren<sup>a</sup>, Xi Li<sup>a,b</sup>, Weili Ren<sup>a</sup>, Jianbo Yu<sup>a</sup>, Y. Fautrelle<sup>b</sup>  
<sup>a</sup>*Lab. of Metallurgy and Materials Processing, Shanghai University, P.R. China*  
<sup>b</sup>*EPM-Madylam CNRS, France*
- 11:50 2-3 **Performance test for a high field powder X-ray diffraction camera**, Y. Mitsui<sup>a</sup>, K. Koyama<sup>a</sup>, K. Takahashi<sup>a</sup>, A. Fujita<sup>b</sup>, K. Watanabe<sup>a</sup>  
<sup>a</sup>*HFLSM, IMR, Tohoku University, Sendai Japan*  
<sup>b</sup>*School of Engineering, Tohoku University, Sendai Japan*
- 12:10 2-4 **Magnetic force effect on solid state crystal growth**, E. Beaunon<sup>a, b</sup>, S. Rivoirard<sup>a</sup>, H. Rui<sup>c</sup>  
<sup>a</sup>*CNRS/CRETA, Grenoble, France*  
<sup>b</sup>*University Joseph Fourier, Grenoble, France*  
<sup>c</sup>*Northwestern Polytechnical University, Xian, P.R. China*
- 12:30 Conference photo  
Lunch
- Session 3 Magneto Electrochemistry Chair: Y. Tanimoto**
- 14:00 3-1 **Electrochemical crystallization in high magnetic fields**, J.-P. Chopart<sup>a</sup>, A. Levesque<sup>a</sup>, A-L. Daltin<sup>a</sup>, S. Chouchane<sup>b</sup>  
<sup>a</sup>*LACMDTI, URCA, Reims, France*  
<sup>b</sup>*Faculté des Sciences, Université Badji Mokhtar, Annaba, Algeria*
- 14:30 3-2 **Numerical and experimental results on copper electrolysis in homogeneous and inhomogeneous magnetic fields**, G. Mutschke<sup>a</sup>, T. Weier<sup>b</sup>, P. Schäfer<sup>a, b</sup>, A. Hess<sup>a, b</sup>, A. Bund<sup>c</sup>, J. Fröhlich<sup>a</sup>  
<sup>a</sup>*Institute of Fluid Mechanics, Dresden University of Technology, Dresden, Germany*  
<sup>b</sup>*Forschungszentrum Dresden-Rossendorf, Dresden, Germany*  
<sup>c</sup>*Department Physical Chemistry. Electrochemistry., Dresden University of Technology, Germany*
- 14:50 3-3 **Magnetochemical chirality and micro-MHD effect in Ag electrodeposition**, I. Mogi, K. Watanabe  
*Institute for Materials Research, Tohoku University, Sendai, Japan*

- 15:10 3-4 **Mechanism of the chirality in magnetoelectrodeposition**, R. Aogaki<sup>a</sup>,  
R. Morimoto<sup>b</sup>, A. Sugiyama<sup>c</sup>, M. Asanuma<sup>d</sup>  
<sup>a</sup>*Polytechnic University, Kanagawa, Japan*  
<sup>b</sup>*Saitama Industrial Technology Center, Kawaguchi-shi, Saitama, Japan*  
<sup>c</sup>*Waseda Institute for Advanced Study, Tokyo, Japan*  
<sup>d</sup>*Yokohama Harbor Polytechnic College, Yokohama, Japan*
- 15:30 Coffee break
- Session 4**                      **Magnetic Field Effects I**                      **Chair: D. Stass**
- 16:00 4-1 **Properties of water interacting with magnetic fields**, S. Ozeki  
*Department of Chemistry, Shinshu University, Nagano, Japan*
- 16:30 4-2 **Design and Magnetic Studies of Novel Nitronyl Nitroxide Radicals**,  
Y.B. Borozdina<sup>a</sup>, B. Wolf<sup>b</sup>, C.T. Pham<sup>b</sup>, K. Remović-Langer<sup>b</sup>, M. Lang<sup>b</sup>,  
M. Baumgarten<sup>a</sup>  
<sup>a</sup>*Max-Planck-Institut für Polymerforschung, Mainz, Germany*  
<sup>b</sup>*Phys. Institut, J.W. Goethe-Universität Frankfurt, Germany*
- 16:50 4-3 **Magnetic field induced corrosion patterning of ferromagnetic electrodes**, R. Sueptitz<sup>a</sup>, J. Koza<sup>a</sup>, M. Uhlemann<sup>a</sup>, A. Gebert<sup>a</sup>, L. Schultz<sup>a</sup>,  
X. Yang<sup>b</sup>, K. Eckert<sup>b</sup>  
<sup>a</sup>*Leibniz Institute for Solid State and Materials Research IFW Dresden, Germany*  
<sup>b</sup>*Technical University Dresden, Institute for Fluid Dynamics, Germany*
- 17:10 4-4 **Maxwell stress in paramagnetic liquid tubes**, J.M.D. Coey, P. Stamenov  
*School of Physics and CRANN, Trinity College, Dublin, Ireland*

October 27<sup>th</sup>. (Tuesday)

Session 5	Magnetic Processing II	Chair: E. Beaugnon
09:00	<b>5-1</b> <b>Microstructure control by magnetic field during thermo-treatment of metallic materials – a review</b> , <u>C. Esling</u> <sup>a</sup> , Y.D. Zhang <sup>a</sup> , X. Zhao <sup>b</sup> , L. Zuo <sup>b</sup> <sup>a</sup> LETAM, CNRS-FRE 3143, University of Metz, France <sup>b</sup> Key Laboratory (Northeastern University), Ministry of Education, Shenyang P. R. China	
09:30	<b>5-2</b> <b>Differential thermal analysis of MnBi under high magnetic fields up to 26 T</b> , <u>K. Koyama</u> , Y. Ikehara, Y. Mitsui, K. Watanabe <i>High Field Laboratory for Superconducting Materials, Institute for Materials Research, Tohoku University, Sendai, Japan</i>	
09:50	<b>5-3</b> <b>Experimental analysis of the austenite to ferrite transformation in Fe-C-Mn alloys under high magnetic field</b> , <u>T. Garcin</u> <sup>a</sup> , S. Rivoirard <sup>a</sup> , P. Pouteau <sup>b</sup> , E. Beaugnon <sup>a</sup> <sup>a</sup> CNRS/CRETA, Grenoble cedex9, France <sup>b</sup> CRM Gent, Zwijnaarde, Belgium	
10.10	<b>5-4</b> <b>Competing interactions in the frustrated metamagnet CuFeO<sub>2</sub></b> , <u>T.T.A. Lummen</u> <sup>a</sup> , C. Strohm <sup>b</sup> , H. Rakoto <sup>c</sup> , A. Nugroho <sup>d</sup> , P.H.M. van Loosdrecht <sup>a</sup> <sup>a</sup> Zernike Institute for Advanced Materials, Groningen, The Netherlands <sup>b</sup> Institut Néel, Grenoble Cedex 9, France <sup>c</sup> Laboratoire National des Champs Magnétiques Pulsés, Toulouse, France <sup>d</sup> Institut Teknologi Bandung, Bandung, Indonesia	
10:30	Coffee break	
Session 6	Magnetic Levitation	Chair: T. Kimura
11:00	<b>6-1</b> <b>Progress of protein crystallization in high magnetic field in NWPU</b> , <u>D.-C. Yin</u> <sup>a, b</sup> , Y-Z. Guo <sup>a, b</sup> , Q-Q. Lu <sup>a, b</sup> , Z-K. Wang <sup>a, b</sup> , P. Shang <sup>a, b</sup> , N.I. Wakayama <sup>c</sup> <sup>a</sup> Key Laboratory for Space Bioscience & Biotechnology, Northwestern Polytechnical University, Shaanxi, Xi'an, P.R. China <sup>b</sup> Institute of Special Environmental Biophysics, Northwestern Polytechnical University, Shaanxi, Xi'an, P.R. China	

<sup>c</sup>*Tsukuba Magnet Laboratory, Tsukuba, Ibaraki, Japan*

- 11:30 **6-2** **Dynamic motions of small diamagnetic particles induced by static field in microgravity condition; examination of mass dependence**, C. Uyeda, K. Hisayoshi, S. Kanou  
*Graduate School of Science, Osaka University, Toyonaka, Osaka, Japan*
- 11:50 **6-3** **Progress of biological effects and molecular mechanisms under diamagnetic levitation condition**, P. Shang, A-R. Qian, Z-C. Tian, R. Meng, D-C. Yin  
*Institute of Special Environmental Biophysics, Northwestern Polytechnical University Xi'an, P.R. China*
- 12:10 **6-4** **The shapes of levitating and spinning water droplets**, R.J.A. Hill, L. Eaves  
*School of Physics and Astronomy, University of Nottingham, Nottingham, United Kingdom*
- 12:40 Lunch
- 14:00 **Poster Session I**
- PI-01 **Additives effects on magnetic orientation of helical and membrane mesoporous silica**, A. Hamasaki<sup>a</sup>, Y. Yamane<sup>a</sup>, K. Kubota<sup>a</sup>, H. Abe<sup>b</sup>, S. Ozeki<sup>a</sup>  
<sup>a</sup>*Department of Chemistry, Shinshu University, Nagano, Japan*  
<sup>b</sup>*National Institute for Materials Science, Tsukuba, Japan*
- PI-02 **Organization and orientation of gold nanorods on a substrate using a strong magnetic field**, H. Yonemura<sup>a</sup>, J. Suyama<sup>b</sup>, N. Sakai<sup>c</sup>, T. Arakawa<sup>b</sup>, S. Yamada<sup>a</sup>  
<sup>a</sup>*Department of Applied Chemistry, Kyushu University, Fukuoka, Japan*  
<sup>b</sup>*Department of Materials Physics and Chemistry, Kyushu University, Fukuoka, Japan*  
<sup>c</sup>*Department of Materials Science and Engineering, Kyushu University, Fukuoka, Japan*
- PI-03 **Two-dimensional simulation of laser-induced convection of benzene solution in high magnetic fields**, R. Nishikiori<sup>a, b</sup>, S. Morimoto<sup>a</sup>, Y. Tanimoto<sup>a</sup>, Y. Fujiwara<sup>b</sup>  
<sup>a</sup>*Faculty of Pharmacy, Osaka Ohtani University, Japan*  
<sup>b</sup>*Graduate School of Science, Hiroshima University, Japan*

- PI-04 **Effluence of a Magnetic-Field-Assisted Solvo/Hydro-thermal Synthesis on one dimensional nano-structure of Te**, Weili Ren, Yongbin Xu, Zhongming Ren, Chunxia Cheng, Kang Deng, Zhong Yunbo  
*Shanghai Key Laboratory of Modern Metallurgy & Materials Processing, Shanghai University, Japan*
- PI-05 **Formation and disappearance of magnetized nano-bubble water under the pulsed-magnetic field**, K. Uehara<sup>a</sup>, Y. Yano<sup>b</sup>  
<sup>a</sup>*Research Institute of Advanced Science and Technology, Sakai, Japan*  
<sup>b</sup>*Micro-Energy Institute, Tokyo, Japan*
- PI-06 **DNA Electromagneticphoresis under the Condition of B.IE**, S. Ozawa<sup>a</sup>, D. Kurosaka<sup>a</sup>, C. Tanaka<sup>a</sup>, I. Yamamoto<sup>a</sup>, T. Takamasu<sup>b</sup>  
<sup>a</sup>*Department of Physics, Yokohama National University, Japan*  
<sup>b</sup>*National Institute for Materials Science, Tsukuba, Japan*
- PI-07 **Magnetic quenching of light scattering in red chromatophore of gold fish scale**, M. Iwasaka<sup>a</sup>, K. Suzuki<sup>b</sup>  
<sup>a</sup>*Chiba University, Japan*  
<sup>b</sup>*The University of Tokyo, Japan*
- PI-08 **Diamagnetic levitation affects structure and function of bone cells**, A.-R. Qian, W. Zhang, X. Gao, L-F. Hu, R. Meng, P. Shang  
*Institute of Special Environmental Biophysics, Northwestern Polytechnical University Xi'an, P.R. China*
- PI-09 **Control of three-dimensional orientation of carbon nanotubes in magnetic microgravity**, A. Katsuki<sup>a</sup>, H. Takeuchi<sup>b</sup>, M. Fujiwara<sup>b</sup>, Y. Fujiwara<sup>b</sup>, Y. Tanimoto<sup>c</sup>  
<sup>a</sup>*School of General Education, Shinshu University, Nagano, Japan*  
<sup>b</sup>*Graduate School of Science, Hiroshima University, Japan*  
<sup>c</sup>*Department of Pharmacy, Osaka Ohtani University, Japan*
- PI-10 **Effects of hypomagnetic field on bone remodel of hind-limb unloading in rats**, B. Jia, Q. Zheng, P-F. Yang, L. Xie, P. Shang  
*Key Laboratory for Space Bioscience and Biotechnology, Northwestern Polytechnical University Xi'an, P.R. China*
- PI-11 **Magnetic alignment of amorphous polymers**, L. Garrido  
*Departamento de Química Física, Instituto de Ciencia Tecnología de Polímeros, Madrid, Spain*
- PI-12 **Tuning the flexibility of thiocyanine fibers with a magnetic field**, K. Takazawa<sup>a</sup>, J.C. Gielen<sup>b</sup>, I.O. Shklyarevskiy<sup>b</sup>, G. Portale<sup>c</sup>, W. Bras<sup>c</sup>, J.C. Maan<sup>b</sup>, P.C.M. Christianen<sup>b</sup>

<sup>a</sup>National Institute for Materials Science, Tsukuba, Japan

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<sup>c</sup>Netherlands Organisation for Scientific Research (NWO), DUBBLE@ESRF, Grenoble, France

- PI-13 **Effects of high magneto-gravitational environment on silkworm embryo-genesis and gene expression**, Z. Tian, A. Qian, H. Xu, Z. Wang, S. Di, W. Zhang, M. Luo, J. Han, Y. Huang, P. Shang  
<sup>a</sup>Key Laboratory for Space Biosciences and Biotechnology, Northwestern Polytechnical University Xi'an, P.R. China  
<sup>b</sup>Institute of Plant Physiology and Ecology, Chinese Academy of Sciences, Shanghai, P.R. China
- PI-14 **Magnetic field polymerization**, A.P. Chiriac, L.E. Nita  
*"Petru Poni" Institute of Macromolecular Chemistry, Iasi, Romania*
- PI-15 **Pulsed magnetic field effects on ice crystal formation**, M. Iwasaka<sup>a</sup>, S. Kurita<sup>b</sup>, N. Owada<sup>b</sup>  
<sup>a</sup>Chiba University, Japan  
<sup>b</sup>ABI Co. LTD, Abiko, Japan
- PI-16 **Electrodeposition in inhomogeneous magnetic fields**, J.M.D. Coey, L. Mazza, P. Dunne, L. Monzon  
*School of Physics and CRANN, Trinity college, Dublin, Ireland*
- PI-17 **Magnetic field effect on structure and function of aqueous salt solutions**, T. Matsushita, Y. Ohara, A. Hamasaki, S. Ozeki  
*Department of Chemistry, Shinshu University, Matsumoto, Japan*
- PI-18 **Magnetic signature of biogenic magnetite in the tissue from Rainbow trout**, J. Peters, J.W. Gerritsen, R.A. de Groot, S. Speller  
*Institute for Molecules and Materials, Radboud University Nijmegen, the Netherlands*
- PI-19 **Patterns of diacetylene-containing peptide amphiphiles using polarization holography**, M. van den Heuvel<sup>a</sup>, A.M. Prenen<sup>b</sup>, J.C. Gielen<sup>c</sup>, P.C.M. Christianen<sup>c</sup>, D.J. Broer<sup>b</sup>, D.W.P.M. Löwik<sup>a</sup>, J.C.M. van Hest<sup>a</sup>  
<sup>a</sup>Department of Bio-organic Chemistry, Radboud University Nijmegen, the Netherlands  
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*<sup>c</sup>High Field Magnet Laboratory, IMM, Radboud University Nijmegen, the Netherlands*

15:30		Coffee break	
<b>Session 7</b>		<b>Magnetic Field Effects II</b>	<b>Chair: Y. Zhong</b>
16:00	<b>7-1</b>	<b>Observation and analysis of the behavior of feeble magnetic materials under high magnetic fields, <u>N. Hirota</u><sup>a</sup>, T. Ando<sup>b</sup>, H. Wada<sup>a</sup>, Y. Sakka<sup>a</sup></b> <i><sup>a</sup>National Institute for Materials Science, Tsukuba, Japan</i> <i><sup>b</sup>Department of Chemical System Engineering, University of Tokyo, Japan</i>	
16:30	<b>7-2</b>	<b>Magnetic field induced change of solid-liquid phase transition, <u>I. Yamamoto</u><sup>a</sup>, K. Kawamata<sup>a</sup>, T. Mizuno<sup>a</sup>, S. Ozawa<sup>a</sup>, H. Hayashi<sup>b</sup>, T. Takamasu<sup>c</sup></b> <i><sup>a</sup>Yokohama National University, Yokohama, Japan</i> <i><sup>b</sup>Chiba University, Chiba, Japan</i> <i><sup>c</sup>National Institute for Material Science, Tsukuba, Japan</i>	
16:50	<b>7-3</b>	<b>Magnetic dust alignment in giant star envelop &amp; proto-planetary region caused by anisotropy of susceptibility at extreme temperatures, K. Hisayoshi, <u>C. Uyeda</u>, S. Kanou</b> <i>Graduate School of Science, Osaka University, Japan</i>	
17:10	<b>7-4</b>	<b>Lorentz force driven rotating flows in electrochemical systems, <u>T. Weier</u>, G. Gerbeth</b> <i>Forschungszentrum Dresden–Rossendorf, Dresden, Germany</i>	

October 28<sup>th</sup>. (Wednesday)

Session 8	Spin Chemistry	Chair: I. Mogi
09:00	<b>8-1</b> <b>Chemical magnetoreception in birds: the radical pair mechanism,</b> <u>P.J. Hore</u> <i>Department of Chemistry, University of Oxford, United Kingdom</i>	
09:30	<b>8-2</b> <b>Magnetic field effect on photoinduced electron transfer between calf thymus DNA and ternary copper complex containing amino acids,</b> <u>S. Basu<sup>a</sup></u> , <u>D. Dey<sup>b</sup></u> <sup>a</sup> <i>Chemical Sciences Division, Saha Institute of Nuclear Physics, Kolkata, India</i> <sup>b</sup> <i>Department of Chemistry &amp; Environment, Institute of Technology, Kolkata, India</i>	
09:50	<b>8-3</b> <b>Mechanical properties of crystals, controlled by magnetic resonance,</b> <u>R. Morgunov</u> <i>Institute of Problems of Chemical Physics, Russia</i>	
10:10	<b>8-4</b> <b>Enhancing spectral content of level crossing spectra,</b> <u>D.V. Stass<sup>a,b</sup></u> , <u>T.I. Pichugina<sup>a,b</sup></u> , <u>E.V. Kalneus<sup>a</sup></u> , <u>V.N. Verkhovlyuk<sup>a</sup></u> , <u>A.A. Kipriyanov<sup>a,b</sup></u> , <u>P.A. Purto<sup>a,b</sup></u> , <u>Y.N. Molin<sup>a</sup></u> <sup>a</sup> <i>Institute of Chemical Kinetics and Combustion, Novosibirsk, Russia</i> <sup>b</sup> <i>Novosibirsk State University, Novosibirsk, Russia</i>	
10:30	Coffee break	
11:00	<b>Poster Session II</b>	
PII-01	<b>Effects of heterogeneous magnetic fields on the electrodeposition of metallic layers,</b> <u>K. Tschulik</u> , <u>J. Koza</u> , <u>M. Uhlemann</u> , <u>A. Gebert</u> , <u>L. Schultz</u> <i>Leibniz Institute for Solid State and Materials Research Dresden, Germany</i>	
PII-02	<b>Hydrogen evolution as a side reaction during Fe-group metals and alloys deposition under influence of external magnetic fields,</b> <u>J. Koza<sup>a</sup></u> , <u>S. Mühlenhoff<sup>b</sup></u> , <u>M. Uhlemann<sup>a</sup></u> , <u>K. Tschulik<sup>a</sup></u> , <u>K. Eckert<sup>b</sup></u> , <u>A. Gebert<sup>a</sup></u> , <u>L. Schultz<sup>a</sup></u> <sup>a</sup> <i>Leibniz Institute for Solid State and Materials Research Dresden, Germany</i> <sup>b</sup> <i>Dresden University of Technology Institute for Fluid Mechanics, Germany</i>	
PII-03	<b>Magneto-electrodeposition in superimposed uniform high magnetic fields,</b> <u>M. Uhlemann<sup>a</sup></u> , <u>J. Koza<sup>a</sup></u> , <u>A. Krause<sup>a</sup></u> , <u>K. Tschulik<sup>a</sup></u> , <u>S. Mühlenhoff<sup>b</sup></u> , <u>L. Schultz<sup>a</sup></u> <sup>a</sup> <i>IFW Dresden, Germany</i>	

<sup>b</sup>TU Dresden Institute of Aerospace Engineering, Germany

- PII-04 **Effect of high-magnetic-field annealing on magnetic properties and microstructure of sintered NdFeB magnets**, S. Wang, T. Li  
*School of Materials Science and Engineering, Dalian University of Technology, P.R. China*
- PII-05 **Using molecular probe to study the properties of doped lanthanum manganite surface**, S. Zikirin<sup>a, c</sup>, D. Stass<sup>a, c</sup>, S. Trukhan<sup>b, c</sup>, O. Martyanov<sup>b, c</sup>  
<sup>a</sup>*Institute of Chemical Kinetics and Combustion of the Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia*  
<sup>b</sup>*Boreskov Institute of Catalysis of the Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia*  
<sup>c</sup>*Novosibirsk State University, Russia*
- PII-06 **Nano-structured TM-doped ZnO synthesized by high magnetic field - hydrothermal method**, M. Zhu, Y. Li, H. Jin, Y. Li, T. Yang, H. Jin  
*School of Materials Science and Engineering, Shanghai University, P.R. China*
- PII-07 **Grain elongation and texture in steels during austenitic decomposition under high magnetic field**, C. Esling<sup>a</sup>, Y.D. Zhang<sup>a</sup>, X. Zhao<sup>b</sup>, L. Zuo<sup>b</sup>  
<sup>a</sup>*LETAM, CNRS-FRE, Metz, France*  
<sup>b</sup>*Key Laboratory (Northeastern University), Ministry of Education, Shenyang, P.R. China*
- PII-08 **Structures of carbon materials prepared under high magnetic fields**, A. Sakaguchi, T. Sadatou, A. Hamasaki, S. Ozeki  
*Department of Chemistry, Faculty of Science, Shinshu University, Nagano, Japan*
- PII-09 **Magnetostriction of ferromagnetic particles embedded in an elastic matrix**, G. Digue<sup>a, b</sup>, E. Beaunon<sup>a</sup>, J.Y. Cavaillé<sup>b</sup>  
<sup>a</sup>*CNRS-CRETA, Grenoble, France*  
<sup>b</sup>*MATEIS, UMR5510, CNRS, INSA-Lyon, Villeurbanne, France*
- PII-10 **An analysis of electromagnetic field of electroslag remelting processes**, B. Li, F. Wang  
*School of Materials and metallurgy, Northeastern University, Shenyang, P.R. China*
- PII-11 **An analysis of electromagnetic field of electroslag remelting process with application of rotating magnetic field**, B. Li, F. Wang  
*School of Materials and metallurgy, Northeastern University, Shenyang, P.R. China*
- PII-12 **Interlayer tunneling spectroscopy of graphite at high magnetic fields**, Y.I. Latyshev, A.P. Orlov, a.Y. Latyshev, D. Vignolles

<sup>a</sup>*Institute of Radio-Engineering and Electronics RAS, Moscow, Russia*

<sup>b</sup>*National Laboratory of Pulsed Magnetic Fields, Toulouse, France*

- PII-13 **Effective transition moment for the Faraday rotation of lanthanide(III) ions,** K. Miyamoto, M. Suwa, H. Watarai  
*Department of Chemistry, Graduate School of Science, Osaka University, Japan*
- PII-14 **Negative magnetoresistance in nonmagnetic and magnetic semiconductors. The one effect - the one physical model?** S. Obukhov  
*A.F.Ioffe Institute of Physics & Technology, Saint-Petersburg, Russian Federation*
- PII-15 **Microstructure evolution of Cu-23.9wt%Ag alloy under high magnetic field and drawing deformation,** E-G. Wang, G-M. Li, L. Zhang, X-w. Zuo, J-C. He  
*Key Laboratory of EPM (Ministry of Education), Northeastern University, Shenyang, P.R. China*
- PII-16 **In-situ preparation of MnBi/Bi magnetic materials by using a dilute alloy via magnetic separation with high magnetic field gradients,** Q. Wang, T. Liu, C. Lou, K. Wang, Y. Liu, J. He  
<sup>a</sup>*Key Laboratory of EPM (Ministry of Education), Northeastern University, Shenyang, P.R. China*  
<sup>b</sup>*Department of Materials Science and Engineering, University of California at Berkeley, USA*  
<sup>c</sup>*School of Materials Science and Engineering, Shenyang Ligong University, P.R. China*
- PII-17 **Anisotropy of the spin density wave onset for (TMTSF)<sub>2</sub>PF<sub>6</sub> in magnetic field,** Y.A. Gerasimenko, V.A. Prudkoglyad, A.V. Kornilov, V.M. Pudalov, V.N. Zverev, A.-K. Klehe, A. Ardavan, J.S. Qualls  
<sup>a</sup>*P.N. Lebedev Physical Institute, Moscow, Russia*  
<sup>b</sup>*Institute for Solid State Physics, Chernogolovka, Russia*  
<sup>c</sup>*Clarendon Laboratory, Oxford University, United Kingdom*  
<sup>d</sup>*Sonoma State University, Rohnert Park, USA*
- PII-18 **The velocity field of a MHD flow under pulsed current conditions,** S. Mühlenhoff, X. Yang, K. Eckert, S. Odenbach  
*TU Dresden, Institute of Fluid Mechanics, Germany*
- PII-19 **Experimental observations of the electromagnetic shaping of aluminium and tin melts,** W. An, L. Liu, H. Fu  
*State Key Laboratory of Solidification Processing, Northwestern Polytechnical University, Xi'an, P.R. China*

PII-20 **The influence of powder particle size on properties of anisotropic Nd-Fe-B magnets textured with hot plastic deformation method**, W. Lipiec  
*Electrotechnical Institute, Wroclaw, Poland*

12:30 Lunch  
14:00 Conference excursion  
Kröller Müller Museum  
18:00 – 22:00 Conference banquet  
Wijnfort Lent

**October 29<sup>th</sup>. (Thursday)**

**Workshop Thematic Network "Molecular Materials in High Magnetic Fields"**



Session 9	Biological Systems I	Chair: P. Hore
09:00	<b>9-1 The magnetic compass of migratory birds: from behaviour to molecules and cognition</b> , <u>H. Mouritsen</u> , M. Zapka, D. Heyers, C. Hein <i>AG Neurosensory Sciences/Animal Navigation University of Oldenburg, Oldenburg, Germany</i>	
09:30	<b>9-2 Magnesium isotope effect on enzymatic phosphorylation and growth of E.coli cells</b> , <u>U. Shevchenko</u> <sup>a</sup> , V. Koltover <sup>a, b</sup> , D. Deryabin <sup>a</sup> , V. Berdinsky <sup>a</sup> <sup>a</sup> <i>Orenburg State University, Russia</i> <sup>b</sup> <i>Institute of Problems of Chemical Physics, Chernogolovka, Russia</i>	
09:50	<b>9-3 Magnetic levitation of human A431 cells</b> , M.J.A. Moes <sup>a</sup> , J.C. Gielen <sup>b</sup> , R. Bleichrodt <sup>a</sup> , <u>J.J.W.A. van Loon</u> <sup>c</sup> , P.C.M. Christianen <sup>b</sup> , J. Boonstra <sup>a</sup> <sup>a</sup> <i>Cellular Architecture and Dynamics, Utrecht University, Utrecht, the Netherlands</i> <sup>b</sup> <i>High Field Magnet Laboratory, IMM, Radboud University Nijmegen, the Netherlands</i> <sup>c</sup> <i>Dutch Experiment Support Centre, Vrije Universiteit, Amsterdam, the Netherlands</i>	

- 10:10 9-4 **Exposure of *Drosophila melanogaster* to magnetic levitation: changes in the behaviour, development and gene expression profile and exploitation as a long-term altered gravity simulator**, R. Herranz<sup>a,b</sup>, O. Larkin<sup>c</sup>, C. Dijkstra<sup>c</sup>, E. de Juan<sup>d</sup>, J. van Loon<sup>e</sup>, J. Medina<sup>b</sup>, M. Davey<sup>c</sup>, L. Eaves<sup>c</sup>, R. Marco<sup>a</sup>  
<sup>a</sup>*Departamento de Bioquímica & Instituto de Investigaciones Biomédicas (UAM-CSIC)*  
<sup>b</sup>*Centro de Investigaciones Biológicas, Madrid, Spain*  
<sup>c</sup>*School of Biosciences, University of Nottingham, United Kingdom*  
<sup>d</sup>*Dept. Fisiología, Universidad de Alicante, Spain*  
<sup>e</sup>*Dutch Experiment Support Centre, Vrije Universiteit, Amsterdam, the Netherlands*
- 10:30 Coffee break
- Session 10**                      **Magnetic Alignment**    **Chair: J. Valles**
- 11:00 10-1 **Various methods of magnetic alignment and their applications to materials science and crystal structure analyses**, T. Kimura  
*Graduate School of Agriculture, Kyoto University, Japan*
- 11:30 10-2 **Kinetics of magnetic alignment in rotating fields studied by rotational diffusion model**, M. Yamaguchi, S. Ozawa, I. Yanamoto  
*Department of Physics, Yokohama National University, Japan*
- 11:50 10-3 **Dynamic alignment of single walled carbon nanotubes in high magnetic fields**, N. Ubrig<sup>a</sup>, A. Nicholas<sup>a</sup>, G. Parra-Vasquez<sup>b</sup>, J. Shaver<sup>c</sup>, M. Pasquali<sup>b</sup>, J. Kono<sup>c</sup>, O. Portugall<sup>a</sup>  
<sup>a</sup>*Laboratoire Nationale des Champs Magnetiques Intenses, Toulouse, France*  
<sup>b</sup>*Department of Chemical and biomolecular Engineering, Rice University, Houston, USA*  
<sup>c</sup>*Department of Electrical and Computer Engineering, Rice University, Houston, USA*

12:10	<b>10-4</b>	<b>Hard X-rays and strong magnetic fields: playgrounds for hard and soft condensed matter</b> , <u>W. Bras</u> <i>Netherlands Organisation for Scientific Research (NWO), DUBBLE@ESRF, Grenoble, France</i>	
12:40		Lunch	
<b>Session 11</b>	<b>Biological Systems II</b>		<b>Chair: P. Shang</b>
14:00	<b>11-1</b>	<b>Seeding microtubule pattern formation with magnetic alignment</b> , <u>J.M. Valles</u> , Y. Guo, Y.Liu, J.X. Tang <i>Department of Physics, Brown University, Providence, USA</i>	
14:30	<b>11-2</b>	<b>The role of magnetic orientation in structure determination, cell biology and regenerative medicine</b> , <u>J. Torbet</u> <i>DUBBLE, ESRF, Grenoble, France</i>	
14:50	<b>11-3</b>	<b>Effect of static magnetic fields on firefly bioluminescence</b> , <u>M. Iwasaka</u> <i>Chiba University, Chiba, Japan</i>	
15:10	<b>11-4</b>	<b>Orientation growth of pollen tubes in vertical strong magnetic fields</b> , <u>Y. Fujiwara</u> <sup>a</sup> , R. Shimizu <sup>b</sup> , M. Aoyama <sup>c</sup> , T. Shioji <sup>c</sup> <sup>a</sup> <i>Graduate School of Science, Hiroshima University, Japan</i> <sup>b</sup> <i>Faculty of Science, Hiroshima University, Japan</i> <sup>c</sup> <i>Technical Centre, Hiroshima University, Japan</i>	
15:30		Coffee break	
<b>Session 12</b>	<b>Magneto-Chemistry</b>		<b>Chair: R. Hill</b>
16:00	<b>12-1</b>	<b>Chemical self-assemblies in high magnetic fields</b> , <u>J.C. Gielen</u> <sup>a</sup> , M.M.J. Smulders <sup>b</sup> , A. Verheyen <sup>c</sup> , J.C. Maan <sup>a</sup> , A.P.H.J. Schenning <sup>b</sup> , S. De Feyter <sup>c</sup> , P.C.M. Christianen <sup>a</sup> <sup>a</sup> <i>High Field Magnet Laboratory, IMM, Radboud University Nijmegen, the Netherlands</i> <sup>b</sup> <i>Laboratory of Macromolecular and Organic Chemistry, Eindhoven University of Technology, the Netherlands</i> <sup>c</sup> <i>Division of Molecular and Nanomaterials and Institute of Nanoscale Physics and Chemistry, Katholieke Universiteit Leuven, Belgium</i>	

- 16:30 **12-2** **Magnetic field effect on chiral symmetry-breaking induced by stirring in supramolecular porphyrin aggregates**, L. Monsù Scolaro<sup>a</sup>, N. Micali<sup>b</sup>, H. Engelkamp<sup>c</sup>, P.C.M. Christianen<sup>c</sup>, J.C. Maan<sup>c</sup>  
<sup>a</sup>*Dipartimento di Chimica Inorganica, Università di Messina, Italy*  
<sup>b</sup>*I.P.C.F. – C.N.R., Messina, Italy*  
<sup>c</sup>*High Field Magnet Laboratory, IMM, Radboud University Nijmegen, the Netherlands*
- 16:50 **12-3** **Controlling magnetic interactions in Mn<sub>4</sub>-clusters via carboxylate ligands**, E. Kampert<sup>a, b</sup>, J.C. Russcher<sup>b</sup>, D.W. Boukhvalov<sup>c</sup>, F.F.B.J. Janssen<sup>b</sup>, J.M.M. Smits<sup>b</sup>, R. de Gelder<sup>b</sup>, B. de Bruin<sup>b</sup>, P.C.M. Christianen<sup>a</sup>, U. Zeitler<sup>a</sup>, M.I. Katsnelson<sup>c</sup>, A.E. Rowan<sup>b</sup>, J.C. Maan<sup>a</sup>  
<sup>a</sup>*High Field Magnet Laboratory, IMM, Radboud University Nijmegen, the Netherlands*  
<sup>b</sup>*Molecular Materials, IMM, Radboud University Nijmegen, the Netherlands*  
<sup>c</sup>*Theory of Condensed Matter, IMM, Radboud University Nijmegen, the Netherlands*
- 17:10 **12-4** **Effect of strong magnetic field on inhomogeneous chemical reactions**, Y. Tanimoto<sup>a, b</sup>, A. Shinyama<sup>b</sup>, K. Omote<sup>b</sup>  
<sup>a</sup>*Faculty of Pharmacy, Osaka Ohtani University, Japan*  
<sup>b</sup>*Graduate School of Science, Hiroshima University, Japan*
- 18:00 Farewell party @ High Field Magnet Laboratory (HFML)  
 Drinks & buffet  
 HFML Lab Tour

# Abstracts

## Dynamic Force Analysis of Chemical Bonding with Electromagneto-Buoyancy

**Hitoshi Watarai and Takehiro Kato**

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Dynamic force spectroscopy has been recently developed as a new technique for the analysis of chemical interactions and chemical structures of biological molecules, which is usually performed by using atomic force microscopy (AFM). However, in case of AFM, an analyte such as cell and protein has to be fixed on a cantilever of AFM prior to the measurement. We have proposed an alternative method applying electromagnetophoretic (EMP) buoyancy on a micro-particle or a biological cell, which is served to be analyzed [1].

The electromagnetophoretic buoyancy,  $F_{EMP}$ , on a particle in an electrolyte solution can be generated by applying homogeneous magnetic field and electronic current perpendicular to the magnetic field. The force,  $F_{EMP}$ , on a particle in a capillary including the electrolyte solution can be controlled due to the next equation,

$$F_{EMP} = 2 \left( \frac{\sigma_p - \sigma_f}{2\sigma_f + \sigma_p} \right) \frac{iBV}{S}$$

where  $V$  is the volume of the spherical particle,  $S$  the inner sectional area of the capillary,  $\sigma_f$  the electric (ionic) conductivity of solution and  $\sigma_p$  the apparent conductivity of the particle. The apparent conductivity of particle was actually the surface conductivity of particles produced by the electric double layer on the particle surface, and could be determined from an independent measurement of electromagnetophoretic migration velocity of the particle. By applying current from 0 to 1200  $\mu\text{A}$  in 1M KCl ( $\sigma_f = 0.112 \text{ Scm}^{-1}$ ) under 10 T, a yeast cell bound with a lectin (Concanavalin A, 54 kDa) fixed to the capillary wall was pulled with a loading rate of  $3\text{pNs}^{-1}$  from 0 to 60 pN [2]. Then, the averaged interaction force between the mannose chains on a yeast cell and the lectin through hydrogen bonding was determined as  $41 \pm 10$  pN under the experimental conditions. Furthermore, carboxyl-terminated polystyrene particles (PS, diameter:  $10\mu\text{m}$ ) dispersed in the KCl solution containing metal ion,  $\text{Cu}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Fe}^{3+}$  or  $\text{Al}^{3+}$ , were introduced into the carboxyl modified capillary (inner diameter:  $100\mu\text{m}$ ) and the effect of the metal ions as well as the  $\text{H}^+$  concentrations on the interaction force between a polystyrene particle and the wall was investigated by the dynamic force analysis,

$$\ln \left( \frac{1}{t} \ln \frac{N(0)}{N(t)} \right) = \ln k_{\text{off}}(0) + \left( \frac{rx}{k_B T N_B} \right) t$$

where  $N(0)$  and  $N(t)$  are the number of bound particles in the initial state and after loading time  $t$ ,  $k_{\text{off}}(0)$  is the spontaneous dissociation rate constant,  $r$  the loading rate,  $x$  the critical increase of the bonding. According to this analysis, the parameters of  $k_{\text{off}}(0)$  and  $x$  for the dissociation of PS-COO<sup>-</sup>-metal ion (or H<sup>+</sup>)-COO<sup>-</sup>-silica wall interactions were evaluated. The slow dissociation kinetics for  $\text{Fe}^{3+}$  and  $\text{Al}^{3+}$  were well reproduced in the values of  $k_{\text{off}}(0)$ , giving  $2.28 \times 10^{-2} \text{ s}^{-1}$  ( $10^{-6}\text{M Fe}^{3+}$ ) and  $2.76 \times 10^{-2} \text{ s}^{-1}$  ( $10^{-6}\text{M Al}^{3+}$ ), respectively.

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## Magnetic forces for the versatile manipulation of diamagnetic and paramagnetic particles in microfluidic devices

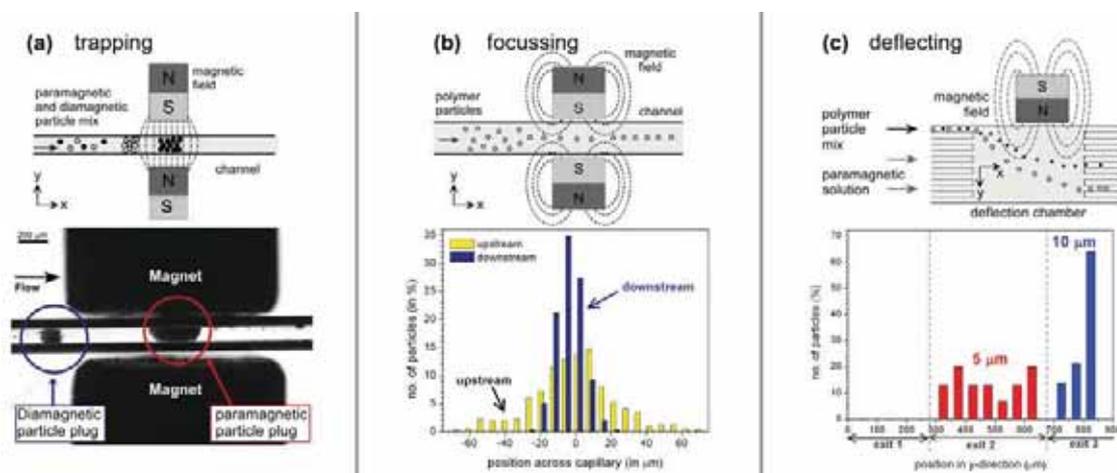
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We demonstrate the manipulation of paramagnetic and diamagnetic particles suspended in a paramagnetic buffer for three particle handling techniques in microfluidic devices.

Conventionally, to repel diamagnetic materials, the high magnetic field gradients generated by superconducting magnets are required. Microfluidics is an exciting and useful technology for magnetoscience [1]. The miniature scale of such devices allows objects to be handled closer to a magnet surface, thus sufficient diamagnetic repulsion forces can be generated by small, conventional magnets [2]. Here, we demonstrate the versatility of diamagnetic repulsion for three novel methods of manipulating diamagnetic and paramagnetic particles in microfluidic devices.



**Trapping of mixed particle suspensions:** A pair of NdFeB magnets was placed either side of a 100 μm i.d. microcapillary with opposite poles facing. A mixture of paramagnetic and diamagnetic microparticles in 10% w/v MnCl<sub>2</sub> were pumped through the capillary and sorted into two separate plugs according to magnetic susceptibility (fig. a).

**Particle focussing:** A pair of magnets was arranged across a 150 μm i.d. microcapillary with like poles facing. Diamagnetic particles were focussed and preconcentrated between the two magnets into a thin narrow stream (fig. b). The focussing of particles at different concentrations of paramagnetic buffers MnCl<sub>2</sub> and GdCl<sub>3</sub> was compared.

**Particle deflection for size-selective diamagnetophoresis:** A mixture of 5 μm and 10 μm diamagnetic particles was pumped through a single channel into a rectangular chamber with multiple outlets. In the absence of a magnetic field the particle mixture exited via exit 1. When a field was applied the particles were deflected from flow according to size (fig. c).

This work demonstrates the versatility of diamagnetic repulsion forces for the on-chip manipulation of diamagnetic and paramagnetic particles including plug formations, focussing and size-selective separations.

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## **Strong acceleration of the isothermal martensitic transformation kinetics in high magnetic fields**

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We have monitored the isothermal transformation kinetics of the paramagnetic austenite phase into the ferromagnetic martensite phase in a metastable austenitic steel by time-dependent magnetization measurements for temperatures from 4 to 298 K and continuous applied magnetic fields up to 30 T. The transformation kinetics is shown to be accelerated by several orders of magnitude when high magnetic fields are applied. This allows us to map out the complete transformation kinetics of this system within realistic time scales. The temperature dependence of the transformation rate identifies both the energy barrier for martensite nucleation and the activation energy for the mobility of dislocations. Analyzing the transformation rate as a function of magnetic field and temperature provides direct insight into the martensite nucleation process.

## Investigation on Solidification of Metals under a Strong Magnetic Field

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Several aspects of solidification of metals under a strong magnetic field have been investigated experimentally. It is found that magnetic field apparently influences the solidification temperature of Al alloys and Bi.. For pure aluminum, imposing of a strong magnetic field will decrease the solidification temperature but not melting temperature, which suggests influence of the magnetic field on kinetics of solidification. A magnetic field induced- solidification of the no-ferromagnetic substance has been realized experimentally by solidifying the liquid Bi during increasing the magnetic field. Experiments of directional solidification of Al-Cu, Zn-Cu and Al-Ni alloys show that morphological instability of the S/L interface has occurred due to the magnetic field. A strong magnetic field of 10T has caused the cell and dendrite to twist and deflect from the solidification direction. Moreover, it is found that a strong magnetic field has enhanced the enrichment of the solute Cu element in the diffusion boundary layer. Moreover, the stresses in the solid near the interface and micro-convection near the solid/liquid interface under a strong magnetic field due to the thermoelectric magnetic effect and magnetization have been analyzed; and they should be responsible to the interface irregularity; and also be capable of inducing the interface instability.

Effect of a strong axial magnetic field on the growth of eutectics has been investigated in directionally solidified Al-Cu and Pb-Sn eutectic alloy. It was found that the magnetic field modified the eutectic microstructure evidently and caused the morphological instabilities of the eutectic. It is observed that a strong axial magnetic field changed the crystal direction [001] of the Al<sub>2</sub>Cu oriented along the direction of the field (the direction of solidification). Moreover, the field caused the decrease of eutectic spacing and segregation. Stresses during directional solidification under a strong magnetic field have been analyzed and the morphological instabilities and the deformation and dislocation are attributed to the stresses caused by the magnetization force and the thermoelectric magnetic force.

The migration of the primary silicon grains during solidification of Al-18wt%Si alloy from semisolid zone has been investigated experimentally under a gradient strong magnetic field, and a theoretical model responsible for the migration of a single grain in molten metal was proposed. The results showed that the migration of the primary silicon grains did not take place until the magnetic flux density was over a certain value when the flux gradient was kept at a certain value. The magnetic field will suppress migration of primary silicon when the field flux is over a certain value, indicating that the influence of the flux on the migration intended to get saturation. From the model a formula for the migration velocity is deduced. It is also demonstrated that the grain size decreased with increase of the magnetic gradient.

## Performance Test for a High Field Powder X-ray Diffraction Camera

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High performance materials controlled by magnetic fields have been studied all over the world. In these materials, a structural transformation or a large strain is observed, often accompanied by a magnetic phase transition at the working temperature. To develop these materials, it is necessary to clarify the relationship between magnetic and structural properties of the materials. In order to investigate the relations, high field X-ray diffraction (HF-XRD) measurement is one of the useful techniques. In HFLSM, a HF-XRD system using a split-pair cryocooled superconducting magnet (CSSM) was developed in 1997[1]. Some important results have been reported using this system. However, in order to investigate the potential ability of the materials, further high magnetic fields over 5 T were required.

In this work, we have developed a powder HF-XRD camera (TRY-HF-XRDC-IMR) in fields up to 10 T. The overview of the system is shown in Fig. 1. In this system, a Debye-Scherrer camera is inserted into a cryocooled superconducting magnet with a room temperature bore of 100 mm. An image plate is used to detect the diffracted X-ray. To evaluate the performance of the system, the HF-XRD measurements were carried out with some materials. For example, we measured the magnetically oriented process of ferromagnetic MnBi powder. MnBi has a hexagonal structure, and has magnetic anisotropy along *c*-axis. X-ray diffraction patterns of MnBi at 0 T and 10 T are shown in Fig. 2. The diffraction lines derived from MnBi and Bi were detected. Applying a magnetic field of 10 T, the 202 reflection of MnBi was detected strongly and other lines were weaker than those of 0 T. This result suggests that a magnetic orientation can be observed at 10 T by using TRY-HF-XRDC-IMR. In this presentation, we will report the ability of this HF-XRD camera system.

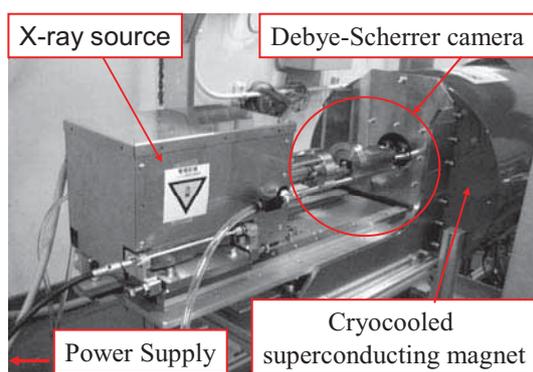


Fig. 1. The overview of the system.

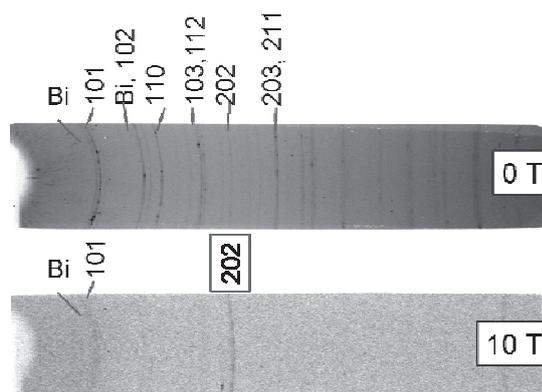


Fig. 2. X-ray diffraction pattern of MnBi.

Acknowledgments: This work was supported by the Mazda Foundation.

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## Magnetic force effect on solid state crystal growth

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A magnetic force can be exerted on single atoms or ions diffusing at high temperature in a solid material, due to the coupling between the magnetization of the diffusing particle with a local magnetic field gradient. This effect is expected to be negligible as the magnetic energy involved in motion is several order of magnitude lower than the thermal disordering energy  $kT$ .

However, it has been experimentally demonstrated that grain growth morphology is strongly influenced by an external field of a few Tesla. In systems where a ferromagnetic phase is growing in a paramagnetic one, it has been observed that the ferromagnetic phase exhibits a preferred growth along the applied direction, while the growth is isotropic without magnetic field.

Several mechanisms can be suggested to account for this result:

- a magnetic torque orientating solid particles in the solid matrix, through local creeping at high temperature;
- a particle deformation to minimize the demagnetizing energy, also through local creeping at high temperature;
- a local effect of the magnetic forces due to local field around the particle, polarizing atomic diffusion and modifying the growth.

This latter phenomenon is studied both by numerical simulations and an analytical model. The effect is based on a local field increase near the magnetic poles of the particle immersed in an external homogeneous magnetic field. This local field increase attracts paramagnetic ions diffusing around the ferromagnetic particle and responsible for its growth. On the contrary, along the equator of the particle (in the middle plane between the poles), the ion concentration is depleted as the magnetic field value is decreased.

The concentration change is very weak, but it is shown that the classical curvature effects responsible for the growth and coarsening (Ostwald ripening) is of the same order.

Both numerical and analytical simulation confirms the efficiency of such a phenomenon which can be used as a new tool for controlling the microstructure anisotropy in some specific systems.

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## Electrochemical Crystallization in High Magnetic Fields

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Magnetic field effects on electrocrystallization have attracted much interest during the last decades and the magnetically induced changes that have been observed are various and sometimes promising. The magnetohydrodynamic (MHD) effect has been reported as responsible for size grain and texture modifications. Some physical properties of the deposits can be modified by the convection that is created by superimposed magnetic fields. These changes can influence the surface reactivity or induce some chiral phenomena [1] and therefore it is very important to investigate the magnetic effects on several electrochemical systems as metals, alloys, polymers or oxides.

We have undertaken studies on the electrocrystallization of different materials as alloys or oxide under superimposition of high magnetic fields. The experiments have been carried out by using the facilities of the Grenoble High Magnetic Field Laboratory (LNCMI). The magnetic field was vertical and parallel to the plane working electrode.

For zinc-nickel alloys, the magnetic field had weak effects on the intensity current and amounts of metals in the alloys, but provoked changes in the alloy textures (Fig. 1). Depending on the applied magnetic field during the deposition process, the hydrogen evolution on the alloy was modified and therefore corrosion potential was cathodically shifted. Another example is Copper oxide  $\text{Cu}_2\text{O}$  deposition that has been obtained by copper(II) reduction from a lactate copper(II) solution.. In this case, with a constant applied current, no magnetically induced effect on texture and habitus could be exhibited but shape of the crystallites became labyrinthine (Figure 2).

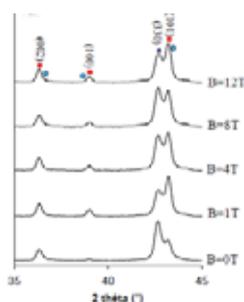


Figure 1. XRD diagrams for zinc-nickel alloys electrodeposited under magnetic field superimposition

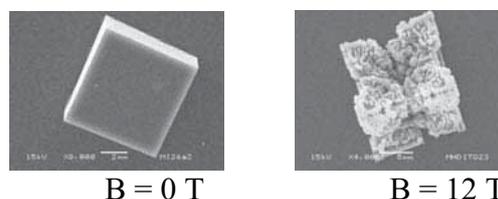


Figure 2.  $\text{Cu}_2\text{O}$  deposits on ITO substrate

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## Numerical and experimental results on copper electrolysis in homogeneous and inhomogeneous magnetic fields

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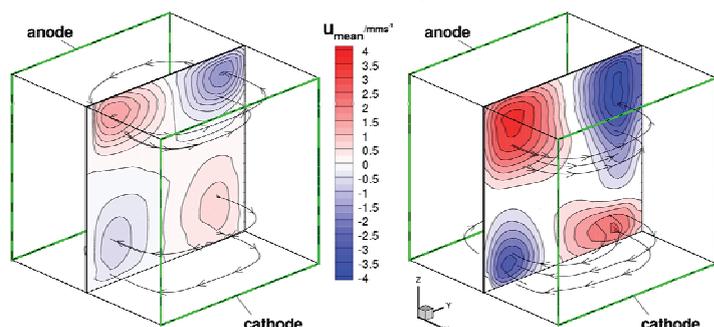
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Lorentz forces due to external magnetic fields are well known to force electrolyte flow and thereby to influence mass transport in electrochemical reactions. To achieve a quantitative understanding of this so called “MHD-effect” and maybe to tailor it, it is crucial to study the magnetically forced convection in as much detail as possible.

The present work aims to further clarify the role of magnetically forced convection during copper electrolysis in cuboid cells with vertical wall electrodes. Both, homogeneous and inhomogeneous magnetic fields of different directions are investigated. Substantial differences in the convection forced arise from the fact that only the rotational part of the Lorentz force drives additional convection [1]. In case of homogeneous magnetic fields, this results in characteristic horizontal counter-rotating flow in the top and the bottom region of the cells (see Fig. 1) [2]. Inhomogeneous magnetic fields characterized by a constant gradient in a certain direction give rise to simpler convection patterns as the Lorentz force possesses a natural rotational part. This way, tailored electrolyte stirring throughout the cell can easily be generated.

The presentation will summarize recent results of numerical simulations combined with detailed experimental PIV measurements of the electrolyte flow. The influence of the forced convection on the limiting current, the vertical density stratification and the vertical distribution of the current density at the cathode will be discussed.



*Fig. 1: Horizontal counter-rotation of different strength detected by time-averaged PIV-measurements for electrolytes of different copper concentration. Contours of the velocity magnitude in the center plane and streamtraces indicating the horizontal convection.*

**Acknowledgment:** We are very grateful to C. Cierpka for contributing to the initial DP-PIV setup. This work was supported by Deutsche Forschungsgemeinschaft in frame of the collaborative research center SFB 609 "Electromagnetic flow control in metallurgy, crystal growth and electrochemistry"

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## Magnetochemical Chirality and Micro-MHD Effect in Ag Electrodeposition

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Magnetochemical allows control of convection of electrolytic solution, morphology and texture of electrodeposits, kinetics of electrode reactions, etc. One of the most intriguing aspects in magnetochemical is to induce chirality in the electrodeposits. This is called magnetochemical chirality.

When a magnetic field is imposed to an electrochemical cell, the Lorentz force acting on the faradaic current causes convection of the electrolytic solution. This is well known as the magnetohydrodynamic (MHD) effect. Aogaki proposed the micro-MHD effect in electrodeposition under the magnetic fields perpendicular to the electrode surfaces [1]. In electrodeposition processes, non-equilibrium fluctuation produces a lot of humps on the deposit surfaces. The faradaic current around such humps is not parallel to the magnetic field, so that the Lorentz force could cause vortex-like convection in the local areas around the humps. If such local convection leads to chiral structures on the deposit surfaces, the chirality could be an intrinsic feature in magnetochemical, and the magnetochemical deposition would be a useful method to prepare chiral surfaces.

We tried the magnetochemical deposition of Ag films and employed them as modified electrodes. Such Ag film electrodes were found to exhibit different oxidation currents between the enantiomers of glucose [2]. Here, we report the surface morphology of the magnetochemical deposited Ag films prepared at various overpotentials and their chiral behaviors.

Fig. 1 shows microphotographs of the surfaces of the Ag (a) 0T- and (b) +2T-films electrodeposited at  $-0.3$  V (vs Ag | Ag<sup>+</sup>). While the 0T-film is aggregates of a lot of single crystals with sizes of  $\sim 1$   $\mu\text{m}$ , the +2T-film consists of crystals with sizes of  $2\sim 3$   $\mu\text{m}$  and a powder-like background. The latter morphology implies the presence of local micro-MHD convection around the crystals. The +2T-film electrode exhibited chiral behavior for the oxidation of the enantiomers of glucose, as shown in Fig. 2. Such chiral behavior was observed in the +2T-films prepared at potentials less than  $-0.1$  V. These results suggest that the micro-MHD effect could induce chiral structures on the crystals, such as kinks or corner kinks.

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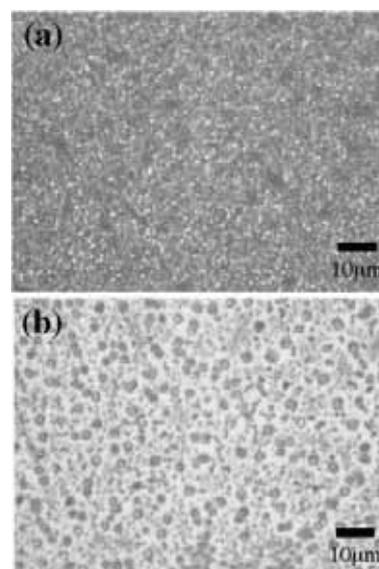


Fig. 1. Microphotographs of the surfaces of the Ag (a) 0T- and (b) +2T-films.

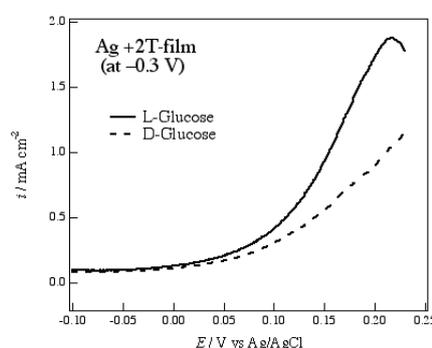


Fig.2. Voltammograms of 20 mM D- and L-glucoses in a NaOH aqueous solution on the Ag +2T-film electrode.

## Mechanism of the Chirality in Magneto-electrodeposition

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In electrochemical reactions under a vertical magnetic field, it is well known that various vortices called micro-magnetohydrodynamic (MHD) flows and vertical MHD flows are generated. Recently, using the electrodes made by electrodeposition in a vertical magnetic field, Mogi obtained chiral products in enantiomorphic electrochemical reactions [1]. These results indicate that such chirality is first bestowed on an electrode surface by vortices. However, chiral symmetry is always kept for the vortices on a single surface. To break the symmetry, it is necessary to prepare a surface containing two kinds, rigid and free portions. Because of friction, a solid surface is rigid, so that for a frictionless free surface, ionic vacancies in solution are recognized as lubricant. The vacancies are created in electrodeposition, and thought as the elementary structures of nanobubble promoting slip at a free surface [2]. Theoretical consideration reveals that the rotational directions of the vortices on the free and rigid surfaces are determined by the polarity of magnetic field. However, only the chirality of the vortex on the free surface can be transferred to a deposit surface. As shown in Fig. 1, theoretical calculation exhibits regular holes among dendrites called micro-mystery circles. Figure 2 shows the calculated image of the bottom of the circle; a pattern of concentric-circles is the evidence of the chirality formed on the free surface.

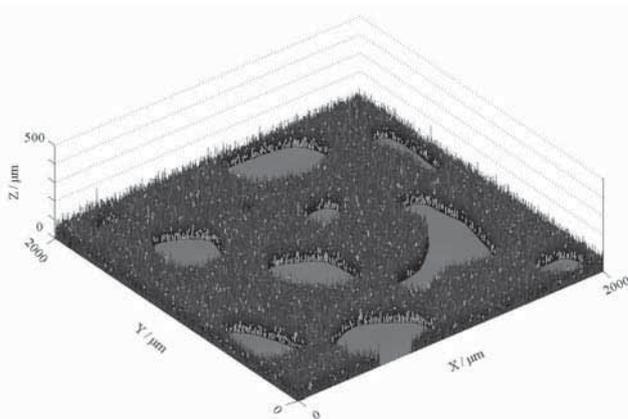


Fig. 1 Computed micro-mystery circles

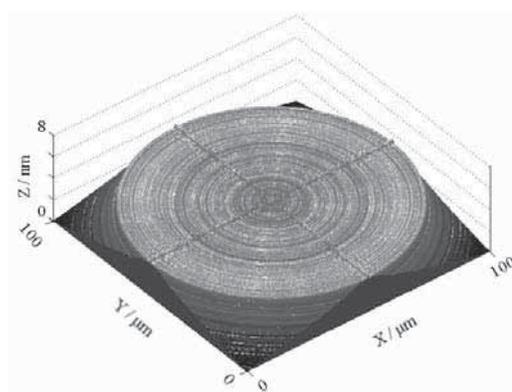


Fig. 2 Computed bottom of the circle

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## Properties of Water Interacting with Magnetic Fields

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Many peoples report the magnetic treatment (MT) of water and believe that they observed structural change of  $\text{CaCO}_3$ , changes of crystal growth and properties, and inhibition of corrosion<sup>1</sup>, and changes in water properties due to MT. Scientists, however, still suspect the existence of such magnetized water because of no reason why pure water may be changed by MT. Higashitani et al. persisted that the hydration layer around ions and colloids in aqueous solutions should be thickened by MT. Ozeki et al. found that water adsorption on solid surfaces affected by steady magnetic fields.<sup>2</sup> A few papers recently reported that some properties of pure water changed very slightly even when the pure water stood in steady magnetic fields. Most magnetic field effect was attributed to hydrogen bond development. The changes due to steady, homogeneous magnetic fields were much larger than those from theoretical prediction, but still very much small compared with the MT effects, suggesting that the magnetic flux changes should affect strongly the structure or properties of oxygenated water.

The change of the interfacial energy of water/Pt interface due to MT of pure water suggests that a hydrated layer on a Pt surface may develop in MT water. The increase in the energy corresponds to ca. 200 nm in thickness of bulk ice, suggesting hydration development due to MT. Our careful experiments, however, very recently showed existence of “magnetic field-affecting water” indirectly through the remarkable results on contact angle, electrolysis, Raman bands, metal corrosion and calcium carbonate formation<sup>3</sup>. The MT water required  $\text{O}_2$  and the relative motion of water against a magnetic flux, and seemed to be accompanied with formation of clathrate-like hydrate of  $\text{O}_2$  and promotion of hydration layer. We here report the infrared and Raman spectroscopic evidence indicating quasi-stable structures in the MT water; oxygen clathrate-like hydrate and developed water networks, which were induced by magnetic interactions while a vacuum-distilled water, followed by oxygen exposure, crossed a steady magnetic field<sup>3</sup>. Moreover, the viscosity of the MT water dissolving  $\text{O}_2$  decreased systematically depending on the kind of ion, treatment temperature, etc.

The mechanism of MT water formation is a future problem still.

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## Design and Magnetic Studies of Novel Nitronyl Nitroxide Radicals

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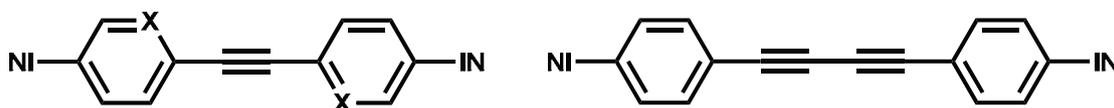
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The design and synthesis of molecular-based magnetic materials is one of the major subjects of material science. Molecular-based materials may offer promising advantages as compared to classical ones: low-density, flexibility, transparency, chemical versatility, etc. The challenge in this field consists of assembling functional derivatives such that interactions between spin carriers can be controlled and tailored at will through the rational design of the molecular backbone (spacer).

Three nitronyl-nitroxide-biradicals coupled via modified tolane linkers were synthesized and their magnetic behavior<sup>1</sup>. The design of the spacer allows to decrease effect of direct coupling. Here we focused on weakly coupled spin-dimer system ( $J \sim 10\text{K}$ ) with singlet ground state which can be switched by magnetic field into triplet occupation. This may serve as molecular models of a gas of magnetic excitations which may be used for quantum computers. As radical units we have chosen the nitronyl nitroxides known to be very stable and containing ligation sites for H-bonding and metal complexation:



**X = C, N**

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<sup>1</sup> B Wolf<sup>1</sup>, C T Pham<sup>1</sup>, K Remović-Langer<sup>1</sup>, Y B Borozdina<sup>2</sup>, E Mostovich<sup>2</sup>, M Baumgarten<sup>2</sup>, M Lang<sup>1</sup>, submitted CCR, 2009

## Magnetic field induced corrosion patterning of ferromagnetic electrodes

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The magnetization of a ferromagnetic electrode in an external homogeneous magnetic field leads to a stray field in front of the electrode. This stray field and its gradients can alter the free corrosion behaviour as well as the anodic behaviour of the electrode significantly [1-4]. To investigate the influence of an superimposed magnetic field up to 0.6 T on the surface profile of the crosssectional area of a cylindrical iron electrode ( $d = 4$  mm) potentiostatic polarisation measurements were performed in a 0.5 M sulfuric acid solution (pH 0.25). Additional long time exposure experiments (7 days) were performed in 0.001 M hydrochloric acid solution under free corrosion conditions with and without applied magnetic field. Afterwards the surface of the electrode was investigated by means of optical microscopy and profilometry. While at low anodic overpotentials and in the passive state no influence of the superimposed magnetic field on the electrode surface profile was observed, a localization of the corrosion reaction to the center of the cross-sectional area of the iron cylinder occurred when the dissolution was diffusion limited.

During long time exposure without an applied magnetic field the electrode corroded uniformly. Under the influence of a magnetic field the corrosion was localized to the centre of the electrode while the rim was not affected. The observed effects of a superimposed magnetic field on the corrosion behaviour of iron are discussed with respect to an increase of the mass transport due to the Lorentz-force-driven magnetohydrodynamic (MHD) effect, the magnetic field gradient force and its interaction with the paramagnetic iron ions. It is shown that the effect of the field gradient force can become very important due to the high magnetic field gradient at ferromagnetic electrodes.

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## Maxwell Stress in Paramagnetic Liquid Tubes.

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A tube of a paramagnetic solution such as  $\text{CoCl}_2$  can be stabilized in water by means of a suitable  $\nabla B^2$  magnetic field. The field may be produced around a ferromagnetic track, which is magnetized in a uniform vertical field, which also serves to magnetize the paramagnetic solution. The stability against convection and dispersion (but not diffusion) is due to the interaction of the induced magnetization of the liquid with the magnetic field gradient in the vicinity of the track. Another stable configuration is an ‘antitube’ of water in a paramagnetic solution, which is stabilized in an horizontal field [1]. The basic setup is illustrated in Fig 1a. The form of the cross section of the paramagnetic liquid tubes two of which are shown in Fig 1b, is determined by a balance of interfacial tension, buoyancy forces and Maxwell stress. The effects of Maxwell stress are quite negligible in solids, which have a large shear modulus. They are significant in ferrofluids; the remarkable peaked shapes appearing when a magnet is placed beneath a dish of ferrofluid arise from Maxwell stress. Here we show that there are effects to be seen in liquids whose susceptibility is three or four orders of magnitude smaller.

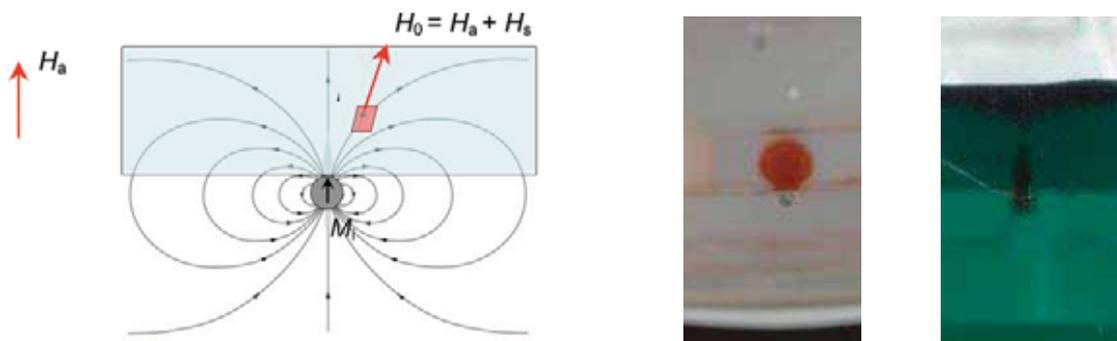
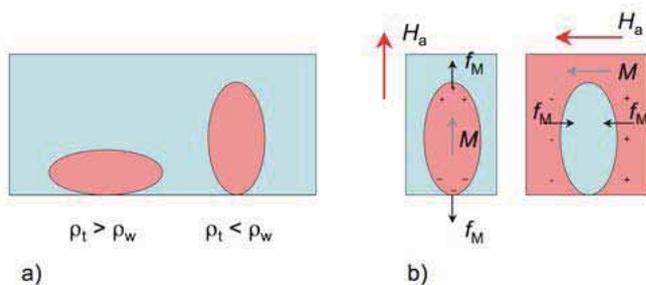


Figure 1. Magnetic fields acting on an element of paramagnetic liquid (red). On the right is seen the cross section of a tube of  $\text{CoCl}_2$  (red) in water, and an antitube of water (black) in  $\text{NiSO}_4$  (green).

Maxwell stress can be considered as the force exerted by the applied field on the induced magnetic ‘charge’ in the paramagnetic liquid, as illustrated in figure 2b. The effect of



buoyancy is contrasted in figure 2a. The Maxwell force exceeds the gravitational force in these examples, and is the main reason for the departure of the shape of the tube from the contour

$$r = h(\cos 2\theta)^{1/2}$$

Here is an example where a magnetic force related to the concentration gradient *can* produce an observable effect in a paramagnetic liquid with a susceptibility that is only of order  $10^4$ .

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## Microstructure control by magnetic field during thermo-treatment of metallic materials – a review.

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**Abstract:** Control of microstructures that result from phase transition during thermo-treatment (casting and solid state heat treatment) in engineering materials is one of the goals of materials science. Magnetic field shows promising applications in materials processing procedures. Our group is one the early ones involved in this study. In this paper, some of our recent results in phase equilibrium, microstructure, texture and orientation relationship resulting from the application of a magnetic field during solidification and diffusional phase transformation in steels and aluminum alloys have been summarized.

A magnetic field up to 14 T was applied to the diffusional decomposition of austenite in 0.49C-Fe and 0.81C-Fe alloys. For the 0.49C-Fe alloy, the effect of the magnetic field is dependent on the cooling rate. When cooling is slow, it promotes the growth of the proeutectoid ferrite grains along the field direction to minimize the magnetic volume energy. The balance of the magnetic volume energy and the interfacial energy that determines the final shape of the grains is quantitatively analyzed. It is found that when cooling is fast, it promotes the growth of grains whose  $\langle 001 \rangle$  direction is parallel to the transverse field direction (TFD) and thus enhances the TFD  $\langle 001 \rangle$  texture component. It is found that the formation of this component is related to the counterbalance between the lattice distortion caused by the solution of carbon atom in bcc Fe and the magnetic dipolar interaction among Fe atoms. For the 0.81-Fe alloys, it was found that the magnetic field shifts the eutectoid composition from 0.77C% wt. to 0.84C%wt. Further calculation showed that this field increases the eutectoid temperature by 29°C. The magnetic field applied also showed the influence on the occurrences of the orientation relationships (ORs) between pearlitic ferrite and cementite. Without the field, there are mainly four ORs between ferrite and cementite that are Isaichev (IS), near Bagaryatsky (Bag) and two near Pitsch-Petch (P-P-1 and P-P-2) ORs, whereas with the field, there are mainly P-P-2 ORs. Analysis shows that the selection of different ORs between ferrite and cementite in pearlite is dependent on the nucleation sequence of the two phases in pearlite. As the magnetic field promotes the formation of high magnetization phase, i.e., ferrite, as a leading phase, in the field, the P-P 2 is more frequent.

A 0.2-T static magnetic field was applied during the semi-continuous casting process of a Al-9.8wt%Zn alloy. It was found that the static magnetic field transferred the microstructure from a mixture of equiaxed and columnar grains to feathery grains with the primary and secondary arms growing in  $\langle 110 \rangle$  directions. The decreased undercooling resulting from reducing the heat transfer and lowering the solute transmitting capacity at the solid front through damping the convection of the melt by Lorentz force accounts for the transformation of crystallographic growth direction. The different atomic radii of Zn and Al and the related incoming flow gives rise to the formation of twinned crystals, and the request to reduce the liquid/solid interface area contributes to the formation of the lamellas.

**Keywords:** Electromagnetic Processing of Materials (EPM); Microstructure; Grain elongation; Crystallographic texture; Phase transformation; Solidification.

## Differential thermal analysis of MnBi under high magnetic fields up to 26 T

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Binary compound MnBi with a NiAs-type hexagonal structure (low temperature phase: LTP) is a ferromagnet at room temperature. With increasing temperature in a zero magnetic field, MnBi undergoes a first-order magnetic phase transition from the ferromagnetic (FM) state to the paramagnetic (PM) state at  $T_i=355^\circ\text{C}$ , accompanied by a peritectic decomposition of MnBi into  $\text{Mn}_{1.08}\text{Bi}$  (high temperature phase: HTP) and liquid Bi. Our previous results of differential thermal analysis (DTA) under magnetic field  $B$  suggests that  $T_i$  increases with increasing  $B$  and will reach the peritectic temperature of HTP ( $T_m^{\text{MnBi}}=446^\circ\text{C}$ ) upon applying  $B \sim 45$  T [1,2]. This means that we can control the solidification process of the MnBi magnetic material by high magnetic fields. However, there is no report on thermal analysis under high magnetic field over 15 T. Therefore, we have developed a new high field DTA apparatus (HF-DTA) that is designed for hybrid magnets with a 32 mm room temperature bore, in order to get the first data of the magnetic field effect on the decomposition process under the highest magnetic field in the world.

For the developed HF-DTA, the temperature difference between sample and reference ( $\text{Al}_2\text{O}_3$ ) is measured by Pt-Rh thermocouples. HF-DTA signals for powder MnBi ( $\sim 50\text{mg}$ ) were measured in  $B \leq 18$  T using a cryogen-free 18 T superconducting magnet (52mm bore),  $B \leq 23$  T using a cryogen-free 28T-hybrid magnet (32mm bore) and  $B \leq 26$  T using a 28T-hybrid magnet (52mm bore) in the temperature range of 20-480°C. The temperature was raised at the rate of  $\sim 3^\circ\text{C}/\text{min}$ .

Fig.1 shows the typical result of HF-DTA curves of MnBi under various magnetic fields up to 26 T. With increasing  $B$ ,  $T_i$  increases linearly at the rate of  $\sim 2^\circ\text{C}/\text{T}$ . The increase of  $T_i$  by  $B$  probably originates in the field-induced magnetic moment in FM-LTP MnBi. That is, upon applying  $B$  to MnBi, the decrease in the magnetic free energy of FM-LTP MnBi is much larger than that of PM-HTP  $\text{Mn}_{1.08}\text{Bi}$  because of the addition of the Zeeman energy. We present the designed of our HF-DTA apparatus and experimental data using it.

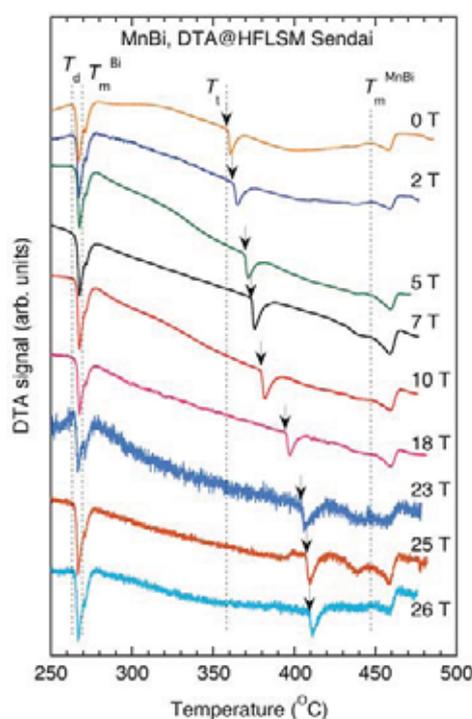


Fig.1. Typical result of DTA curves of MnBi under various magnetic fields up to 26 T.

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## Experimental analysis of the austenite to ferrite transformation in Fe-C-Mn alloys under high magnetic field.

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### Abstract:

The non-isothermal decomposition of austenite into ferrite and pearlite in carbon manganese steels (Fe-C-1.5wt%Mn with 0.1, 0.2 and 0.3wt%C) in high magnetic field is experimentally investigated by in situ dilatometry, microstructure characterization and high temperature magnetometry.

It has been found that the  $A_{r3}$  critical temperature is linearly increased of 2.2, 2.4 and 2.7 °C/T respectively for the 0.1, 0.2 and 0.3wt%C alloy up to 16T. The  $A_{r1}$  temperature is increased of 2.5°C/T in the presence of magnetic field. The differentiation between the pro-eutectoid ferrite formation process and pearlite precipitation is detected as a second well-formed expansion in the cooling dilatometric curve and this transition is found to be shifted of 1.8°C/T toward higher temperature for both alloys. As expected by dilatometry experiment, microstructure analysis has shown a systematic increase in the pro-eutectoid ferrite fraction, associated to a reduction of Vickers hardness values. Furthermore, significant alignment of pearlite colonies in the direction of magnetic field is observed in the field annealed specimens.

In this work, the impact of magnetic field on the phase boundaries and microstructures has ever been measured greater in the alloy with higher carbon content. Therefore, high temperature magnetic measurements have been done in a Faraday balance to experimentally demonstrate that the increase in carbon content lead to an increase in the magnetic contribution for pro-eutectoid ferrite transformation and thus, to an increase of the magnetic field impact in the phase boundaries and microstructures.

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## Competing interactions in the frustrated metamagnet $\text{CuFeO}_2$

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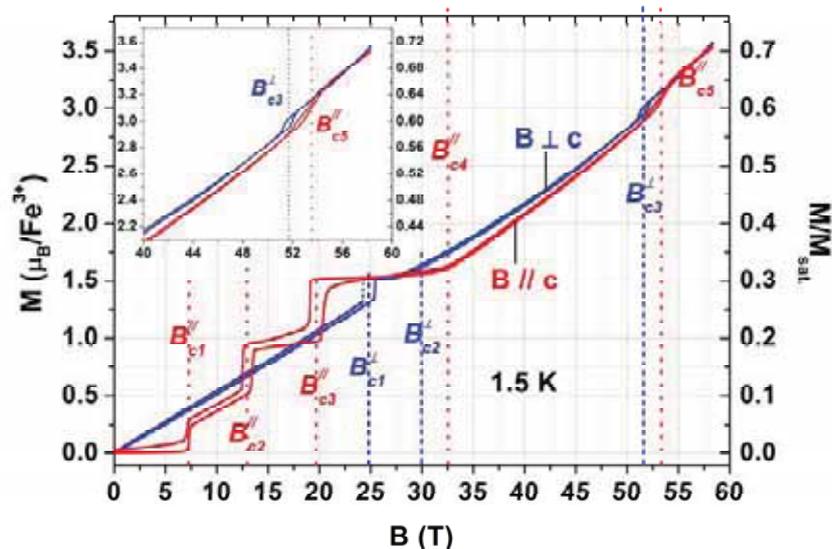
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Frustration typically occurs when one is hindered or blocked from achieving a personal goal. The analogous physical phenomenon, geometric magnetic frustration, occurs in systems with similar characteristics. Due to competing magnetic interactions between individual spins the system is prevented from selecting a unique magnetic ground state. At low temperatures, secondary interactions can (partially) lift this ground state degeneracy and favour a particular, often exotic, magnetic ordering. As an illustrative example, this work focuses on the multiferroic layered triangular antiferromagnet  $\text{CuFeO}_2$ , an archetype delafossite compound. This material adopts a multitude of successive collinear and noncollinear magnetic structures when subjected to an applied magnetic field and has recently attracted a surge of scientific attention due to the multiferroic nature of one of these field-induced phases. High magnetic field experiments, including magnetization measurements (See Figure) and nuclear forward scattering in pulsed fields at various temperatures, have been employed to extend the cascade of magnetic phase transitions in  $\text{CuFeO}_2$  up to 58 T, while simultaneously determining the spin structures in the successive phases. Experiments reveal a new, first order phase transition for both the parallel and perpendicular field configuration, which is interpreted in terms of a reversed spin-Teller transition. Above this transition virtually complete isotropic behavior is retrieved, signaling the recovery of the undistorted triangular lattice at high magnetic fields. The most important result of our study is the phenomenological rationalization of the intricate magnetic phase diagrams which necessarily includes both spin-phonon coupling as well as a field dependent distortion-induced easy-axis anisotropy.

*Figure: Cascade of magnetic phase transitions in the anisotropic magnetization process of  $\text{CuFeO}_2$ .*



## Progress of Protein Crystallization in High Magnetic Field in NWPU

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Protein crystallization in high field magnet is an interesting topic in that the magnetic field provides both magnetic field and field gradient, which are thought beneficial for growing good quality protein crystals [1-3]. Many investigations have been conducted both experimentally and theoretically, and evidences have been found that high field magnetic field can be applied in the practical crystallization of proteins.

The cumulating needs for structural determination of biological macromolecules urges the protein crystal growers to find selectable and useable methodologies to obtain high quality macromolecular crystals. As one solution to this requirement the investigations of protein crystallization in high field magnet should be addressed with particular emphasis.

This report summarizes the recent investigations on the protein crystallization in high magnetic field carried out in Northwestern Polytechnical University (NWPU) and Tsukuba Magnet Laboratory (TML) using superconducting magnet. The researches include the investigations on the containerless protein crystallization levitated by gradient magnetic field [4], the multiple orientation responses of lysozyme crystals in the magnetic field, etc.

Figure 1 (a) showed a photo of lysozyme crystals grown in a levitated droplet. Figure 1(b) showed an example of multiple orientation responses of lysozyme crystals when paramagnetic ions were used as precipitants.

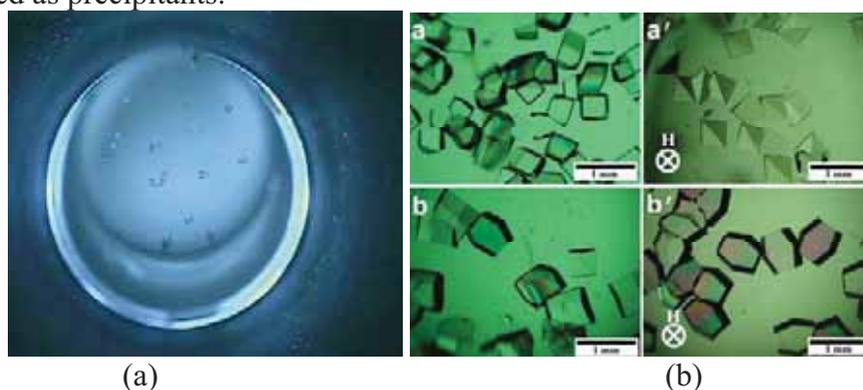


Fig 1. Crystallization of lysozyme in magnetic field. (a) Crystals grown in a levitated droplet; (b) multiple magnetic orientation responses when  $\text{NiCl}_2$  was used as precipitant.

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## Dynamic Motions of Small Diamagnetic Particles Induced by Static Field in Microgravity Condition; Examination of Mass Dependence.

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Rotational[1] and translational[2] motion caused by static magnetic field  $\mathbf{B}$  were recently observed for various diamagnetic samples released in microgravity  $\mu\text{G}$ . The two types of motions are well known for conventional magnetic materials that bear spontaneous moments, however possibility of such motions has been ignored for weak magnetic materials. Acceleration  $a$  of the translational motion caused by field gradient force is described as  $a = -(1/2)\text{grad}(\chi_{DIA}B^2)$  [see Fig.1(a)]; here  $\chi_{DIA}$  denote diamagnetic susceptibility per unit mass, while  $m$  is the mass of the sample. The rotational motion derives from anisotropy of diamagnetic susceptibility  $\Delta\chi_{DIA}$ . A rotational oscillation follow an equation  $I(d^2\theta/dt^2) = -m\Delta\chi_{DIA}B^2\theta$  [see Fig.1(b)]; here  $I$  is the moment of inertia of the particle, while  $\theta$  denote direction of magnetically stable axis with respect to field direction. Period of oscillation is described as  $\tau = 2\pi(I m^{-1}\Delta\chi_{DIA})^{1/2}B^{-1}$ . It is seen that  $a$  and  $\tau$  are both independent to  $m$ . In a given distribution of field gradient, value of  $a$  uniquely depends on intrinsic  $\chi_{DIA}$  value of the material [1]. As for rotational oscillation,  $\tau$  is determined by  $I m^{-1}$  and intrinsic  $\Delta\chi_{DIA}$  value of the material [2], in a given homogeneous field  $B$ . In the present report, the motions are measured for  $\alpha$ -quartz single crystals that posses various  $m$  values. The mass independencies of the two motions discussed above are examined based on the observed results as shown in Fig.2. Value of  $\chi_{DIA}$  and  $\Delta\chi_{DIA}$  are two basic parameters in investigating magnetic property of a material. The need of clarifying the properties for a single small particle is increasing rapidly with the growing interest on nano-sized materials. At present, these values are difficult to obtain for most of the diamagnetic materials using a conventional method. By observing the above-mentioned motions in  $\mu\text{G}$ , detection of  $\chi_{DIA}$  and  $\Delta\chi_{DIA}$  becomes possible on micron-sized sample [1]. This is because reduction of sample size is possible as long as motion of the sample is observable.

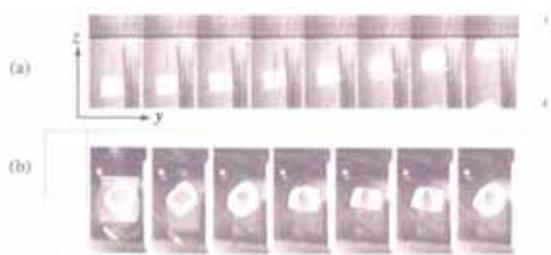


Fig.1. (a) Translational motion of Rochelle salt induced by field gradient[1]. (b) Rotational oscillation of calcite that derive from diamagnetic anisotropy [2].

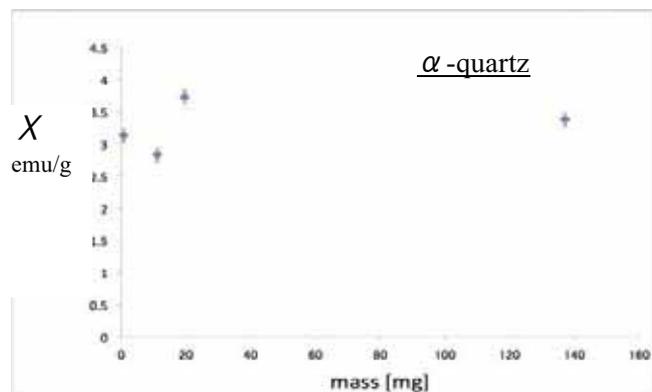


Fig.2. Relationship between measured  $\chi$  [emu/g] and mass observed for  $\alpha$ -quartz.

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## **Progresses of Biological effects and molecular mechanisms under Diamagnetic Levitation Condition**

**Peng Shang, Ai-Rong Qian, Zong-Cheng Tian, Rui Meng and Da-Chuan Yin**

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The diamagnetic levitation technology has been widely applied into many fields, such as physics, chemistry, material science and biology. Although at present the studies on the biological effects of diamagnetic levitation by high gradient superconducting magnet have just started, the rapid developing trends have been highlighted. Many studies have utilized this technique, such as those on frogs, frog embryos, and cell cultures of plants. Valles in Brown University has carried out the magnetic levitation-based Martian and Lunar gravity simulator under the support of NASA. Brooks reported that the leaves of transgenic plants produce resonant-type stress response in strong magnetic fields and in magnetic levitation (low gravity) environments ( $17 \text{ T} < B < 25 \text{ T}$ ) but null response in roots. Blade et al has reported that the magnetic levitation inhibits microtubule self-organization, which is consistent with the results reported in spacecraft. These findings indicate that magnetic levitation can be as a new ground-based simulated weightlessness technology.

In China, some studies in the field of high magneto science and technology have been carried out. At present, Hefei Institutes of Physical Science, Chinese Academy of Sciences (CASHIPS) is constructing the "High Magnetic Field Centre". In our laboratory, the diamagnetic levitation platform has been developed using a superconducting magnet (JASTECH, Japan) with large gradient high magnetic field. The effects of diamagnetic levitation on the structure and functions of tumor cells (hepatocellular carcinoma cells, breast cancer cells and kidney cancer cells), bone tissue cells (human mesenchymal stem cells, osteoblast, osteocyte and osteoclast) and other normal tissue cells (skin fibroblast, embryonic hepatocyte) have been investigated. The effects of diamagnetic levitation on silkworm embryogenesis and protein crystals also have been carried out. The results indicate that the diamagnetic levitation technology, as a novel ground-based technique, will provide new technological means for biological studies and will be widely applied into life science in the future.

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## The shapes of levitating and spinning water droplets<sup>[1]</sup>

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The shape of a weightless, spinning liquid droplet is governed by the balance between the surface tension and centrifugal forces. In 1863, Plateau conducted experiments on a droplet of olive oil suspended in a density-matched immiscible liquid [2]. When he started the droplet spinning, he observed that the droplet became flattened at the poles and bulged at the equator as the droplet picked up speed; above a critical angular velocity, he observed that the droplet progressed through a series of ‘2-lobed’ shapes. In 1980 Brown and Scriven predicted the existence of 3 and 4-lobed equilibrium shapes at higher angular velocity [3].

Whilst Plateau’s technique for studying fluids in weightless conditions is attractive for its simplicity, it suffers from the effects of viscous drag on the droplet from the surrounding fluid, complicating comparisons between experiment and theory. To avoid this problem we use *diamagnetic levitation* to levitate centimetre-sized water droplets using a 17T superconducting magnet. We spin the droplet by inserting two gold-wire electrodes into it, and passing an electric current through the liquid: in the magnetic field, the magnetic Lorentz force on the current-carrying ions develops a torque on the droplet.

We observe the formation of a stable, triangular droplet, in good agreement with the prediction of Brown and Scriven, but until now, not clearly observed. In addition, we observe that the electrodes generate waves on the surface of the droplet that travel around the droplet’s equator. These waves give the droplet a triangular, square, and pentagonal outline, with increasing angular velocity.



Spinning three-lobed equilibrium shape.



Travelling waves.

A spinning liquid droplet, held together by its surface tension, can be used as a ‘toy model’ of objects held together by other cohesive forces: Plateau’s experiments were inspired by the idea that a droplet could model the shape of a spinning astronomical object (a problem which interested Newton) and the liquid-drop model of the atomic nucleus is well-known. Recently, the behaviour of a spinning droplet has become interesting to cosmologists studying the stability of spinning astronomical objects with event horizons [4].

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## Additives Effects on Magnetic Orientation of Helical and Membrane Mesoporous Silica

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The mesoporous silica, which is formed by the interaction of surfactants and silica precursor, has homogeneous pores of the diameter of 2-50 nm, which are produced by burning surfactant molecules in it. The mesoporous silicas are used for adsorbents, catalytic supports, and molecular separator. Therefore, if silica's morphology is controlled by external fields, they must be much useful for application as described above. Magnetic fields, which bring about small magnetic energy in feebly magnetic molecules, can orient molecular assemblies such as micelles due to magnetic anisotropy. Magnetic orientation can be used as a tool to control molecular direction. Rodlike micelle is used as a template in mesoporous silica. Therefore, we expect that the orientation of mesoporous silica may be brought about via magnetic orientation of the template. Moreover, additives having large magnetic anisotropy such as pentacene and mesitylene may amplify magnetic orientation of mesoporous silica.

Helical silicas were prepared by mixing sodium dodecyl sulfate (SDS), TEOS, and *N*-trimethoxysilylpropyl-*N,N,N*-trimethylammonium chloride (TMAPS) under magnetic field ( $B \leq 18$  T). Membrane mesoporous silicas were synthesized by a blockcopolymer of ethylene oxide and propylene oxide (EO<sub>20</sub>PO<sub>70</sub>EO<sub>20</sub>, Pluronic P123) as a template under magnetic fields ( $B \leq 30$  T) at 293 and 298 K. The precursor was prepared from solutions containing P123, ethanol (EtOH), tetraethyl orthosilicate (TEOS), water, and hydrochloric acid. Benzene, naphthalene, anthracene, mesitylene, and pentacene were used for additives. Mesoporous silica and helical silicas were characterized by X-ray diffraction and scanning and transmission electron microscopes.

Helical silicas added mesitylene and pentacene oriented for axis of magnetic fields of up to 18 T compared with that at 0 T. Magnetic Orientation is expressed by the order-parameter,  $S = 1/2 \langle 3\cos^2\theta - 1 \rangle$ , where  $\theta$  is the angle between direction of a magnetic field and rod axis. When rods are well-oriented,  $S$  value is close to 1. The order-parameters of helical silicas added mesitylene and pentacene, prepared under 18 T, were about 0.8 and 0.95, respectively. Larger magnetic anisotropy of pentacene than mesitylene leads to high order structure of helical silicas. To evaluate magnetic anisotropy dependence of magnetic orientation, we examined X-ray diffraction of membrane mesoporous silicas containing benzene, naphthalene, anthracene, and pentacene. The intensity of (100) peak of a hexagonal structure increased with increasing magnetic anisotropy.

## Organization and Orientation of Gold Nanorods on a Substrate using a Strong Magnetic Field

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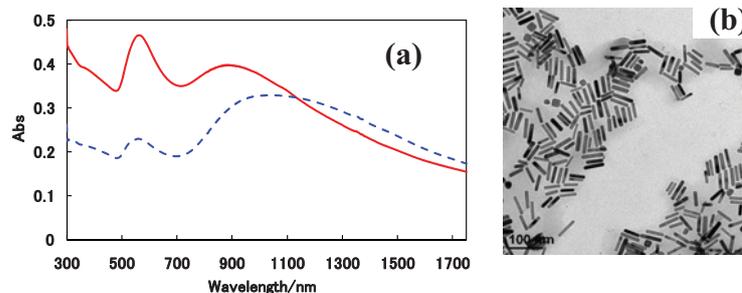
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Gold nanorods (AuNRs) possess unique optical properties depending on size and aspect ratio (the ratio of longitudinal-to-transverse length). Though the spherical gold nanoparticle show only one surface plasmon (SP) band in the visible region, the AuNR show a couple of SPs, that one SP band corresponding to the transverse oscillation mode locates in the visible region at around 520 nm, while the another corresponding to the longitudinal oscillation mode between far-red and near-infrared region. In this study, we examined magnetic processing of organization and orientation of AuNR/PSS (poly(styrenesulfonate)) composites or AuNRs on a TEM grid or a glass substrate [1].

AuNR/PSS composites were prepared on the basis of the electrostatic interaction between hexadecyltrimethylammonium bromide (CTAB) as a stabilizing agent on the AuNR and PSS. Magnetic processing was carried out using a superconducting magnet (Oxford) with vertical direction of magnetic field. A TEM grid or a glass substrate was immersed in the aqueous solution of AuNR/PSS composites. The samples were placed at 10 T and outside magnetic field (0 T). After drying the solvent at 323 K under atmospheric pressure, TEM and absorption spectra or polarized absorption spectra measurements were carried out.

In absorption spectra of AuNR/PSS composites on glass substrates, two SP bands due to longitudinal (1035 nm) and transverse modes (557 nm) were observed in the absence of magnetic processing, while the peak of the SP band corresponding to the longitudinal mode (883 nm) was significantly blue-shifted in the presence of magnetic processing (Fig. 1(a)). In TEM images, no aggregation of AuNR/PSS composites was observed in the absence of magnetic processing, while side-to-side aggregation of AuNR/PSS composites was observed in the presence of magnetic processing (10 T) (Fig. 1(b)). The results of TEM images are in fair agreement with those in the polarized absorption spectra. We will also discuss effect of magnetic processing on organization of AuNRs.

Fig. 1. (a) Absorption spectra of AuNR/PSS composites in the absence (blue broken line) and the presence of magnetic processing (10 T; red solid line). (b) TEM image of AuNR/PSS composites (10 T).



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## Two-Dimensional Simulation of Laser-Induced Convection of Benzene Solution in High Magnetic Fields

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Magnetic field effect on thermal convection of benzene solution containing a photochromic compound, 1,2-dicyano-1,2-bis(2,4,5-trimethyl-3-thienyl)ethene (CMTE)<sup>1)</sup> is numerically simulated. When a CMTE solution is irradiated using a UV laser from the bottom of a vessel, CMTE undergoes photoisomerization to its photoisomer(PI) and the PI solution moves upward, as the solution is heated by light absorption. The removal time of PI solution from the bottom is remarkably affected by the fields.

In the present study, we tried to understand this phenomenon semiquantitatively by a computer simulation technique based on finite element method where the influence of the magnetic susceptibility change of benzene and that of the solute due to photoisomerization is included.

Figure 1 shows the distribution patterns of PI solution in magnetic fields. These patterns agree well with the reported experimental result<sup>1)</sup>. By application of magnetic fields, convection of the solution changes, as magnetic force acts on the solution in addition to the buoyancy induced by light absorption. As a result, the pattern of the PI solution changes.

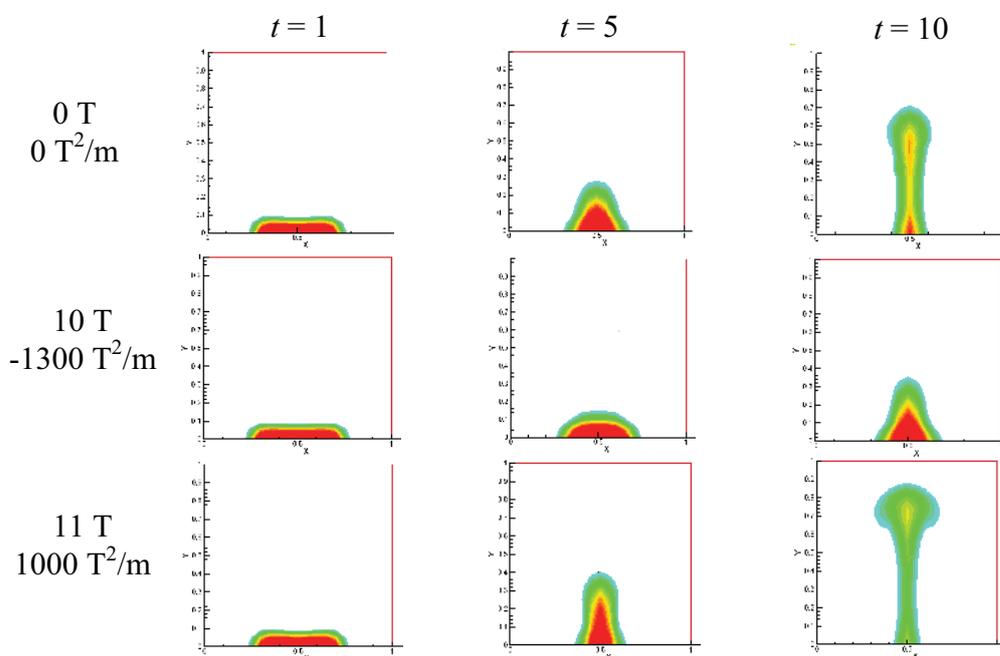


Fig.1 Simulation of photo-induced convection of benzene solution of CMTE in magnetic fields

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## **Effluence of a Magnetic-Field-Assisted Solvo/Hydro-thermal Synthesis on one dimensional nanostructure of Te**

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**Abstract** One dimensional nanostructure shows the unique applications in mesoscopic physics and fabrication of nanoscales devices. The effluence of strong magnetic field on the one dimensional nano-structure of Te by solvo/hydro-thermal synthesis in this study. The results show a strong magnetic field can promote the one dimentinal growth of nano-Te. With enhancing the intensity of magnetic field, the length-diameter ratio of one dimentinal Te increases synthesized by both solvothermal and hydrothermal. Promotion of one dimentinal growth in strong mganetic field may be attributed to a decrease in reaction velocity due to an increase in the nucleation energy.

## Formation and disappearance of magnetized nano-bubble water under the pulsed-magnetic field

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A mineral water (Volvic<sup>TR</sup>) exposed to a pulsed-magnetic field (North-pole; 1.8 mT) showed an increase of pH together with a concomitant magnetization to North-pole. About 0.03 mT (N-pole) magnetization was imprinted together with 0.28 pH unit increase for more than 1 day. Whereas static magnetic field (North-pole; 1.8 mT) induced by a commercial ferrite magnet was less effective. Formation of a nano-bubble water was observed by a dynamic light-scattering method and supported by an ozone trapping experiment into nano-bubble. It is suggested that a pulsed-magnetic field 2BD6 (Fig.1) might facilitate to re-organize the water structure into a nano bubble water surrounded by anions and cations (metal ions and/or protons) involving a coherent vibrational or rotational motions cychronous to the repeated pulse of magnetic flux. On the other hand, disappearance of nano bubble was observed by irradiation of a pulsed-magnetic field ULF code (Fig. 2). A possible mechanism is proposed.

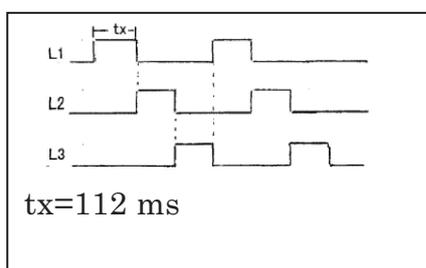


Fig. 1 2BD6 code

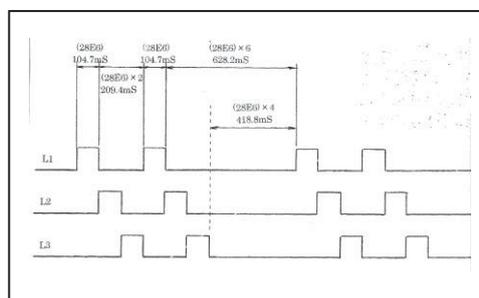


Fig. 2 ULF code

## DNA Electromagneticphoresis under the Condition of $B \perp E$

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Magnetic field effects on the electrophoresis of DNA have been investigated under the homogeneous and gradient magnetic fields. Four electromagnetic forces are thought to be influenced for the DNA motion: (1) the electrophoretic migration of the negative charged DNA towards the positive electrode, (2) the magnetic torque due to the anisotropic susceptibility, and (3) the magnetic force for the diamagnetic DNA towards the direction of the low magnetic flux density in the gradient magnetic field. Moreover, (4) Lorentz force is added when the magnetic line of force is not parallel to the electric line of force. These magnetic forces and Lorentz force change the course and/or the velocity of the DNA electrophoresis. In this paper, Lorentz force effect is investigated for the DNA electrophoresis. When the electric field was horizontal and the magnetic field was vertical, Lorentz force effect of the DNA electrophoretic pattern was observed. Figure 1 shows the voltage dependence of the fractional side slip  $f_s$ . Here, the  $f_s$  was defined as  $f_s = y/x \times 100$ , where  $x$  and  $y$  were the distance of the direction of Coulomb's force and the distance of the direction of  $E \times B$ , respectively. In addition the angle  $\theta$  was calculated as  $\theta = \tan^{-1}(y/x)$ . The  $f_s$  was increased with voltage above  $E=30$  V, and became saturated at around  $E=50$  V. On the other hand, the shift  $y$  is not observed below  $E=20$  V. At the peak of  $E=40$  V, the  $f_s$  of 7, 10 and 12% were observed for DNA of 2, 4 and 10 kb, respectively. The experimental results could apply a new application of the strong magnetic field to the separation of materials.

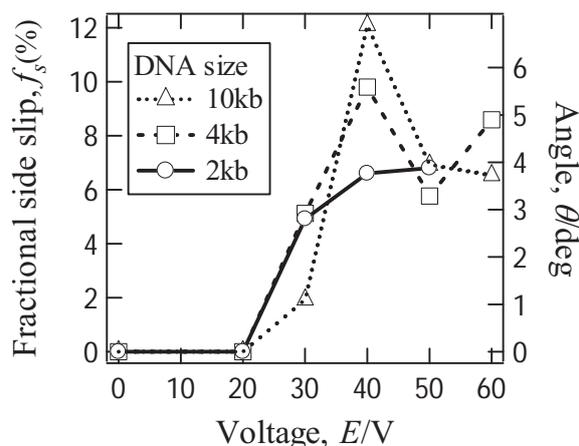


Fig. 1. Voltage dependence of the fractional side slip  $f_s$  and angle  $\theta$ .

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## Magnetic Quenching of Light Scattering in Red Chromatophore of Gold Fish Scale

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It needs over several Tesla of magnetic fields to observe magnetically oriented biological macromolecules under a polymerization process [1, 2]. In the case with objects several hundreds microns in length, magnetic fields at less than one Tesla can provide the magnetic orientation of objects, such as retinal rod [3] and tubular vesicle made of lipid bilayer [4]. The magnetic orientation is expected to be applied to new methods for cellular function control and protein function measurement.

The present study reports on an effect of magnetic fields on guanine crystal controlling light scattering/interference in red chromatophore of gold fish's scale. Light scattering in a guanine crystal plate in gold fish's scale was observed due to a structural color, which was produced by multi laminate lamella of guanine plates.

The microscopic observation of scale was carried out with a mono-zoom lens set in the vertical bore of 5-T superconducting magnet. The light scattering was quenched by magnetic fields of more than one Tesla when the applied magnetic fields were increased (Fig. 1). The quenching was reversibly occurred when the applied external magnetic fields were changed between 0 Tesla and 5 Tesla. In the case with decreasing magnetic fields, the quenched red chromatophore started the scattering again at 0.3 Tesla. The numbers of light scattering chromatophores in the range of 0 T – 5 T exhibited a hysteresis pattern. We speculate that the observed phenomenon was generated by magnetic orientations of tubulin and actin, because the light scattering in guanine crystal plate occurred by changing the angle of plates by tubulin and actin fibers.

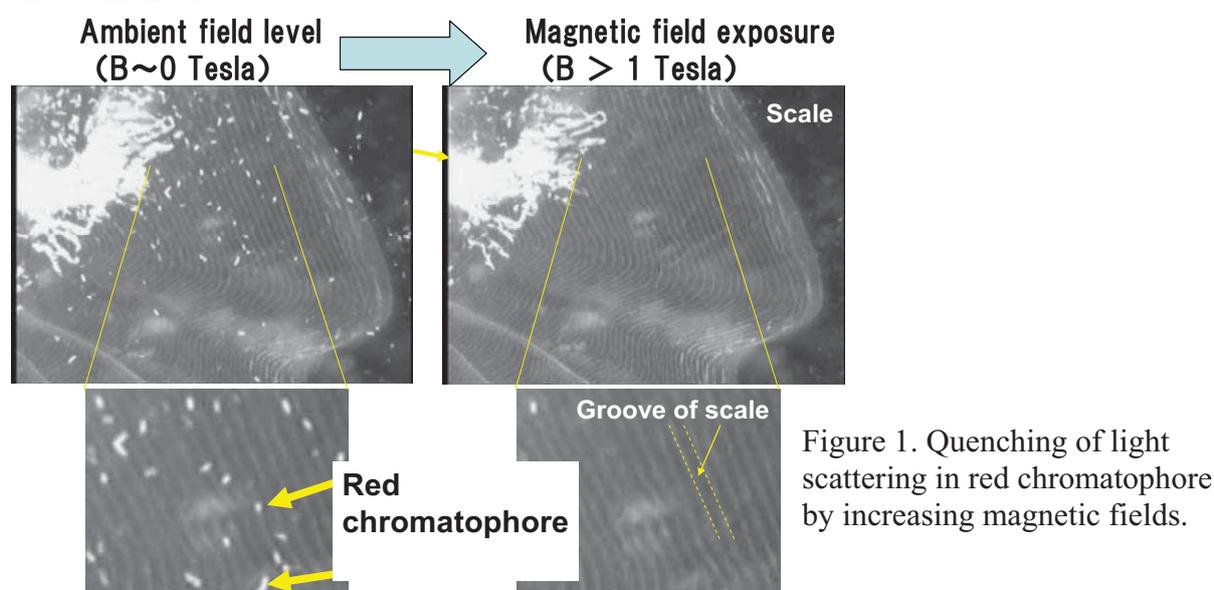


Figure 1. Quenching of light scattering in red chromatophore by increasing magnetic fields.

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## Diamagnetic Levitation Affects Structure and Function of Bone Cells

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With the development of superconducting technology, the superconducting magnet, which can produce a stable large gradient high magnetic field (LG-HMF) environment to make diamagnetic levitation, such as biological macromolecules, cells, tissues and model animals, has become available. In this study, a superconducting magnet which can generate a magnetic force field [ $B \cdot (dB/dz)$ ] of  $-1360 \text{ T}^2/\text{m}$ ,  $0 \text{ T}^2/\text{m}$  and  $1312 \text{ T}^2/\text{m}$  in a 51 mm diameter room temperature bore was employed. Three magnetic force fields correspond to three apparent gravity levels (0, 1, and 2 g) and three magnetic induction intensities (12, 16, and 12 T), respectively. The superconducting magnet therefore can simulate gravitational environment from microgravity (0-g) to hypergravity (2-g). The effects of LG-HMF on bone cells, including osteoblast, osteocyte and bone mesenchymal stem cells (BMSC) were investigated.

The results showed that diamagnetic levitation affected the structure and cytoskeleton architecture of osteoblast, osteocyte and BMSC. Under diamagnetic levitation conditions, the BMSC and osteocyte presented obviously apoptosis, and the process number and cell area of osteocyte dramatically decreased. The cytoskeleton of osteoblast, osteocyte and BMSC reorganized and the expression and distribution of cytoskeleton-related proteins, including vinculin, talin, paxillin was also clearly changed. The cell cycle, the secretory function and adhesive ability of bone cells were also changed by diamagnetic levitation. These findings will enhance our understanding on the biological effects of the high gradient static magnetic field.

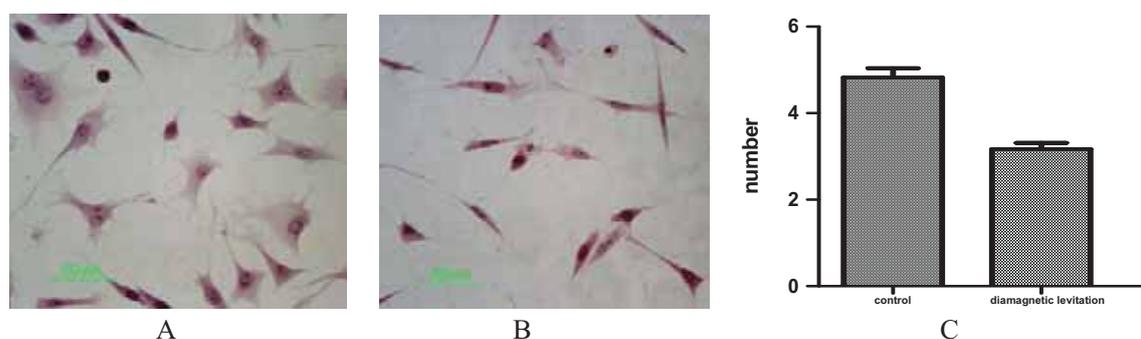


Fig 1. The effects of diamagnetic levitation on osteocyte morphology. A, B: osteocyte morphology under control and diamagnetic levitation conditions, respectively; C: the process number of osteocyte under control and diamagnetic levitation conditions.

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## Control of Three-Dimensional Orientation of Carbon Nanotubes in Magnetic Microgravity

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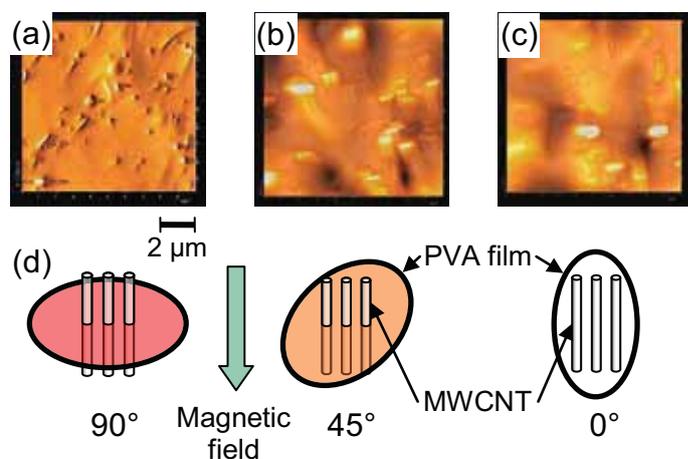
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Microgravity science has provided the creative potential of a new material development. High magnetic fields have opened the availability of producing a stable and long duration microgravity condition on the earth. Previously, we succeeded in the preparation of thin films of liquid, solid, and carbon nanotubes-doped in the magnetic microgravity condition [1-3].

In this study, we prepared polyvinyl alcohol (PVA) thin films doped with multiwall carbon nanotubes (MWCNTs), and arranged MWCNTs not only at a normal angle but at various angles to the PVA films in the magnetic microgravity condition.

The PVA films were put at various angles to the magnetic field. They had a uniform thickness owing to the microgravity condition. Fig. 1 shows AFM images of the PVA films at 90, 45, and 0 degrees to the magnetic field. Clearly, the MWCNTs were oriented parallel to the magnetic field, regardless of the angle relationship. The magnetic field gradient determined the levitation point of the PVA films, whereas the magnetic field direction determined the orientation of the MWCNTs. It is noted that the three-dimensional orientation of the MWCNTs was controlled in the magnetic microgravity condition.



**Fig. 1.** AFM images of the PVA thin films containing MWCNTs. The angles between the films and the magnetic field: (a) 90°, (b) 45°, (c) 0°. (d) Simple sketches of the PVA films with MWCNTs.

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This work was supported partially by JSPS Asian Core Program "Construction of the World Center on Electromagnetic Processing of Materials".

## Effects of Hypomagnetic Field on Bone Remodel of Hind-limb Unloading in Rats

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The hypomagnetic field (HMF) condition is a special environment that the astronauts have to face on the moon or during the long term interplanetary flights. The purpose of this study was to investigate the complex effects of HMF and hind-limb unloading on bone loss in rats. The hypomagnetic field that was generated by a geomagnetic field shielding room, sized in 1.8M×1.6M×1.5M, provides 300nT HMF environment for experimental animals. 20 male S-D rats were randomly divided into 4 groups: control group (normal geomagnetic field), hind-limb unloading group (HLU, tail-suspension, -30°head down tilt), HMF group (rats raised normally in shielding room) and HLU+HMF (HLU rats raised in shielding room) group. The bone mineral density (BMD), bone mineral content (BMC) and bone biomechanical properties of the femur were measured following HLU for 4 weeks by dual-energy X-ray absorptiometry (DXA) and mechanical testing, respectively. DXA analysis showed that the femur BMD and BMC of HLU and HLU+HMF group were decreased significantly, compared with those of the control group, respectively. ( $P<0.05$ ,  $P<0.01$ , and  $P<0.01$ ,  $P<0.01$ ). The BMD of femur in HLU+HMF group was lower than that in HLU group ( $P<0.01$ ), and the BMC of femur in HLU+HMF group was similar to that of HLU group. The difference of BMD and BMC of the femur between HMF group and control group were not significant. There was significant difference of the femur section average outside diameter of HMF+HLU group, compare to those of other groups ( $P<0.01$ ). Mechanical testing showed that the ultimate bending stress of femur were significantly difference between HMF and HLU+HMF group ( $P<0.05$ ), and in HLU group it was similar to that of control group. The femur toughness factor of HLU and HMF+HLU group were increased significantly, compared to those of the control group and HMF group, respectively. The elastic modulus of HLU and HMF+HLU group were increased significantly, compared to those of the control group and HMF group respectively, and HLU+HMF group were less than those of HLU group with significance. In conclusion, the bone remodel of HLU rats are sensitive to hypo-magnetic field which decrease BMD and affect mechanical properties of the femur.

## Magnetic Alignment of Amorphous Polymers

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The control of macromolecular order at the nanoscale during polymer processing is of great interest. In this context, it has been shown that natural and synthetic macromolecular systems with anisotropic magnetic susceptibility can be aligned in sufficiently strong magnetic fields [1,2]. Liquid-crystalline and semicrystalline polymers, block copolymers and polymer fibers are few examples of diamagnetic materials able to undergo magnetic alignment [1]. Amorphous polymers having monomer units with anisotropic magnetic susceptibility should be able to align as well. In fact, alignment of amorphous polymers with electric fields in applications as non-linear optical materials has been shown [3]. However, it has been reported that these polymers lack of anisotropic structures large enough to overcome the thermal energy at the corresponding processing temperature and, consequently, hamper any magnetically induced molecular order [1,2]. This work shows that diamagnetic amorphous polymers with anisotropic magnetic susceptibility could respond to the influence of external magnetic fields.

Commercially available atactic polystyrene (*a*-PS),  $M_w$  of 321,000 g mol<sup>-1</sup> and molecular weight distribution  $M_w/M_n = 2.27$ , was used to prepare disks by solvent casting from polymer solutions in toluene at a concentration of 35 g l<sup>-1</sup> in the presence of a magnetic field (4 to 6 T). Disks thus obtained were levitated in aqueous media using a 9.4 T superconductive magnet (Bruker Analytik GmbH, Karlsruhe, Germany). Also, these samples were analyzed by <sup>13</sup>C solid state 2D NMR spectroscopy at 9.4 T using a Bruker CP/MAS probe. A rotor-synchronized pulse sequence was used [4] to determine the extent of macromolecular order in the PS samples.

The results showed that disks of amorphous *a*-PS prepared by solvent casting in the presence of a magnetic field align under magnetic levitation differently than disks prepared outside the magnet. Furthermore, <sup>13</sup>C solid state rotor-synchronized 2D NMR results indicate that application of an external magnetic field during casting alters the macromolecular order in *a*-PS samples. These findings suggest that macromolecular cooperative segmental motions with reorientation of the diamagnetic susceptibility tensor occur during fluid-solid phase transitions of polymers in the presence of a magnetic field.

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### Acknowledgments

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## Tuning the Flexibility of Thiocyanine Fibers with a Magnetic Field

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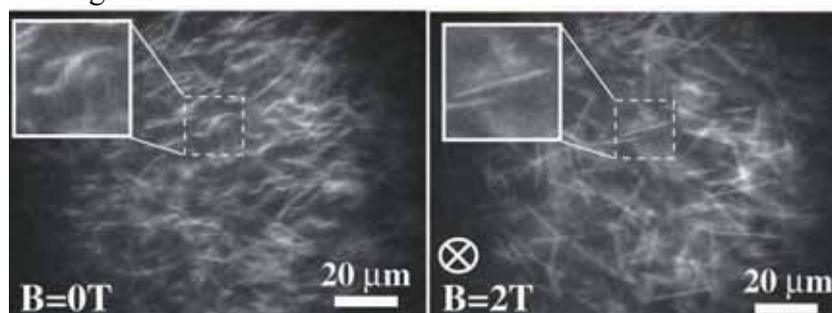
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Among supramolecular systems, there has been a special interest in fiber-shaped aggregates [1-3]. These one dimensional structures are model systems, not only to study chemical self-assembly, but also to investigate the relationship between the internal structure of aggregates and their physical properties, such as the flexibility. We have found that the flexibility of thiocyanine fibers in water changes in a magnetic field. A 2T field induces a transition from flexible fibers to rigid rods (Figure 1), which is remarkable because it is commonly believed that magnetic torques are too small to induce morphological changes at a molecular level.

The field dependent flexibility has been extensively studied by measuring fluorescence microscopy, magnetic birefringence and polarized absorbance as a function of magnetic field. We observe a two-step magnetic orientation process which causes both the magnetic birefringence as well as the absorbance to change sign around 5T. During the first stage (< 2T) the rigidification occurs. Furthermore, to probe changes in the internal molecular structure that is supposed to be responsible for the altering flexibility, we have conducted in-situ small angle X-ray scattering (SAXS) on solutions of thiocyanine in fields of  $B < 7T$  at the European Synchrotron Radiation Facility in Grenoble. Based on the optical and SAXS measurements, the change in the flexibility is discussed in relation with a modification in the internal molecular organization.



**Figure 1.** Fluorescence microscopy images of thiocyanine fibers. Left: without a magnetic field, showing flexible fibers. Right: In a magnetic field of  $B=2T$ , where the fibers have become rigid.

Our results show that magnetic fields can possibly be exploited as an extra parameter, besides light illumination or ionic strength [4], to change aggregate morphologies, which is of interest from a fundamental science point of view, but also might lead to novel industrial applications.

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## Effects of High Magneto-gravitational Environment on Silkworm Embryogenesis and Gene Expression

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The aims of this study are to investigate the effects of high magneto-gravitational environment (HMGE) produced by a superconducting magnet on silkworm embryogenesis and gene expression. A superconducting magnet which can produce HMGE and provide three apparent gravity levels (0g, 1g and 2g) was employed to simulate space gravity environment. The average hatching time, embryos hatching rate, lifespan, growth curves, cocoon weight and differential expression genes of silkworm were detected after exposure of silkworm embryos to HMGE. Suppression subtractive hybridization (SSH) was used to isolate gravity related genes of silkworm embryogenesis in simulated weightlessness and normal gravity environment. Differential expression genes were cloned, sequenced and analyzed on homology. The changes of the silkworm dynein light chain 8 (*Dlc8*) gene expression pattern were studied in different gravitational environments. The full length cDNA for silkworm 3-Hydroxyisobutyrate Dehydrogenase (*hibadh*) was amplified using RT-PCR and RACE technique and its distribution in silkworm tissue was detected.

The average hatching time of silkworm embryos under 0g condition was earlier than that under control condition. The hatching rates of 0g groups were lower than those of control groups and 1 g groups. The silkworms' lifespan of experimental groups was shortened as compared with that of control groups. The differences on the growth curves, mutation rate and the weights of cocoon were not significant between each experimental group and control group. These phenomenon were concordance with those of space flight. 34 differential expression genes, including 16 up regulated genes and 18 down regulated genes under 0g condition, were screened by SSH. Silkworm *Dlc8* gene was down regulated under 2g condition. The full length *hibadh* gene down regulated under 0g condition with 1074bp was successfully amplified. The open read frame of *hibadh* gene was consist of 969bp coding 323aa. GenBank accession number for *hibadh* gene nucleotide sequence was EU719652. Molecular Weight and isoelectric point of Hibadh were 34.1 KD and 9.14 respectively. The RT-PCR expression tests indicated that the *hibadh* gene expressed in head, silk gland, midgut, cuticle, blood, fat, tuba malpighii of silkworm.

These findings suggested that the effects of HMGE on silkworm embryogenesis were not lethal and not mutagenic. The gravitational environment produced by a superconducting magnet can be used as a novel ground-based gravity simulating method to space biology study. *Dlc8* gene could be a molecular target to study gravity bioeffect.

### Acknowledgements

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**Magnetic field polymerisation**  
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The influence of the magnetic field on chemical reactions attracts considerable interest of researchers in the context of possible applications. Magnetic effects can be of technological interest because they offer a new way to perform radical processes. This is because through very weak perturbations of the magnetic field, one can control chemical kinetics and thus the course and the rate of reactions that normally require much higher chemical energies. [1]

Some reactions of polymerisation performed in magnetic field are known and explained on the basis of radical pairs mechanism. The major theories of magnetic effects exploit the concept of singlet-triplet transitions in geminate and random radical pairs. They also reveal how internal and external magnetic forces that operate on the pairs can be employed to design or interpret magnetic field effects on chemical reactions. Thus, magnetic field influences becomes obvious when, in radical pairs from the system, the field will induce or prevent transitions between near fundamental electronic states. The changes in spin multiplicity of the radical pairs under the influence of the field determine the subsequent magneto-kinetic effects. [2]

Besides the modifications brought to the evolution of the radical processes as well as of the polymerisation reactions, the magnetic field also influences the properties of the resulting reaction products as for example polymers obtained through processes in the field. This acts as a supplementary argument justifying the interest in the field.

The changes in the properties of the polymers synthesised in the magnetic field are attributed to the catalytic effect of the field on the molecules that can be re-shaped through growing of distance interactions and modification of angles between bonds. [3]

The behaviour of poly(styrene) as macro-initiator in the magnetic field of 7 T it was taken into this study. Methyl methacrylate grafting process on two variants of poly(styrene) anionic obtained, functionalised as macro-initiator with 4, 4' - azobis (4-cyano-pentanoic) chloride, and having the molecular weights of  $M_w = 1900$  and respectively of  $M_w = 8300$ , it has been realised.

Aspects concerning the grafting reactions kinetics are presented. The comparison between the molecular weights values of the grafted polymers synthesised with and without the MF – data which are sustained by the H-NMR spectra and near infrared chemical imaging – evidences the higher content of the second block copolymer found in the products obtained in the magnetic field.

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## Pulsed Magnetic Field Effects on Ice Crystal Formation in Biological Aqueous Solutions

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Biological effects of magnetic fields are categorized to two mechanisms; the direct effects of magnetic fields and the induced electric field effect which is generated in a medium exposed to a time-varying magnetic fields. Huge numbers of application of the time-varying magnetic fields were reported in biological studies, however, many phenomena remains underlying mechanisms to be clarified. For example, an effect and its mechanism of pulsed magnetic fields on freezing processes of food are not clarified. In the present study, we observed an ice crystal formation process in biological aqueous solutions under a pulsed magnetic field exposure with 10Hz and 10mT.

The experimental system was consisted of a solenoidal coil set in a freezing box which changed the temperature in the box from 9°C to -30°C for 90 min. The solenoidal coil generated 10mT at the edge of coil. An optical microscope with CCD mono zoom lens was set at the edge of solenoidal coil and a real time image of ice crystal was obtained during freezing process. Also by utilizing a time-resolved spectrophotometer with a fiber attachment module in the coil, we observed the change in optical absorption of the freezing sample.

The microscopic observation of aqueous solution at the bottom of a glass container provided us a difference between pulsed magnetic field exposed and non-exposed sample, as shown in Fig.1. The magnetic field exposed sample had broad areas with a uniform ice while the non-exposed sample showed grid patterns. Also the time courses of the optical absorption at 500nm ~ 1000nm showed that the pulsed magnetic field exposure prolonged the time to reach coagulation temperature of aqueous solution as well as the period between coagulation and re-coagulation after dissolution by latent heat. Provably the effect was due to the eddy current which was induced by the magnetic field. The observed phenomenon seems to be one of the mechanisms for effective applications of time-varying magnetic fields for the freezing process of water-containing materials such as food.

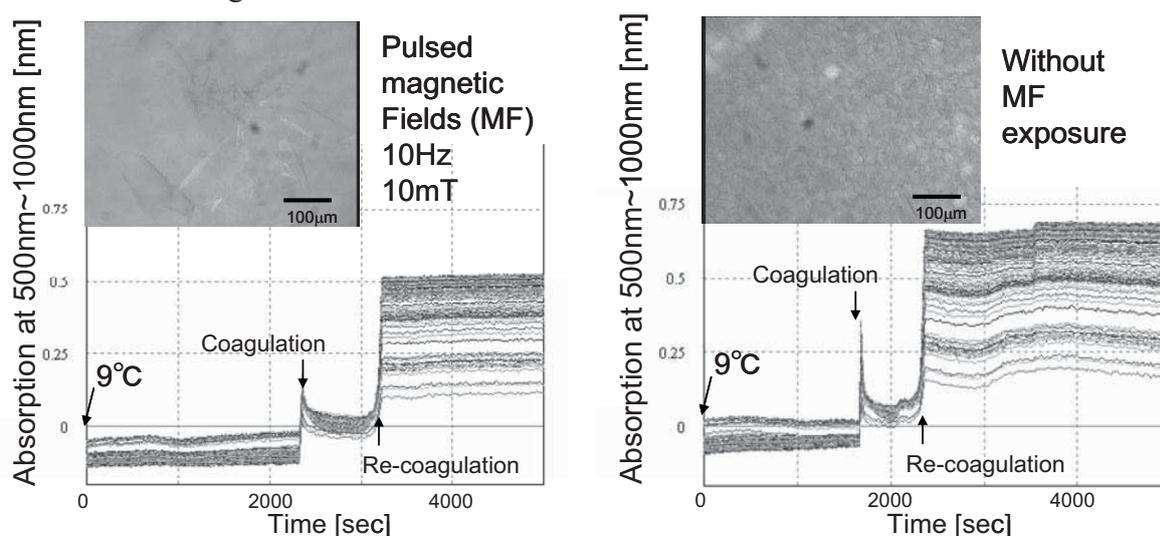


Figure 1. Effects of pulsed magnetic fields on ice crystal formation processes. Optical absorptions and real time images of ice after re-coagulation are shown.

## Electrodeposition in Inhomogeneous Magnetic Fields.

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The magnetohydrodynamic effect in electrochemistry is due to the action of the Lorentz force  $F_L = \mathbf{j} \times \mathbf{B}$  on the current density  $\mathbf{j}$  flowing in an electrochemical cell in the presence of a magnetic field  $\mathbf{B}$ . The magnetic-field-induced convection is most effective at modifying electrodeposition in the mass-transport limited regime, where the thickness  $\delta$  of the diffusion layer is determined by convection. In the simplest case where  $\mathbf{B}$  and  $\mathbf{j}$  are parallel and perpendicular to the cathode surface, respectively, a uniform flow across the electrode surface decreases  $\delta$  and increases the deposition rate as  $B^{1/3}$  [1]. More complex flow arises when the magnetic field or current is nonuniform [2,3]. For example, the radial component of the field around a ferromagnetic microelectrode produces a circular flow pattern of the electrolyte [2]. Here we investigate the magnetohydrodynamic flow, and its effect on electrodeposition. We have done this experimentally for copper with field variations on a scale of 1 mm and a horizontal electrode geometry to minimize gravitational convection, and we have also investigated the effect *numerically* using finite-element solutions of the Navier-Stokes equation with the Lorentz force and the convection-diffusion equation. In Fig 1, we show the field profiles in the electrolyte at a distance equal to the magnet radius for cylindrical magnets with polarization 1.0 T, and with height equal to their diameter. The main flow pattern is indicated by the dotted line. A single magnet (Fig 1a) creates a single clockwise or anticlockwise vortex, depending on the field direction. A periodic square array of magnets with the same polarity creates frustrated vortices with a lattice of planar nodes where there is no movement; the main flow is around the periphery, Fig 1b). An square array with alternating polarity creates coherent vortices, with maximum flow at the midpoints of the magnet array, Fig 1c. The experimental copper profiles will be compared with those calculated by finite-element numerical simulation using COMSOL. Scaling of these results to a submicron lengthscale will be discussed with reference to electrodes backed by arrays of CoPt magnets in an alumina membrane.

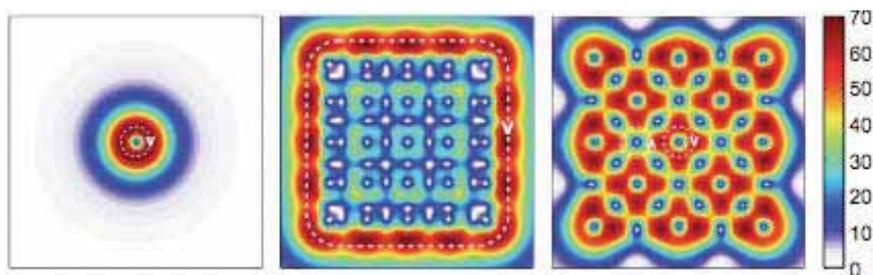


Figure 1. In-plane field contours for  $B_{xy}$  calculated for three different magnet arrays. The main flow pattern is indicated by the dotted line

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## Magnetic Field Effect on Structure and Function of Aqueous Salt Solutions

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Magnetic treatment (MT) water, which is water passed through magnetic fields, has very interesting properties; e.g., decrease of contact angle and viscosity, structural changes of calcium carbonate and inhibition of metal corrosion<sup>1</sup>. It seems still doubtful because of low reproducibility and inconsistencies among reported results, which may arise from impurities and different experimental conditions. Our careful experiments suggest that MT and magnetic fields should develop hydrogen bonds of water. Thus, hydration around ions may be affected by magnetic fields. In this study, effects of MT and magnetic fields on the crystal growth of calcium carbonate and the freezing potential (FP) of ice from aqueous salt solutions were examined.

A calcium chloride solution and a sodium carbonate solution prepared with a Milli-Q water (18.3 M $\Omega$ ) were treated by the oscillating motion of 0.5 Hz both in the region of 2 to 6 T of a static magnetic field of a superconducting magnet (MT) and in the geomagnetic field (NMT) at 298 K for 2.5 h. Magnetic treatment effect was checked by measuring contact angle of water on a Pt plate before use. The crystal growth of calcium carbonate was examined using dynamic light scattering (DLS) and electron and optical microscopes. The electric potential (FP) between a solution and ice formed from aqueous salt solutions was measured using a Peltier device and a Keithley multimeter. XRD method was used for analysis of crystal structure.

The XRD structure of calcium carbonate was unchanged by MT, but microscopic images showed that MT changed the morphology. Average diameters of calcium carbonates obtained were about 70 and 40  $\mu\text{m}$  in the absence and presence of MT, respectively. Using the dynamic light scattering method, average diameters of crystals formed just after mixing were 570 and 700 nm. The results did not change when only  $\text{CaCl}_2$  solution was treated under magnetic fields, indicating that MT should affect solutions containing calcium ion.

Though ice formation or FP could be affected through difference in ion incorporation into ice by MT and magnetic Fields, no FP change was detected for the present.

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## Magnetic signature of biogenic magnetite in the tissue from Rainbow trout

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It has long been known that several animal species can orientate and navigate using the Earth's magnetic field. This ability to 'sense' this field is distributed throughout the entire animal kingdom. In many of these species, nanocrystals of magnetite (5-200 nm) can be found [1]. This applies also for migratory fish species. Ever since the discovery of this biogenic magnetite, it has been proposed as a sensor in magnetoception. However, no consensus has been reached as to the mechanism underlying a magnetite-based receptor. Crucial for the understanding of such a sensor is knowledge about the magnetic properties of the nanocrystals. The size of the crystals found in fish (~40 nm) is at the border of superparamagnetic and single domain. We try to elucidate the magnetic properties of the crystals using Magnetic Force Microscopy (MFM) as our main method. Also, we try to explain the working of the magnetosensor in fish by performing light microscopy and Transmission Electron Microscopy (TEM) on the olfactory tissue of Rainbow trout.

Using a highly specific and very sensitive histological dye (Prussian Blue), we were able to localize the magnetite particles in cells of the olfactory tissue of Rainbow trout under the light microscope, as seen in figure 1. Based on these findings, we use TEM on thin ( $\pm 100$ nm) tissue slices to reveal the ultrastructure of the sensor cells of the fish. We study similar slices in AFM and MFM and correlate the images. This gives insight in the arrangement and properties of magnetic crystals in the cells. These structural results, together with the magnetic properties of the magnetite crystals, allow us to reason on possible sensor mechanisms.

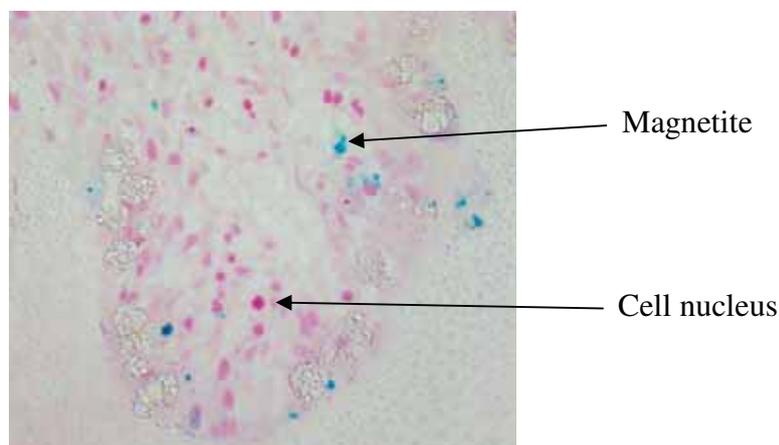


Figure 1: 400x magnification of the olfactory tissue of Rainbow trout. Cell nuclei are pink, magnetite is blue.

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## Patterns of diacetylene-containing peptide amphiphiles using polarization holography

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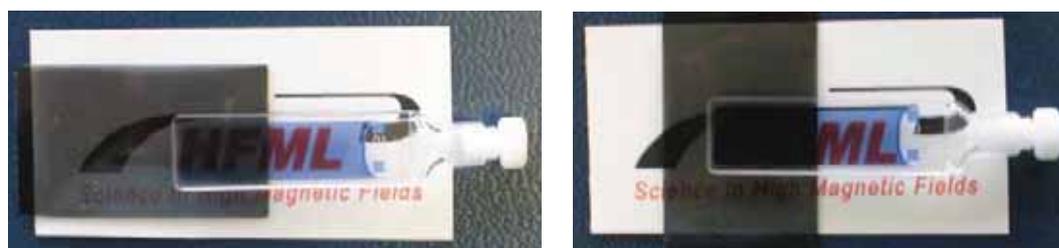
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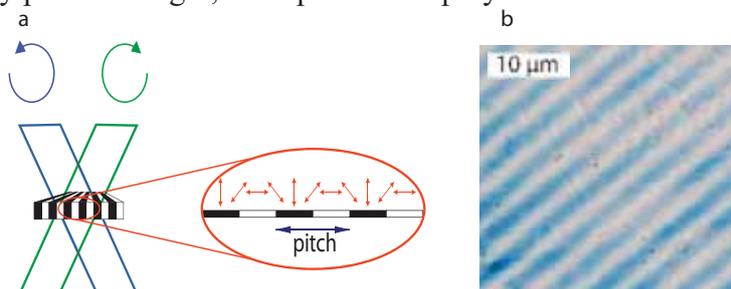
In our lab, short peptides, derived from the CS protein of the Malaria parasite Plasmodium Falciparum, have been coupled to a hydrophobic tail, after which the resulting peptide amphiphile formed fibres in solution.<sup>1</sup> Incorporating diacetylene units in the hydrophobic tail of the peptide amphiphile enabled us to perform a light-initiated radical polymerisation, which locks the structure of the fibre.<sup>2</sup> The fibres can be aligned in a magnetic field, after which polymerization yields a highly anisotropic absorbing blue species (Figure 1).<sup>3</sup>



**Figure 1: After alignment in a magnetic field and polymerisation, the peptide amphiphiles show a large birefringence.**

We investigated the polarization dependence of the polymerization rate. It turned out that the polymerization of randomly oriented fibres with polarized light resulted in an anisotropically absorbing sample. Only the fibres parallel to the incident light polymerize.<sup>4</sup>

The same principle has been used to pattern samples of these peptide amphiphilic fibers. With aligned samples and polarization holography, in which the sample is illuminated using a pattern of linearly polarized light, clear patterns of polymer were observed.



**Figure 2: a) Polarization holography set-up, b) measuring results.**

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## Observation and analysis of the behavior of feeble magnetic materials under high magnetic fields

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One of the characteristic features the utilization of high magnetic fields is that the mechanical effect can be given on the feeble magnetic materials without any direct contact with the matter. The magnetic force is acting on the materials when they were introduced in non-uniform magnetic fields. Through this magnetic force, the structure of materials that have an anisotropy in their magnetic susceptibility are aligned. Furthermore, contactless control of material position or structures can be realized by the application of magnetic force. Therefore, the usage of magnetic fields is expected to be a useful way to control in material processings. To optimize the effect of magnetic force on some processes, the behavior of feeble magnetic materials under high magnetic fields should be understood well. From this stand point, we carried out the optical observation of the behavior of feeble magnetic materials under high magnetic fields using the CCD camera or the confocal scanning laser microscope. Furthermore, to deepen the understandings of their behavior, numerical simulations were carried at the same time. For example, the movement of the glass particles in a fluid under a magnetic field applied parallel to the sample plane and perpendicularly to the gravity. Glass spheres of 0.8 mm in diameter and manganese dichloride aqueous solution (40wt%) were used as sample particles and the surroundings, respectively. Figure 2 shows each one shot of the observation results and the numerical simulation. When glass spheres moved due to the magnetic field gradient, they form the chain-like structure based on the interaction between the induced magnetic dipoles. In this presentation, details of our approach to understand the behavior of feeble magnetic materials under high magnetic fields will be introduced.

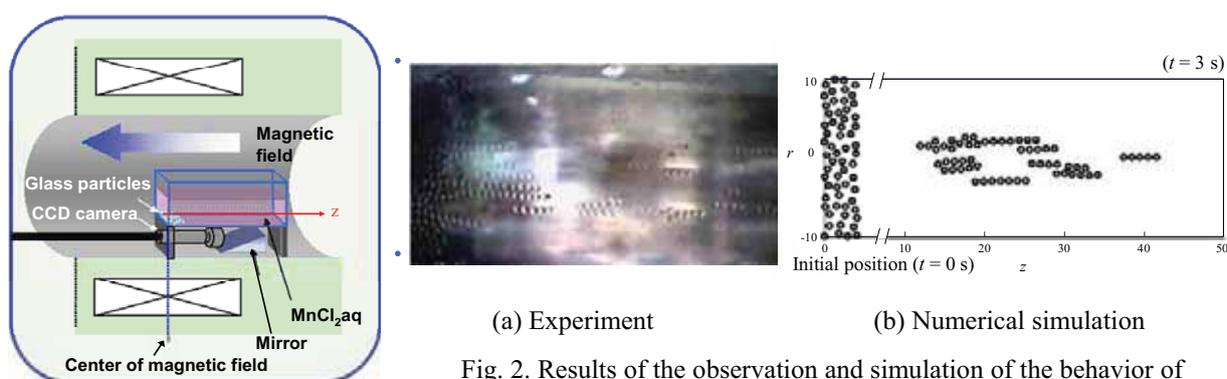


Fig. 1. Schematic illustration of the condition for the simulation and the experiment

(a) Experiment

(b) Numerical simulation

Fig. 2. Results of the observation and simulation of the behavior of glass particles under magnetic field  
Glass particles are moving from left, the centre of magnetic field, to right.

## Magnetic Field Induced Change of Solid-Liquid Phase Transition

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Magnetic field-induced changes of solid-liquid phase transition have been investigated for diamagnetic Mercury and alloys with low melting temperature. Such magnetic field effects were studied previously for some diamagnetic materials using the high-resolution DSC system by Inaba and Hayashi et al.<sup>[1, 2]</sup> They reported that all the melting temperature was increased by the order of  $\Delta T_m=10^{-2}$  K as a magnetic field effect. In this paper we adopted a magnetic measurement to estimate the state of solid or liquid under the influence of the magnetic fields.

The susceptibility was decreased drastically at the melting temperature from  $\chi_s=-1.35$  mJT<sup>-2</sup>kg<sup>-1</sup> for the solid Hg to  $\chi_l=-1.65$  mJT<sup>-2</sup>kg<sup>-1</sup> for the liquid phase. Therefore, the state of the phase can be estimated by the magnetic measurement. Figure 1 shows the magnetic field dependence of the susceptibility of Hg. The susceptibilities for the solid and liquid Hg were not influenced by the magnetic exposure as shown by the broken curves. However the magnetic field induced melting was observed when the solid Hg was set at the temperature just below the melting point of  $T_m=234.96$  K. In the case of  $T=234.90$  K, the susceptibility (full circles) was decreased when the magnetic field was applied, and the phase transition was finished at  $B=0.5$  T. In the case of  $T=234.85$  K, the same tendency of the change was observed in the magnetic field region of  $B=3.0-3.5$  T as shown by the triangles. It was considered that these changes were the magnetic field induced-phase change from solid to liquid. The liquid mercury was thought to be the stable phase in the magnetic field.

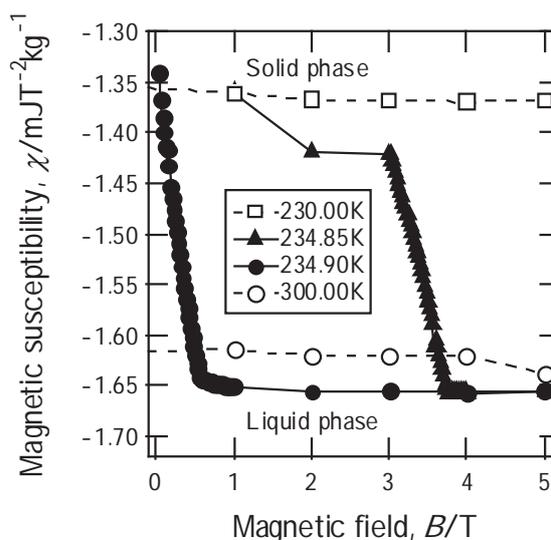


Fig. 1. Change in susceptibility of diamagnetic Mercury as a function of the increasing magnetic field. Solid phase just below the melting point melts in strong magnetic fields.

### Acknowledgments

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## Magnetic Dust Alignment in Giant Star Envelop & Proto-Planetary Region Caused by Anisotropy of Susceptibility at Extreme Temperatures

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At present, magnetic alignment of a particle in a natural environment is believed to occur by the effect of spontaneous magnetic moment. During the last two decades, alignment of micron-sized crystal was newly observed at low field intensity for many of the rock forming mineral free of spontaneous moment, including clay and mica micro-crystal[1]. Field induced energy caused by diamagnetic anisotropy  $\Delta\chi_{\text{DIA}}$  or paramagnetic anisotropy  $\Delta\chi_{\text{PARA}}$  was the cause of the alignment[2]. Here field of alignment  $B_s$  is controlled by 3 parameters, namely temperature  $T$ , average mass of particle  $M$  and  $\Delta\chi$ . Possibility of alignment in a certain natural condition is examined by comparing  $B_s$  with the actual field intensity observed in this region. Based on measured  $\Delta\chi$  data, a mechanism for dust alignment caused by cosmic field has been proposed[3], which is not based on spontaneous moment. Cosmic field is known to be one of the major factors that control evolution of stars and planets. Distribution of magnetic vector, which is a basis of the above discussion, is often estimated from observed polarimetry data caused by the dust alignment. Although it is the most common event of alignment that is distinguished in nature, mechanism of alignment is not clear as yet. Alignment in planet formation region is discussed based on  $\Delta\chi$  below  $T=100\text{K}$  measured for forsterite, which is a major dust component of this area[3]. Dust alignment is effective as well to distinguish magnetic field of star envelopes. Therefore  $\Delta\chi$  above  $1000\text{K}$  was measured for forsterite and  $\text{Al}_2\text{O}_3$ , which were dust components in the envelopes. Based on obtained  $\Delta\chi$ ,  $B_s$  is calculated for both regions, and possibility of alignment is discussed based on astronomical data. It is noted that many of the ceramic materials are synthesized above  $T=1000\text{K}$ ; and the obtained  $\Delta\chi$  are useful in designing a low-cost ecological process in synthesizing highly oriented aggregate-materials; an unnecessary strong field should be avoided. In many cases,  $\Delta\chi$  show unexpected variations and their origins are not clear as yet. It is therefore important to perform  $\Delta\chi$ - $T$  measurement on individual material.

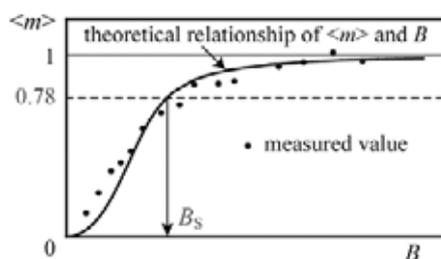


Fig.1 Definition of field of alignment  $B_s$ . Degree of alignment is defined by an order parameter  $\langle m \rangle$  [1].

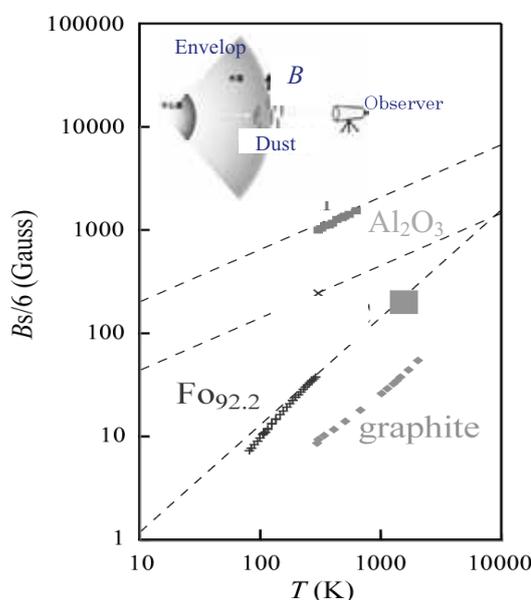


Fig.2 Temperature dependence of  $B_s$ . Solid square describe condition of star envelop.

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## Lorentz Force Driven Rotating Flows in Electrochemical Systems

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Lorentz forces are in almost all cases an inevitable consequence, when electrochemical reactions are performed under the influence of a magnetic field. The reason for this fact is that it is quite difficult to actually guarantee parallelism of magnetic and electric fields everywhere in the electrochemical cell.

The current contribution focuses on cases which are essentially axial symmetric. While the main parts of the electric and magnetic fields are parallel to the axis, an azimuthal Lorentz force is generated by radial components of either the electric or the magnetic field. The Lorentz force acting in circumferential direction drives primarily azimuthal flows. However, pressure differences due to these primary flows as well as the nonuniform Lorentz force density distribution itself give rise to secondary flows which, together with the primary flow, can lead to complex and sometimes unexpected flow patterns. The matter is complicated even more by the action of buoyancy originating from the density changes of the electrolyte solution due to the electrode reactions. Since the flow, i.e. the momentum transfer, determines mass transfer to a good extent electrochemical reactions under mass transfer control are usually influenced by magnetic fields. This fact has been known for a long time and is often referred to as “MHD–effect” in the electrochemical literature. However, often the seeming simplicity suggested by this term is misleading since, as denoted above, the Lorentz force driven flow is frequently rich in features [1].

We use particle image velocimetry (PIV) as well as synthetic schlieren, i.e. background oriented schlieren (BOS), to study velocity and concentration gradient fields in electrochemical cells. On the basis of these measurements, the flow in the cells and its consequences for the concentration distributions and the reactions are discussed. Examples include the retainment of buoyant electrolyte near circular electrodes as described in [2], the reversal of the secondary flow direction depending on the electrode radius [3] and the interplay of gravity and Lorentz forces in cylindrical cells with horizontal electrodes.

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## Chemical magnetoreception in birds: the radical pair mechanism

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Migratory birds travel vast distances each year, finding their way by various means, including a remarkable ability to perceive the Earth's magnetic field. Although it has been known for 40 years that birds possess a magnetic compass, avian magnetoreception is poorly understood at all levels from the primary biophysical detection events, signal transduction pathways and neurophysiology, to the processing of information in the brain.

Two principal mechanisms for avian magnetoreception have been proposed: magnetite particles and magnetically sensitive photochemistry. Inspired by the 'radical pair mechanism' — the source of a plethora of magnetic field effects on chemical reactions *in vitro* [1-3] — Schulten and Ritz have suggested that a magnetically sensitive radical pair is formed by photoinduced electron transfer reactions in spatially ordered cryptochrome molecules located in the bird's retina [4, 5]. Such a photochemical process is potentially compatible with two fundamental behavioural characteristics of the avian compass: its dependence on the wavelength of the ambient light and that the compass responds to the inclination of the geomagnetic field rather than its polarity.

The essential chemical requirements for detecting the direction of an Earth-strength  $\sim 50 \mu\text{T}$  magnetic field will be outlined [6]. Experimental and theoretical evidence for the radical pair mechanism of compass magnetoreception in birds will be presented with particular emphasis on cryptochrome [7-9].

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## Magnetic field effect on photoinduced electron transfer between calf thymus DNA and ternary copper complex containing amino acids

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The role of electron transfer in drug-DNA interaction has become one of the very interesting problems in recent years. It has been found that transition metal complexes are such an important class of compounds, which undergo electron transfer with DNA. The 2:1 1,10-phenanthroline (phen)-copper (I) complex is the first synthetic coordination complex, which acts as a 'chemical nuclease' with an efficient nucleolytic activity in presence of reducing agents, e.g. thiol or ascorbic acid, and molecular oxygen or hydrogen peroxide. We have studied the mechanism of electron transfer phenomenon occurring between calf thymus DNA and  $[\text{Cu}(\text{phen})_2]^{2+}$  complex on photo-excitation using laser flash photolysis and magnetic field effect (MFE) [1]. In this photo-induced electron transfer phenomenon neither any reducing agent nor the presence of oxygen and  $\text{H}_2\text{O}_2$  is necessary for the oxidation of DNA. Among the four amino acids with an aromatic side chain, phenyl alanine, tyrosine, tryptophan and histidine, phenyl alanine contribute mainly to the stabilization of proteins through hydrophobic interactions whereas tryptophan has an electron rich indole ring which has an excellent  $\pi$  electron donating property. Histidine and tyrosine have effective metal binding sites. We have extended our studies with ternary metal complexes comprising aromatic amino acids, e.g. tyrosine and tryptophan and as a second ligand which contains an aromatic ring such as 2, 2'-bipyridyl or 1,10-phenanthroline,  $[\text{Cu}(\text{phen})(\text{Htyr})]\text{ClO}_4$  and  $[\text{Cu}(\text{phen})(\text{Htrp})]\text{ClO}_4$  (Htyr: L-tyrosinato and Htrp: L-tryptophanato) to understand the electron transfer reactions with DNA. It has been observed that in both the complexes intramolecular electron transfer occurs from amino acids to phen on photoexcitation. However in presence of DNA intermolecular electron transfer occurs between DNA and complexes. Quenching of fluorescence of DNA bound ethidium bromide by the complexes suggests that the complexes can displace ethidium bromide from DNA backbone. Interestingly we have found prominent MFE for the triplet born radicals during the interaction of metal complexes with DNA even in homogeneous aqueous medium, which is a rare phenomenon. One of the essential requirements of observation of MFE is the separation of radical ions by diffusion, maintaining their initial spin correlation, to such a distance where exchange interaction becomes negligible to attain maximum intersystem crossing through spin flipping induced by either internal magnetic field, i.e. hyperfine interaction or external magnetic field present in the system. The occurrence of partial intercalation of the complexes within DNA helps in maintaining that proper inter-radical distance between the radical ion pairs generated through photoinduced electron transfer, so that spin correlation exists between them and magnetic field effect could be observed. When we have used organized assemblies, e.g., reverse micelles, as medium, MFE is observed; however different amino acid containing complexes show different behavior due to their differential solubility in reverse micelles.

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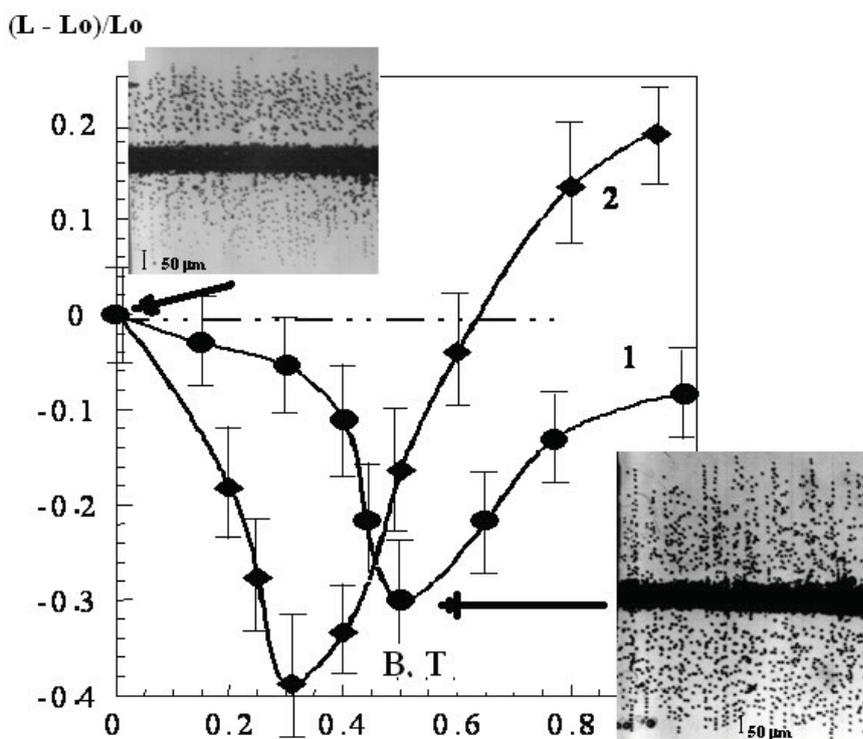
## MECHANICAL PROPERTIES OF CRYSTALS, CONTROLLED BY MAGNETIC RESONANCE

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Physical bases of spin-dependent reaction between structural defects in solids will be considered. Experimental background accumulated by few independent groups in Russia, Japan, France, Israel and USA reliably confirms existing of very strong effects of magnetic field on plasticity, crack propagation and dislocation mobility in a wide circle of diamagnetic materials, containing paramagnetic doping atoms (metals, semiconductors, dielectrics). In the last decade it was evidently shown magnetic field influences very short intermediate stages of plastic deformation and aggregation of doping atoms.



Our attention will be attracted to physical mechanisms of the phenomenon that directly confirms spin-dependent plasticity. This phenomenon is plastic flow excited by electron paramagnetic resonance. An example of resonant induced plasticity of Si crystals shown on the fig.1. There is dependence of relative changes of dislocation passes  $L$  on induction of static magnetic field  $B$  in the presence of microwave magnetic field 0.1 Oe at two perpendicular orientation of crystal. Resonant maxima clear indicate condition of the paramagnetic resonance  $h\nu = \mu_B g B$  ( $h$  is Plank constant,  $\nu = 9.5$  GHz is microwave field frequency,  $g = 2$  is  $g$ -factor). Thus, dislocation displacements are sensitive indicator of paramagnetic resonance instead of usually used absorption of microwave power. Spin-transition, magnetic and optical properties of the defects participating in the resonance will be discussed as well as other types of magnetic resonances, convenient for plasticity control (for example ferromagnetic resonance).

## Enhancing spectral content of level crossing spectra

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**Magnetically Affected Reaction Yield (MARY)**, or level-crossing spectroscopy is a spin-sensitive technique that is particularly suitable for studies of radical ion pairs with short, down to nanoseconds, times of spin-correlated life due to either very fast recombination, relaxation, or chemical decay of its partners. It belongs to the group of magnetic field effect (MFE) techniques, when a system, i.e., a radical pair, is prepared in a coherent spin state in magnetic field and is left as free evolving. If there are internal magnetic interactions comparable in magnitude to the rates of the decay of the coherent spin state, characteristic lines against a slowly varying background on the dependence on external magnetic field can be obtained in a stationary experiment. These resonance-like lines come from degeneracies in the spin system that are lifted by sweeping the magnetic field, their positions reflect the magnetic structure of the pair partners, and their shapes bear kinetic information. Such MFE curves enriched with characteristic lines are referred to as level-crossing (MARY) spectra.

The main weak point of MFE/MARY as compared to magnetoresonance techniques is its low spectral content, which has been traded for sensitivity to short-lived species. The implementation of MARY spectroscopy in the authors' lab using X-ray generated radical ion pairs in nonpolar solution is routinely used to detect radical ions with coherent lifetimes down to nanoseconds, but the spectra are not too rich in features. Still the ubiquitous MARY line at zero field is very useful for measuring kinetic properties of the recombining ions, such as their recombination, relaxation and chemical decay rates, and is currently believed to underlie the chemical magnetic compass mechanism in certain species. For systems with magnetically equivalent nuclei further 'multiple' lines in non-zero field determined by the (only) hyperfine coupling constant can be observed and used to determine the coupling. We shall also discuss two further developments towards enhancing the spectral content of MARY spectra, the resolved spectra from systems with nonequivalent magnetic nuclei, which have already been verified both in theory and in experiments using radical anions of 1,2,3-trifluorobenzene and pentafluorobenzene, and the splitting of the 'multiple' lines due to magnetic structure of the second partner of the pair, the so-called MARY ESR, that we are currently working on and that can yield ESR spectrum of the radical ion without microwave pumping.

## Effects of heterogeneous magnetic fields on the electrodeposition of metallic layers

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Electroplating from aqueous solutions is an established industrial method to produce and refine metal layers. It is well-known that by superposition of homogeneous magnetic fields the deposition process as well as morphology, texture and magnetic properties of deposits can be influenced significantly. This influence is commonly attributed to a Lorentz force induced convection of the electrolyte known as MHD-effect [1]. Additionally it has been shown that non-homogenous magnetic fields are able to change deposition rates dramatically as the field gradient force is acting on paramagnetic ions [2].

Anyway, effects of magnetic gradient fields on deposit properties are still not well investigated, although one could expect interesting results due to the interaction of Lorentz force and field gradient force during the deposition process.

Hence this work focuses on externally applied, well-defined magnetic gradient fields and their impact on deposition behaviour and deposit properties. It has been found that even by application of moderate magnetic gradients at the working electrode structured deposits and significant diversification of roughness and grain structure can be observed.

This work was financially supported by a scholarship of the Studienstiftung des deutschen Volkes and by the Deutsche Forschungsgemeinschaft (DFG) in form of the collaborative research centre SFB 609 “Electromagnetic Flow Control in Metallurgy, Crystal Growth and Electrochemistry”.

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## Hydrogen evolution as a side reaction during Fe-group metals and alloys deposition under influence of external magnetic fields

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A superimposition of an external magnetic field during the electrodeposition, so-called magnetoelectrolysis, has gain a considerable attention during the past decade [1]. It has been shown that a superimposition of external homogenous magnetic fields could significantly affect the electrochemical processes. The influence of magnetic fields on the reaction rates as well as on the resulting layer morphology, texture, chemical and phase composition etc. has been reported. Most of the induced effects during the metal deposition are caused by the Lorentz force ( $F_L$ ) driven convection, i.e. the magnetohydrodynamic (*MHD*) effect. The *MHD* effect is a macroscopic fluid motion but it has been also proposed that a microscopic convection could be induced, so-called micro-*MHD* effect [2].

The electrodeposition of Fe-group metals and alloys from aqueous electrolytes is mostly accompanied by side reactions, mainly the hydrogen evolution reaction (HER) and water decomposition, which could be affected by the magnetic fields as well and as a result improved deposit quality has been observed [3].

The effects of uniform magnetic fields on the HER accompanying the electrodeposition of Fe-group metals and alloys by combining potentiostatic experiments with an electrochemical quartz crystal microbalance (EQCM) have been investigated. It was found that desorption of hydrogen is supported in a magnetic field irrespective of its relative-to-electrode configuration. In the parallel-to-electrode magnetic field an increased HER rate is observed due to the macroscopic *MHD* effect, which stirs the electrolyte and helps to remove the hydrogen bubbles from the electrode surface [3]. On the other hand when the field is applied perpendicular-to-electrode an increased desorption of hydrogen is observed due to the micro-*MHD* convection, which is caused by the fluctuation of the current distribution in the hydrogen bubble vicinity [3]. This has been confirmed by a direct microscopic investigations which revealed that the hydrogen bubbles are rapidly removed from the electrode surface and theirs size is dramatically reduced when magnetic field is applied in the perpendicular-to-electrode orientation [4].

The German Research Foundation (DFG) is gratefully acknowledged for the support of this work in the framework of the Collaborative Research Centre 609 “Electromagnetic Flow Control in Metallurgy, Crystal-Growth and Electrochemistry”.

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## Magneto-electrodeposition in superimposed uniform high magnetic fields

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The effect of uniform magnetic fields on electrodeposition and in particular on diffusion controlled processes is widely approved and its influence on morphology and structure is established. The main reason for magnetically affected deposition behaviour and changed morphology of the deposits are caused by Lorentz force induced magnetohydrodynamic convection in the electrolyte. Some other magnetically generated body forces, which might influence the deposition, are discussed controversially. Besides that natural convection as well as geometry and design of the electrochemical cell can affect considerably the system.

The work aims on the electrodeposition of magnetic transition metals and alloys, which has been conducted in uniform, vertically aligned magnetic fields up to 13 T in dependence on the field strength with different magnetic field-to-electrode configurations and cell and electrode geometries. The electrochemical behaviour, the morphology, and the structure of the deposits are investigated and discussed.

When the magnetic field is applied parallel to the surface the main driving force for convection is the Lorentz force, which leads to the expected increase of the limiting current density and enhanced mass transport to the electrode surface. The increase of the limiting current density and the onset of convection depend strongly on the cell geometry and starts at a higher field strength in a perfectly cylindrical cell without edges and low volume. In the case of perpendicular-to-surface configuration the Lorentzforce should be negligible but interesting electrochemical and structural effects are observed. In this configuration the limiting current density decreases slightly with increasing B followed by an up and down behaviour. An increase at high magnetic flux densities depends on cell geometry. The current efficiency for the alloy deposition decreases unexpected strongly at high magnetic flux densities in parallel as well as perpendicular magnetic field-to-electrode configuration. This leads to the conclusion that the simultaneously proceeded hydrogen reduction is more affected with increasing flux densities [2]. The morphology of the deposits depends strongly on the field strength and magnetic field to electrode configuration. At higher magnetic field strength the deposits are free of oxides and hydroxides independent on the field-to-electrode configuration. In edge free cell-types the thickness of the deposits is uniform whereas in larger cell-types the deposit exhibit a profil leading to the conclusion that the magnetic field generates rotational and complex convective phenomena dominated by the Lorentz force.

This work was supported by the German Research Foundation (DFG) in form of the collaborative research centre SFB 609 Electromagnetic Flow Control in Metallurgy, Crystal Growth and Electrochemistry and the European Commission from the 6<sup>th</sup> framework program N° RITA-CT-2003-505474

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## Effect of High-magnetic-field Annealing on Magnetic Properties and Microstructure of Sintered NdFeB Magnets

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The come out of the rare earth NdFeB permanent magnetic material shaked many correlative fields, and its magnetic properties are more excellent than other magnetic materials. It is called “the king of magnetic material” because of its high remanence, coercivity, and  $(BH)_{\max}$ . But the thermal stability of sintered NdFeB is weaker than other magnetic materials, which limits the application of the NdFeB in many high and diversified temperature fields. So the research to enhance the magnetic properties and the thermal stability is very important.

In 1980s, the technology of low temperature superconduct was developed very fast, and it made more and more application of superconduct high-magnetic-field. High-magnetic-field has effects of alignment , controlling the flow of liquid metals and working on the diversification of material phases. High-magnetic-field can transmit high energy to the atom of materials without touching, and it also can change the alignment , matching and transference of atoms, so the materials' properties would be improved. In high-magnetic-field, non-magnetic materials will get the same effects as magnetic materials.

The microstructure of sintered NdFeB has transmissibility. The raw materials and the process of manufacture(smelting, milling, sintering, heat treatment and so on) have effect on its microstructure. Heat treatment is an easy way to improve the microstructure. As we know, for sintered NdFeB, it is necessary to have annealing after sintering to achieve good magnetic properties. The effect of high-magnetic-field annealing process on the microstructure and magnetic properties of sintered NdFeB magnets are studied here, compared with the way of common annealing. The results show that the magnetic properties of magnets is enhanced after High-magnetic-field annealing, and also the microstructure of magnets is ameliorated. Especially on the effect of high magnetic fields, the Nd-rich phase can make batter lattice matching in the interface with the main  $Nd_2Fe_{14}B$  phase , resulting in smoother grain boundary. The magnets'  $M-H$  Loop squareness is enhanced after high-magnetic-field annealing , resulting in better thermal stability.

**Key Words** : sintered NdFeB; high-magnetic-field; annealing

## Using molecular probe to study the properties of doped lanthanum manganite surface

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The purpose of the work is to find a way to explore the surface of magnetically inhomogeneous materials using molecular probes. Magnetic inhomogeneous systems are substances, in one sample of which coexist the phases with different magnetic ordering — ferromagnetic and antiferromagnetic order. Under an external influence the ratio between the different phases changes. The external influence may be, e.g., the magnetic field, temperature change. Originally we wanted to observe the spectra of electron paramagnetic resonance (EPR) of adsorbed probe molecules. Adsorption occurs on the surface of doped lanthanum manganite, and the probe is a stable radical, whose EPR spectrum was planned to observe. We used the following lanthanum manganites —  $\text{La}_{0.7}\text{Sr}_{0.15}\text{Ca}_{0.15}\text{MnO}_3$ ,  $(\text{La}_{0.5}\text{Eu}_{0.5})_{0.7}\text{Pb}_{0.3}\text{MnO}_3$ , stable nitroxyl radicals — TEMPON, TEMPO, 3-imidazoline radical, as well as some other stable radicals.

Previously, such experiments were carried out using  $\gamma\text{-Al}_2\text{O}_3$  as the surface. EPR spectra of hindered rotation of nitroxyl radicals approaching the surface of  $\gamma\text{-Al}_2\text{O}_3$  are well observed. However, direct observation of the spectrum of hindered rotation on the surface of lanthanum manganite turned out to be impossible. As lanthanum manganite is a magnetic substance, the local magnetic fields do not allow to observe the ESR spectrum of the probes at the surface. There is consequently only the spectrum of the radical dissolved in liquid.

In order to understand whether any adsorption on the surface takes place, we carried out optical measurements. The technique was as follows — we brought radical dissolved in a liquid solvent in contact with lanthanum manganites. Then a sample of the liquid was collected, and UV absorption spectra were registered. We found that in the presence of lanthanum manganite the intensity of the spectrum line at 350 nm decreases with time. We also found that by placing the system in a magnetic field of 0.5 Tesla the rate of the intensity decrease of the 350 nm line increases. The origin of this effect is currently under investigation. IR spectra are promising to connect the surface properties of the manganite with its bulk structure and also currently under study.

## Nano-structured TM-doped ZnO synthesized by high magnetic field-hydrothermal method

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Transition metal (TM)-doped ZnO is a kind of important diluted magnetic semiconductors (DMSs). Its properties and functions are determined by its microstructure which is affected by their synthesis process. That results in much research on the preparation technique of such useful function materials. It mainly focuses on how to get room temperature ferromagnetic TM-doped ZnO.

High magnetic field has been thought as an important tool not only for physics study but also for controlling the microstructure and function of the materials. And hydrothermal method is a simple process with low cost, easy operation and low temperature. In this study, we present a new method which TM-doped ZnO were synthesized by hydrothermal process under high pulse magnetic field. High magnetic field influences the nucleation, growth and the morphology of the nanocrystalline in hydrothermal synthesis, and improves the ferromagnetism of TM doped ZnO diluted magnetic semiconductor.

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## Grain elongation and texture in steels during austenitic decomposition under high magnetic field

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**Abstract:** The introduction of a magnetic field to solid phase transformations in steels has been a subject of much attention in recent years. The effect of the magnetic field on martensitic transformation, bainitic transformation and proeutectoid transformation of steels has been widely studied. In the present work, we applied a 12-Tesla magnetic field to the transformation from austenite to ferrite and then pearlite in steels at various cooling rates. Results show that the effects of the magnetic field at different cooling rates are quite different. When cooling is slow, the magnetic field applied promotes proeutectoid ferrite grains to grow along the field direction and results in a microstructure with elongated grains. It is known that each Fe atom carries a magnetic moment and the moments tends to align along the field direction under a magnetic field. The dipolar interaction of the atomic magnetic moments makes the pairs of atoms aligned parallel to the magnetic field attract each other, while those with their lines of center perpendicular to the field repel each other, which gives rise to the preferential growth along the field direction to minimize the magnetic volume energy. The balance of the magnetic volume energy and the interfacial energy that determines the final shape of the grains is quantitatively analyzed. However, when cooling is fast, the magnetic field enhances the  $\langle 001 \rangle$  texture component along the transverse field direction (TFD). This also results from the dipolar interaction between Fe atoms. The repulsion between Fe atoms in TFD causes the atomic spacing in this direction to increase. The increase in atomic spacing could mitigate the positive lattice distortion in  $\langle 001 \rangle$  direction by carbon solution when  $\langle 001 \rangle$  direction of a grain is parallel to the TFD. Therefore, the nucleation and growth of such grains are energetically favored by the magnetic field.

**Keywords:** Grain elongation; texture; phase transformation; magnetic field; steel.

## Structures of Carbon Materials Prepared under High Magnetic Fields

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Carbon materials typified by activated carbon are used for water purification, effluent treatment, gas separation, battery electrode, and so on. Moreover, nanostructured carbon materials such as carbon nanotube and fullerene, are paid considerable attention to their application during the last two decades; e.g. hydrogen storage, Li-ion batteries, electrical double layer capacitor, and scanning probe microscope tip. Since carbons are very useful materials, development of carbon materials must be very important for not only new materials but also conventional ones. Though the magnetic energy of feebly magnetic molecules is much smaller than thermal energy, a frame-work structure containing the benzene ring-derived conjugated system may be oriented by its large magnetic anisotropy. Therefore, we expect that most carbon materials should be ordered under relatively low magnetic fields.

The electric furnace system was constructed for the 100 mm-diameter bore of a superconducting magnet (Sumitomo Heavy Industries.,Ltd), which generates up to 1523 K (1075 W) in a quartz tube (inner diameter: 23 mm). The electric power was regulated by a Yamabishi variable transformer and the rate of temperature increase controlled by an Omron programmable temperature controller. Temperatures at quartz tube, furnace core, outside of chiller, and the exit of cooling water were monitored by a Keithley multimeter with multi-channel thermocouple scanner. Temperature at the sample position was controlled by a program built by LabVIEW, e.g., within 2 K at 1273 K.

Two kind of coal pitches were treated up to 873 K in air under magnetic fields. The treated coal pitches under magnetic fields less than 6 T for 2 h were characterized by X-ray diffraction and optical microscopic observation. The images of coal pitches treated under magnetic fields show orderly pattern compared with 0 T. The intensity of (002) XRD peak, assigned to graphite carbon layers, increased with increasing magnetic fields, indicating that graphite layers were oriented under magnetic fields.

## Magnetostriction of ferromagnetic particles embedded in an elastic matrix

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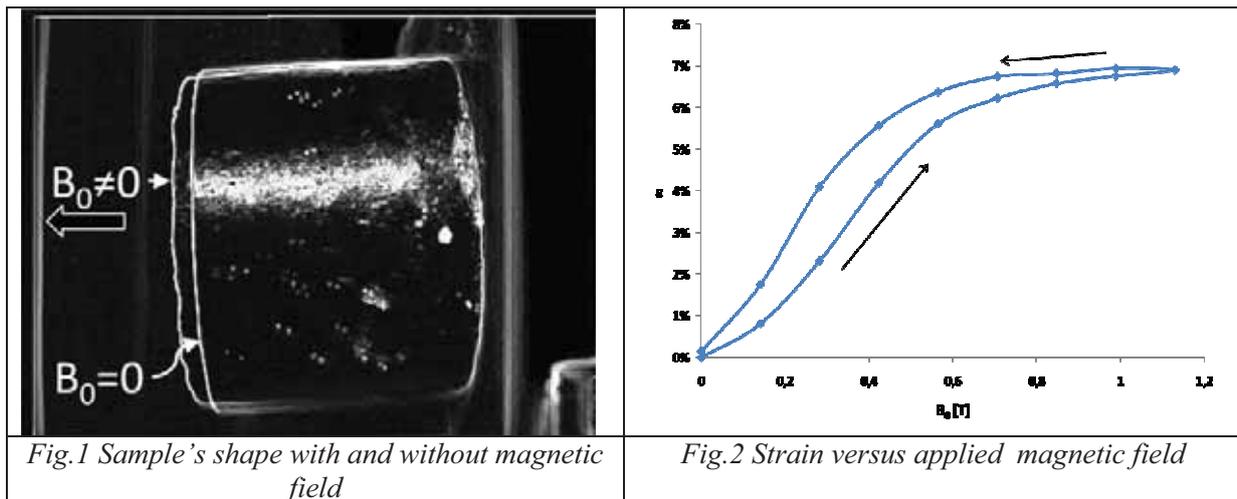
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MRE (Magnetic Rheological Elastomer) are composites made of ferromagnetic particles within an elastic and non-magnetic silicone matrix. Taking benefit of the high saturated magnetization of the Iron particles, and the low Young modulus of the silicone matrix, this kind of material exhibits a larger magnetostriction 5% [1] compared with the classical value of 0.2 % (Terfenol-D).

Figure 1 presents the superposition of pictures taken with and without a homogeneous longitudinal magnetic field, of a cylinder-shape sample randomly filled (30% vol.) of ferromagnetic particles. Figure 2 presents the longitudinal deformation of the sample as a function of the applied magnetic field.



A numerical calculation based on dipolar forces between particles inside the composite has been performed [1] and then used by F.E.M software (Abaqus) to predict the elongation. Such calculation provides a deformation 4.7 % very close to the one measured, 4.3 %.

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## **An Analysis of Electromagnetic Field of Electroslag Remelting Processes**

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### **Abstract**

Electroslag remelting processes are widely used to produce superalloys and specialty steels. Detailed understanding of the electromagnetic field distribution is essential for both ingot quality improving and electric energy saving. In the present work, magnetic vector potential and electric scalar potential are used to express the magnetic field and electric field. The effect of various melting parameters on the current distribution, magnetic flux density, electromagnetic force and Joule heating within the slag and ingot are examined for single and two electrodes in series ESR system. Especially, the skin effect is shown and discussed based on numerical results.

# **An Analysis of Electromagnetic Field of Electroslag Remelting Process with Application of Rotating Magnetic Field**

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## **Abstract**

Electroslag Remelting (ESR) is used to refine the chemical composition and microstructure of metals. However, macro-segregation of solute elements and coarse grain structure cause defects in ESR ingot. Low frequency rotating magnetic field is applied to fine grain structure and minimize macro-segregation. Numerical simulation is conducted to understand the effect of applied rotating magnetic field on an ESR electroslag remelting process, overlap of ESR electromagnetic field and applied external rotating magnetic field are examined and discussed.

## Interlayer tunneling spectroscopy of graphite at high magnetic fields

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The studies of interlayer tunnelling in graphite mesa-type structures of micron lateral sizes and containing few tens of graphene layers [1] reveal the features characteristic for tunnelling of Dirac fermions between individual graphene layers.

In moderate fields of 1-10T oriented along the *c*-axis we found the peaks of tunnelling conductivity corresponding to the interband tunnelling transitions between Landau levels with energy  $E_n \propto (nH)^{1/2}$  typical for Dirac fermions in graphene [2]. The peaks observed correspond to transitions with a selection rule  $\Delta|n| = 0$ . The mostly pronounced peak corresponds to (-1,1) transition. These data are consistent with results of IR magneto-transmission spectroscopy of thin graphite single crystals [3]. At high fields of 20-55 T we observed zero bias peak of tunneling conductivity with a small dip on its top. We consider that this peak reflects DOS at zero Landau level.

In parallel magnetic fields up to 55T we found the local maximum on interlayer tunnelling conductivity which position  $V_0$  is proportional to the field. We consider that the tunneling between graphene layers in parallel field change Dirac fermion momentum by  $\Delta k = 2 \pi e B d / (h c)$  with  $d$  the interlayer spacing. The increase of tunnelling current occurs when shifted in *k* spectra touch tangentially at  $V_0 = h v_F \Delta k / (2 \pi e)$ . The experiment gives  $V_0 = 70$  mV at 55T which is close to the estimation. The linear dependence of  $|V_0|$  on  $\pm H$  is a direct evidence of conic type spectrum of tunnelling carriers.

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## Effective Transition Moment for the Faraday Rotation of Lanthanide(III) Ions

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The Faraday rotation is the rotation of the plane of polarized light due to magnetic-field-induced circular birefringence in a material, which occurs in the case that the direction of light propagation and that of magnetic field are parallel. Measurement of the Faraday rotation might be used for the magneto-optical analysis of solutions and interfaces. The Faraday rotation has been studied mainly for solid and solid thin films, but only a few measurements have been reported for solutions. In order to clarify the relationship between Faraday rotation and the magnetic moment of paramagnetic ion, systematic measurements have been carried out in the present study using aqueous solutions of 14 lanthanide (III) ions.

The pulsed magnetic field was generated by combining a 2000  $\mu\text{F}$  condenser bank and a solenoid coil. The laser light of 410 nm or 640 nm was irradiated into a sample cell in a magnetic coil through the crossed pair of polarizer and analyzer. The Faraday rotation angle was obtained from the intensity change accompanied with the pulsed magnetic field.

The Faraday rotation angle was proportional to both of the magnetic flux density and the optical length of sample with a proportional constant, Verdet constant,  $V$ . From the dependence of  $V$  on the wavelength it was confirmed that the  $4f^n \rightarrow 4f^{n-1}5d$  transition in ultraviolet region mainly contributed to the Faraday rotation of Ln(III) ion. The Faraday rotation of a Ln(III) ion that has a degenerate ground state can be quantum-mechanically comprehended by the Faraday  $C$ -term [1], which can be expressed as:

$$C = -\frac{3g\beta}{2J+1} \sum_{M_J=-J}^J M_J \text{Im} \left( \langle n, M_J | \mu_X | j \rangle \langle j | \mu_Y | n, M_J \rangle \right) = \frac{3g\beta}{2J+1} K \quad (1)$$

where  $g$  is the Landé splitting factor,  $\beta$  is the Bohr magneton,  $J$  is the total angular momentum quantum number ( $M_J = -J, -J+1, \dots, J-1, J$ ) is the magnetic quantum number and  $\mu_X$  and  $\mu_Y$  are the electric dipole moment operators perpendicular to the magnetic field. The value of  $3g\beta/2J+1$  could be estimated for each Ln(III) ion, therefore, the effective transition moment,  $K$ , could be experimentally determined from the Faraday rotation angle as shown in Figure 1. The filled dot indicates the root of molar magnetic susceptibility,  $\chi_m^{1/2}$ , which is proportional to the effective magnetic moment of Ln(III) ion. The correlation between  $K$  and  $\chi_m^{1/2}$  was observed in Fig. 1 [2]. This suggests that it is possible to measure the magnetic moment of paramagnetic ion from the Faraday rotation measurements.

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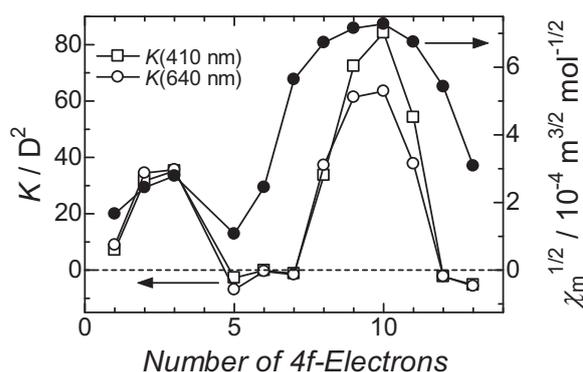


Figure 1. Values of  $K$  (red and blue) and  $\chi_m^{1/2}$  (black) plotted against the number of 4f-electrons

## Negative magnetoresistance in nonmagnetic and magnetic semiconductors. The one effect - the one physical model?

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The effect of specific resistance decrease in magnetic field known as Negative Magnetoresistance (NM) was observed over the last 50 years practically in all semiconductor types- nonmagnetic, diluted magnetic and magnetic semiconductors. The maximal decrease of resistivity in magnetic field observed experimentally in non-magnetic semiconductors for example InSb, Ge, ZnSb and GaAs did not exceed the value  $1 \div 50\%$ . On the other hand magnetic (MS) and diluted magnetic semiconductors (DMS), for example EuSe,  $Gd_{1-x}V_xS_4$ , EuTe and  $Hg_{1-x}Mn_xTe$ , showed in magnetic field gigantic resistance decrease ( $\rho_{B=0}/\rho_B \sim 10^2 \div 10^7$ ). This drastic discrepancy in NM values gave the ground for physical models, providing different explanation of NM in nonmagnetic and magnetic semiconductors. The most popular are the model of charge carriers spins scattering on impurity magnetic moments [1], the model of quantum correction [2] and magnetic polaron model [3]. This work represents the attempt to develop one integral physical NM model for both nonmagnetic and magnetic semiconductors.

We studied NM in uniaxial stressed nonmagnetic semiconductor single crystals - p-InSb doped with Ge and Mn and p-Ge doped with Ga - at low temperatures ( $T=4,2K \div 1,2K$ , as well as down to 0,3K in unstressed crystals), magnetic field  $B=0 \div 15T$  and compression  $X=0 \div 5 \cdot 10^{10}Pa$ . It was revealed that NM reached its maximum within critical concentration  $N_{cr}$  of metal-insulator transition in nonmagnetic semiconductors ( $N_{cr} \sim N_a \sim 10^{17}cm^{-3}$ ) and its maximal value varied in the range ( $\rho_{B=0}/\rho_B \sim 10^2 \div 10^5$ ) depending on compression and impurity type. Observed value of  $\rho_{B=0}/\rho_B$  was comparable with the previously revealed NM in MS and DMS at charge carrier concentration in these materials within  $N_{cr}$ .

Therefore we came to the conclusion that the nature of NM in semiconductors could be also related to some other factors than the magnetic field influence on charge carriers scattering on host or impurity magnetic moments atoms. We propose that the field of elastic stresses around impurities or vacancies can restructure energy band and form antiferromagnetic spin ordered sub-bands in the forbidden gap in both nonmagnetic and magnetic semiconductors within  $N_{cr}$ . These sub-bands are separated by energy gap  $\Delta$  with the maximal value  $\Delta \sim 1meV$  in the case of InSb [4] and Ge and by energy gap  $\Delta$  in the range  $1 \div 10meV$  in MS and DMS. External magnetic field aligns spins, closes the gap  $\Delta$  between sub-bands and causes insulator-metal transition e.g. NM in semiconductors.

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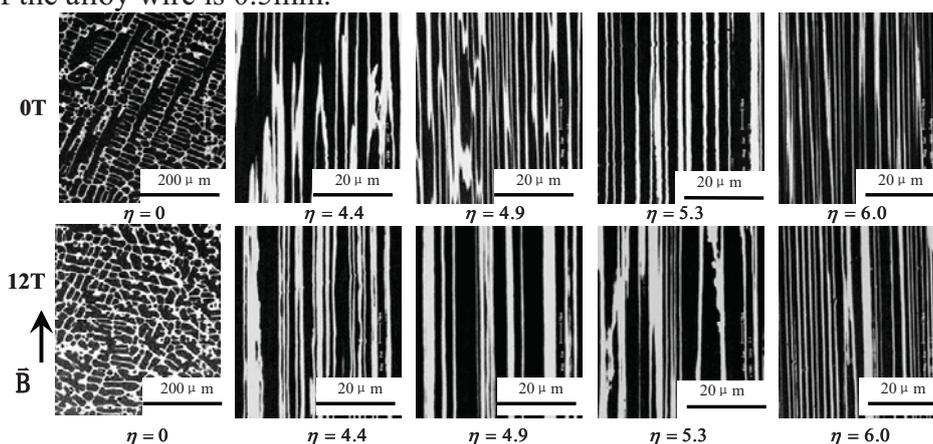
## Microstructure Evolution of Cu-23.9wt%Ag Alloy under High Magnetic Field and Drawing Deformation

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The cold drawing wire of Cu-Ag alloy has been considered to be the promising conductor material for excitation windings of pulsed high-field magnets because of their excellent mechanical strength and relatively high electrical conductivity<sup>[1]</sup>. The wire properties are mainly dependent on its microstructure, which is mostly dependent on strain ratios and the casting solidification structure<sup>[2]</sup>. In this paper, a high magnetic field (HMF) was used to investigate the solidified microstructure of Cu-23.9wt%Ag alloy and its influence on the filamentary of cold drawing deformation. The samples of Cu-23.9wt%Ag alloy are fabricated in a vacuum furnace with and without 12T HMF respectively, and then drawn to different diameter wires at ambient temperature by different strain ratio  $\eta = \ln(A_0/A)$ . The final diameter of the alloy wire is 0.5mm.



**Fig. 1** Microstructure evolution of Cu-23.9wt%Ag alloy

The morphology of Cu-23.9wt.%Ag alloy show that the microstructure is consist of coarser and non-homogeneous pro-eutectic Cu-rich dendrites (black) without HMF, compared to the mainly cellular and distributed uniformly microstructure under 12T, which has the thicker lamellar eutectic phase (white). After deformation, the microstructure changed from net structure into filamentary structure of fibrous bundles along the wire axis. As the strain increased, the diameter of the Ag-rich fibrous bundles decreased. However, the mean diameter of eutectic fibrous bundles with 12T solidification sample is coarser than one of solidification sample without HMF. The different microstructure evolution of Cu-23.9wt%Ag with and without HMF has an apparent effect on the ultimate tensile strength and electrical conductivity of the Cu-Ag alloy wires.

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## In-situ Preparation of MnBi/Bi Magnetic Materials by Using a Dilute Alloy via Magnetic Separation with High Magnetic Field Gradients

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A novel method for the in-situ preparation of magnetic materials is proposed in which high magnetic field gradients are imposed on alloys during the solidification processes. In the experiments, bulk MnBi/Bi composites are prepared by magnetic separation in a dilute Bi-4.36wt.%Mn master alloy. Also, the influence of high magnetic field gradients on the morphologic transition of MnBi phases and magnetic properties of the specimens were investigated in detail. Compared with the irregular shapes and unequal dimensions of the MnBi grains under conventional conditions, the MnBi grains aggregate at a specified end of the specimen with a local volume fraction in the MnBi phase above 40%. Furthermore, the coarsened MnBi grains exhibit preferred orientations with their c axes parallel to the direction of the imposed fields. The direction and the gradient of the imposed fields play a key role in the migration and aggregation of the ferromagnetic primary MnBi grains in the melt. The magnetic force drives the primary grains to the end of the specimen during the solidification process, especially in the mushy phase. The repulsive force induced by ferromagnetic grains affects the spacing between the MnBi grains. On the other hand, the easily magnetized c axis of the MnBi grains parallel to the imposed field is attributed to the rotation of the magnetized MnBi grains under the effects of high magnetic fields. In addition, compared with specimens solidified without a magnetic field, the magnetic property of Bi-4.36 wt.% Mn alloy solidified under a negative gradient magnetic field apparently increases. The uniform orientation and high degree of crystallization ensure the improvement of the magnetic property of MnBi/Bi composites. It is therefore possible to fabricate high purity permanent materials with high volume fraction and preferably aligned MnBi phases directly from a dilute Bi-Mn master alloy.

Keywords: Magnetic Materials; High gradient magnetic fields; Phase separation; Solidification; Grain morphology

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## Anisotropy of the Spin Density Wave Onset for $(\text{TMTSF})_2\text{PF}_6$ in Magnetic Field

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$(\text{TMTSF})_2\text{PF}_6$  is a layered organic compound that demonstrates a complex phase diagram, containing phases, characteristic of one-, two- and three-dimensional systems. At ambient pressure and zero magnetic field the carrier system undergoes a transition to a spin density wave (SDW) state [1] with a transition temperature  $T_{\text{SDW}} \approx 12$  K. When an external hydrostatic pressure is applied,  $T_{\text{SDW}}$  gradually decreases and the SDW state becomes completely suppressed at the critical pressure of  $\sim 6$  kbar. Application of a sufficiently high magnetic field along the least conducting (interlayer) direction  $\mathbf{c}$  restores the spin ordering via a cascade of the field induced SDW states (FISDW) [2].

Theory [3] predicts  $T_{\text{SDW}}$  to increase quadratically in weak magnetic fields  $\mathbf{B} \parallel \mathbf{c}^*$ . A number of experiments [4] confirmed this prediction. Murata et al. [5] observed that the uniaxial stress in the interchain ( $\mathbf{b}'$ ) direction affected  $T_{\text{SDW}}$  weaker than in the intrachain ( $\mathbf{a}$ ) direction. This is in contrast to the theory suggestion, that a growth with pressure of the next-to-nearest interchain hopping integral leads to deterioration of conditions for the SDW transition; the latter leads to decrease in  $T_{\text{SDW}}$ . This result suggests the possibility of corresponding anisotropy of  $T_{\text{SDW}}$  in magnetic field. Earlier, no  $T_{\text{SDW}}(B)$  dependence was observed for both  $\mathbf{B} \parallel \mathbf{a}$ ,  $\mathbf{B} \parallel \mathbf{b}'$  field directions at ambient pressure [4], however such dependence (if any) might become more pronounced close to the critical pressure of 6 kbar. We report our measurements of the magnetic field dependence  $T_{\text{SDW}}(B)$  made at  $P = 0$  and 5 kbar for the three orientations  $\mathbf{B} \parallel \mathbf{a}$ ,  $\mathbf{B} \parallel \mathbf{b}'$ , and  $\mathbf{B} \parallel \mathbf{c}^*$ . Our main result is that for  $\mathbf{B} \parallel \mathbf{a}$ ,  $\mathbf{B} \parallel \mathbf{b}'$  there is no distinct shift of the  $T_{\text{SDW}}$  within the uncertainty of 0.05 K at pressure up to 5 kbar and in fields up to 19 T. We found also quadratic  $T_{\text{SDW}}(B)$  dependences for  $\mathbf{B} \parallel \mathbf{c}^*$  both at zero and non-zero pressures, in a quantitative agreement with previous studies [4]. We analyze our experimental data in the framework of the mean-field theory.

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## The velocity field of a MHD flow under pulsed current conditions

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Because of its strong influence on the morphology, homogeneity or corrosion resistance of a sample, as well as the composition of alloys, pulse plating is a widespread technique in electrochemical deposition. The intention of our work [1] is to combine these effects with a superimposed convection generated by the Lorentz force. Due to the enhanced mass transport, convection is capable to affect the sample properties and to increase the deposition rate. In our approach the so called magneto hydrodynamic (MHD) convection is induced by an external magnetic field with a linear field gradient (Fig. 1). In this way it is possible to create a particular force distribution, in which the Lorentz and the buoyancy force can act either parallel or antiparallel, but always in the same orientation in front of the vertical electrodes. The resulting oscillating circular convection (Fig. 2) is studied by particle image velocimetry (PIV). Several current densities from 1 to 6 mA/cm<sup>2</sup> and pulse durations from 4 to 10 s as well as an infinite pulse length have been examined. The experiments showed a strong dependence of the velocity on the orientation of the forces. Furthermore they allowed us to derive important parameters such as the characteristic timescales required to establish fully developed flows with respect to the cell geometry. They are governed by the complex coupling of the particular onset and strength of the forces. The experiments with an infinite pulse length showed that also the formation of a density stratification has an significant influence on the behavior of the system.

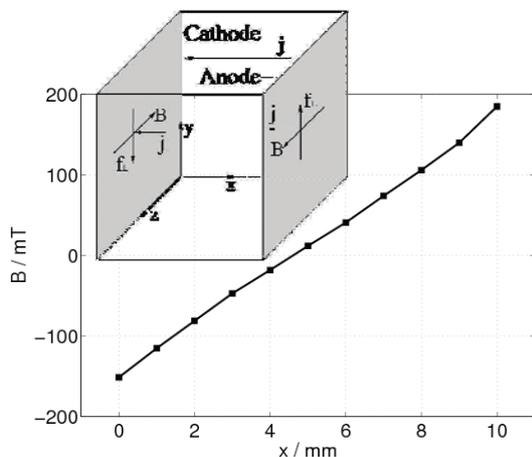


Fig. 1: Distribution of the magnetic field gradient and the resulting forces in the cell (inset).

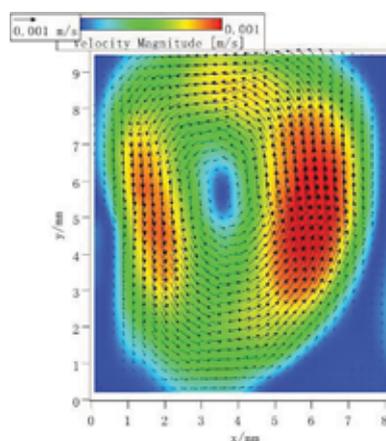


Fig. 2: Velocity field resulting from the superposition of Lorentz and buoyancy force.

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## Experimental Observations of the Electromagnetic Shaping of Aluminum and Tin Melts

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Electromagnetic shaping is a recently developed technique of materials processing, which can simultaneously achieve the heating, melting, and shaping of metals using electromagnetic fields normally in a vacuum chamber. Previous work has shown that the surface and shape of the samples are not well controlled for stainless steels and nickel-based superalloys and that it is difficult to observe the samples and measure process parameters for samples are installed in a vacuum chamber. In order to clarify the basic principles of electromagnetic shaping, some low melting point metals of aluminum and tin was studied under atmosphere. This provides an experimental and theoretical basis for industrial production using electromagnetic shaping.

The melting areas of the three samples formed hemispheres after electromagnetic heating, as shown in Fig.1. For aluminum, liquid metal with a length of about 22 mm was shaped under electromagnetic pressure in the inductor. Residue of the oxide scale on the aluminum with a diameter of 10 mm was found after cutting off the power supply. However, the melt of the aluminum with a diameter of 20 mm completely collapsed when the power supply was cut off. Tin with a 15 mm diameter in the electromagnetic shaping process is shown in Fig. 1 (c). The results indicate that the oxide skin has a significant influence on the shaping process of aluminum melt for small sample size.

The characteristics of the magnetic field in the inductor were also analyzed. The height, angle and diameter of the inductor impact the distribution characteristics of the magnetic field in the inductor more than the load does. The height of the inductor can be achieved by magnetic induction, and the magnetic induction that is needed to form a certain height of the melt can also be calculated using the height of the inductor. Accordingly, the theoretical model and calculation can provide guidance to designing the inductors for electromagnetic shaping.



(a) aluminum:  $\Phi 10$  mm (b) aluminum:  $\Phi 20$  mm (c) tin:  $\Phi 15$  mm  
Fig. 1. Samples with different diameters during the electromagnetic shaping process.

## **The influence of powder particle size on proprieties of anisotropic Nd-Fe-B magnets textured with hot plastic deformation method**

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The influence of powder particle size on magnetical proprieties of isotropic precursors as well as the structure and magnetical proprieties of Nd-Fe-B anisotropic magnet produced with hot plastic deformation method was showed. It was established, that from viewpoint of efficiency of texturing process, it exists the critical powder particle size which is applied in isotropic precursors' production process. For MQP - A powder, it amounts 58  $\mu\text{m}$ . For fraction of powder of such or larger particle size, the material of isotropic precursor shows profitable building, characterizing small participation of large grains, that do not undergo texturing. The use of fraction of 58  $\mu\text{m}$  powder particle size, and larger deformation (75% instead 65%) permitted to produce anisotropic magnets with following proprieties: remanence  $J_r = 1,41$  T, coercivity the  $\mu H_c = 780$  kA /m, and energy product  $(BH)_{max} = 390$  kJ/m<sup>3</sup>.

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## The magnetic compass of migratory birds: from behaviour to molecules and cognition

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Migratory birds can use a magnetic compass to find their way, but how do they sense the reference direction provided by the geomagnetic field? In recent years, two biophysical mechanisms have become established as the most promising magnetodetection candidates [1]: (1) iron-mineral-based sensors in the upper beak connecting to the brain through the ophthalmic branch of the trigeminal nerve and/or (2) light-dependent radical-pair processes in the eyes converting the magnetic signal into a visual signal, which is then processed in visual brain areas. In my lecture, I will start out introducing the two hypotheses. Then, I will present our most recent findings strongly suggesting that the magnetic compass of night-migratory songbirds is part of the birds' visual system [2-8]. This conclusion is based on a number of combined experiments involving molecular biology, anatomy, chemical analyses, neurobiology and behaviour: We have shown that potentially magnetosensitive molecules called cryptochromes are found in highly active neurons of the retina of night-migratory birds [2]. In contrast, the cryptochromes are virtually absent in the retina of non-migratory birds during the night [2]. We have shown that these cryptochromes possess a number of key biophysical prerequisites that makes them ideally suited as magnetodetectors [3]. We have also located a specific forebrain area, named Cluster N, which is the only part of a migratory bird's forebrain being highly active processing sensory information when birds perform magnetic compass orientation [4-7]. We have also shown that this brain region is involved in processing some sort of specialized night vision seemingly in night-migratory birds only [4-5,7]. Finally, we have just performed the critical, double-blind, experiments that we think were needed to conclusively separate between the two hypotheses [8].

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## Magnesium isotope effect on enzymatic phosphorylation and growth of *E.coli* cells

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A.L.Buchachenko and co-authors [1] have proved the magnetic isotope <sup>25</sup>Mg being in active sites of some enzymes (ATPase, phosphocreatine and phosphoglycerate kinases) is able to increase the rate of ATP production. The molecule of ATP is the main source of energy in living organisms. So the increase of ATP production should affect on life activity and growth of living organism too. The biochemical role of the magnetic isotope <sup>25</sup>Mg was explained by ion-radical mechanism of joining phosphatic groups to ADP in active sites of phosphorylating enzymes [1]. This mechanism is capable to predict influence of magnetic fields (static or oscillating) on similar enzymatic reactions and the following biological processes [2-4].

The main purpose of our work was revealing of magnesium isotope effects *in vivo*. The *E.coli* cells were used as object of research. Microorganisms were cultivated in the liquid nutrient mediums containing exclusively pure isotope forms of Mg (magnetic <sup>25</sup>Mg and non-magnetic <sup>24,26</sup>Mg) in equimolar concentration. Magnetic isotope <sup>25</sup>Mg increased the growth rate of *E.coli* cells. Some distinctions were found for the stage of cells logarithmic growth and for the maximum reached cellular biomass. The presence of a magnetic isotope <sup>25</sup>Mg considerably increased the growth rate of *E.coli* cells comparing with non-magnetic forms <sup>24,26</sup>Mg.

The received experimental results prove the magnesium isotopes effect on growth and promotion of *E.coli* cells.

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## Magnetic Levitation of Human A431 Cells

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During the last decades a wide variety of experiments during space flights have demonstrated that gravity has profound effects on whole organisms, organs and tissues. Interestingly, the virtual absence of gravity also had profound effects on the cellular and molecular level, including changes in cell morphology, modification of gene expression, changes in signal transduction cascades and even changes in the self-organisation of tubulin. One of the gravity sensitive components in cells appears to be actin. Our experiments in real microgravity using sounding rockets revealed a modified actin cytoskeleton of A431 epidermoid carcinoma cells in space resulting in the rounding of these cells and an increased polymerization of actin. Actin is a major component of the cytoskeleton and has important functions, amongst other in signal transduction, motility, attachment, and cell morphology.

The aim of the present research was to use magnetic fields as analogues for real microgravity to study the effect of levitation on the actin cytoskeleton in human A431 cells, in order to establish the potential of magnetic levitation as a simulation of microgravity conditions. We compare the results with data found in the past in real microgravity and in simulated microgravity using the fast rotating clinostat and RPM. During magnetic levitation cells are exposed to high magnetic fields. Therefore we studied also the effect of such a magnetic field on the cells without levitation. Human A431 cells were exposed to magnetic levitation for different time intervals and chemically fixed while levitation was ongoing. Subsequently the actin morphology and behaviour of focal adhesions were investigated using fluorescence microscopy. The behaviour of focal adhesions is an indicator for attachment and rounding or spreading of cells. Identical results were obtained in the RPM studies and magnetic levitation studies. However, controls for the effect of the magnetic field raised concern about the potential of magnet simulated microgravity and indicated the importance of this control.

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## **Exposure of *Drosophila melanogaster* to Magnetic Levitation: Changes in the behaviour, development and gene expression profile and exploitation as a long-term altered gravity simulator**

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- (1) Departamento de Bioquímica & Instituto de Investigaciones Biomédicas “Alberto Sols” (UAM-CSIC). # This communication is affectionately dedicated to the memory of our colleague and friend, Professor Roberto Marco.
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Biological systems respond to the presence or absence of gravity. However, since space experiments are expensive and infrequent, simulation ground facilities are exploited that compensate for the effects of gravity. A large gradient magnetic field can be used to levitate objects and as a facility that allows intermediate g levels (like those of Mars or the Moon). By exploiting the effect of diamagnetic levitation, we have been able to expose *D. melanogaster* to zero effective gravity (0g\*) for extended periods, up to a month or more, in a magnetic levitator and to compare the results with those of experiments in a Random Position Machine. We observed a significant delay in the development of fruit flies from embryo to adult, and a marked enhancement in the motility of the adult flies compared to their behaviour under normal conditions of the Earth's gravity. In terms of overall gene expression patterns, microarray analysis indicated that there were changes in imagoes that were exposed to or that developed under magnetic levitation, and also during exposure to high magnetic fields under 2g\* and 1g\* conditions. Significant changes in the expression of immune/stress/temperature response genes (*e.g.* several heat shock proteins were affected) were observed in the three magnet positions. We have detected the Yuri Gagarin gene, one of the gravity-response genes previously described in *Drosophila*, amongst other genes with unknown function. Although more experiments need to be performed to clarify this statement, gene expression experiments also suggest that the alteration caused by the magnetic field is greater than the altered gravity itself, making it difficult to separate both effects.

## Various methods of magnetic alignment and their applications to materials science and crystal structure analyses

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We have developed various methods of aligning feeble magnetic materials, including (i) magnetic alignment of magnetically isotropic rods[1], (ii) magnetic alignment of metal plates and rods[2], (iii) three-dimensional alignment of biaxial crystals to convert a powder sample to a pseudo-single crystal (PSC)[3-4], and (iv) graded alignment[5] of fillers in gel composite for stimulus-responsive materials.

The first method (i) is based on the use of inhomogeneous magnetic field produced over a field modulator[6] placed in a uniform magnetic field. A magnetically isotropic rod receives a torque due to a local field gradient, resulting in alignment. Disadvantage of this method is that the field modulation persists only over a short distance from the modulator surface. The second method (ii) is based on eddy current induced on a metal or electroconductive particle by applying an oscillating (rotating) magnetic field. Due to the shape anisotropy and phase delay of the induced current, disks, rings, and rods are oriented with respect to the plane of the rotating magnetic field. The topic (iii) is related to preparation of a pseudo single crystal (PSC: a composite or suspension wherein micro/nano crystallites are oriented three-dimensionally) and its application to the crystal structure determination by X-ray and neutron diffraction. We have prepared a PSC (ca. 5 mm $\phi$  x 8 mm) from a microrod sample of LiCoPO<sub>4</sub> (ca. 20  $\mu$ m of length) and successfully obtained a single crystal X-ray diffraction pattern shown in Fig. 1. Using the diffraction data, we were able to perform the indexing and the crystal structure determination of this compound. The result was in good agreement with that reported in literature. We are proposing the PSC method as a third approach to crystal structure determination after the single-crystal and powder methods. The PSC method is especially useful for the crystal structure determination by neutron diffraction when one cannot grow a crystal to a sufficiently large size.

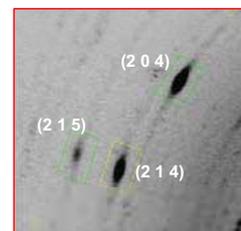


Fig.1 X-ray diffraction spots from a PSC of LiCoPO<sub>4</sub> [4].

The last topic (iv) is about magnetic-field-responsive soft materials. So far, ferromagnetic materials have been mainly used to transduce an applied magnetic field to mechanical deformation such as drug delivery. However, we know that feeble magnetic materials under high magnetic fields behave like ferromagnetic materials under moderate magnetic fields. We show that this concept is valid in fabricating magnetic-field-responsive soft materials.

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## Kinetics of Magnetic Alignment in Rotating Fields Studied by Rotational Diffusion Model

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The rotational diffusion model is useful to investigate the effect of thermal disturbance on magnetic alignment (MA).[1,2] Meanwhile, diamagnetic particles with the anisotropic susceptibility  $\chi_3 < \chi_1 = \chi_2 < 0$  can be uniaxially aligned by applying a rotating magnetic field.[3] In the present paper, we theoretically study the kinetics of the MA in rotating fields on the basis of the rotational diffusion model. Let us presume that a rotating magnetic field  $\mathbf{B}$  with the angular frequency  $\omega$  is applied parallel to the  $X_1X_2$  plane in the space-fixed coordinates, as shown in Fig. 1. The  $x_3$ -axis of a particle is taken as the director  $\mathbf{u}$  and its polar coordinates are  $(r=1, \theta, \phi)$ . When the system consists of many particles,  $P(\theta, \phi, t)$  is defined as the distribution of particles per solid angle. The rotational diffusion equation (RDE) is given by equating the time derivative of  $P$  to the negative rotational divergence of the rotational flux that includes the rotational diffusion constant  $D_R$ . We numerated the RDE to obtain the distribution  $P$  in different situations. Then, we calculated the order parameters  $m_1$  along the  $X_1$ -axis and  $m_3$  along the  $X_3$ -axis. Figure 2 exemplifies the time dependence of the order parameters where  $\alpha = VB^2(\chi_3 - \chi_1)/(2k_B T \mu_0)$  is the ratio of magnetic energy to thermal energy,  $\varepsilon = \omega/(|\alpha|D_R)$  is the reduced frequency and  $\tau_\alpha = |\alpha|D_R t$  is the reduced time. The order parameter  $m_3$  in the rotating field shows the development of the uniaxial ordering along the  $X_3$ -axis.

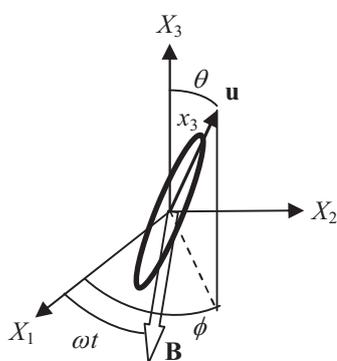


Fig. 1. Polar coordinates of a uniaxial particle.

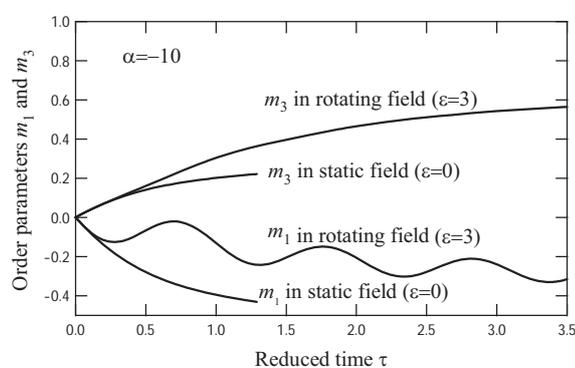


Fig. 2. Time dependence of the order parameters  $m_1$  and  $m_3$ .

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## Dynamic Alignment of Single Walled Carbon Nanotubes in High Magnetic Fields

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Carbon nanotubes are unique nano-objects with highly anisotropic electrical, magnetic and optical properties. In the last years the physics of carbon nanotubes made great progress and the comprehension of complex physical properties of carbon nanotubes increased. In order to continue the investigation of this surprising material we investigate the magnetic properties of single walled carbon nanotubes (SWNT). Semiconducting tubes are diamagnetic both along and perpendicular to their long axis but the magnitude of the perpendicular susceptibility is higher. Metallic tubes are paramagnetic along their long axis and diamagnetic perpendicular to it. This constrains SWNT to align parallel to a magnetic field. The purpose of this work is to investigate this dynamic alignment process through the application of pulsed magnetic fields and the absorption of polarized light. Our data will be analyzed with the aid of a theoretical model elaborated by *shaver et al.* [1].

To measure the alignment of SWNTs we make use of the fact that nanotubes absorb light only if it is polarized parallel to the tube axis. We thus refer to linear dichroism spectroscopy: The absorption ratio between light polarized parallel and perpendicular to the applied magnetic field reflects the degree of alignment of an ensemble of nanotubes under the influence of this field.

In order to distinguish the influence of different mechanisms governing the alignment of SWNTs such as the external magnetic field, Brownian motion or the tube length, we have systematically varied parameters such as the viscosity of the aqueous solution, the sample temperature and the pulse length. To explain the experimental data we have then simulated the alignment of SWNT theoretically with a model based on the Smoluchowski equation for rigid rods. In this contribution we will present experimental results obtained in fields up to 60 T and the associated simulations.

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## Hard X-rays and Strong Magnetic Fields: Playgrounds for Hard and Soft Condensed Matter

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The use of high magnetic fields on high energy X-ray synchrotron radiation (SR) beam lines is slowly growing. The two main driving forces behind this are the developments at the third generation synchrotron radiation sources which can create ever more powerful, smaller and higher photon energy beams and the availability of relatively cheap high magnetic fields due to technical advances in superconducting magnet technology. At present the limits regarding the use of steady high magnetic fields is solely being imposed by the technological limits of superconducting magnet technology. Although at several SR laboratories there are plans to implement continuous fields using Bitter type magnets on X-ray beam lines these so far have not been implemented. Therefore at present the only resort if one would like to use very strong fields is to use pulsed magnetic fields. These indeed have been implemented on some SR beam lines over the last years.

In hard condensed matter research the use of high magnetic fields is quite common and is one of the parameters that can be used to bring the sample in a perturbed state such that with conventional measuring techniques ambiguities in the electronic state of the sample can be resolved. In this case the use of hard X-rays is desirable if the application of the field induces structural changes that are measurable with for instance diffraction, Magnetic Scattering or Extended X-ray Absorption Spectroscopy (EXAFS). An example of the physical deformation in a crystalline lattice are the Jahn Teller distortions that can be found in  $\text{TbVO}_4$  crystals. However, these experiments often also require that the sample is kept at very low temperatures which at times is in conflict with the use of very strong X-ray beams which can cause the sample to locally heat up due to inevitable absorption of some of the X-ray photons in the samples.

In soft condensed matter the application of fields below 1 T have been commonly used in for instance liquid crystal research. Such fields are easy to implement on SR beam lines. The situation is more challenging when dealing with high magnetic fields ( $> 2\text{T}$ ). The main use of such so far has been mainly in introducing orientation in the samples like for instance in biological fibrous proteins. This often can be pursued by using an off-line magnet to induce the orientation and then bring the sample to the beam line. However, this is not satisfactory in all cases. A complication is that, unlike in the case of hard condensed matter, the samples can not be kept in the shielding vacuum required for the cryogenic installation nor can they be kept at cryogenic temperatures since this would inevitably induce a phase change from soft to hard condensed matter. This requires a more complicated arrangement for the cryogenic system and thus of the experiments. In spite of these limitations it has been shown to be possible to perform experiment in fields of up to 10 T. Not only for static structure determinations but also for time-resolved experiments in which the field induced rotation of liquid crystals could be studied.

Several examples of experimental facilities at SR beam lines will be discussed and results from both soft and hard condensed matter will be shown.

## Seeding Microtubule Pattern Formation with Magnetic Alignment

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The capability of Tesla scale magnetic fields to align biological cells, bio-molecular assemblies, and bio-polymers has been demonstrated and exploited to characterize biomaterials and to probe biological processes. One bio-polymer that is particularly important to the mechanics of the cytoskeleton, the microtubule, aligns in magnetic fields of a few Tesla. Within the cell, microtubules can be very dynamic, polymerizing from their tubulin subunits to form structures and patterns important to cellular processes and depolymerizing when those processes have completed. Pattern formation can also occur in purified solutions of tubulin outside of the cell where more controlled investigations of the driving processes can be performed. Investigations of such in vitro phenomena can constrain models of in vivo pattern formation.

Here, I present our in vitro investigations[1-3] of macroscopic, striped patterns that spontaneously form out of concentrated tubulin solutions. We found that magnetic fields can seed this pattern formation by providing an initial alignment of the microtubules and exploited this capability in subsequent investigations. We found that the stripe pattern reveals an underlying wave shaped assembly of microtubule bundles. These waves form through a mechanical instability driven by the forces generated through polymerization. I will present a mechanical model of the process and show how it quenches with the introduction of a polymer that influences the interactions between microtubules.

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## **The role of magnetic orientation in structure determination, cell biology and regenerative medicine**

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Although individual molecules have an extremely weak diamagnetic anisotropy when they behave cooperatively, as in crystals, liquid-crystals, stiff polymers, cell fragments or entire cells, a high degree of alignment can be attained by the application of a strong magnetic field. Magnetically orientation has contributed structural studies of large non-crystalline complexes (e.g. filamentous viruses, fibrin, actin, microtubules, bacterial flagella and membranes). There is evidence to suggest that magnetic processing may influence crystal growth in certain circumstances. The alignment of cells and their supporting extracellular matrix is often crucial to the overall properties of soft tissue. Magnetically oriented scaffolds of collagen and fibrin can be used to ask fundamental questions about how matrix morphology influences cell processes such as wound repair and vascularisation in vitro. Finally, magnetically oriented biomaterials might eventually be incorporated into specialized wound dressings, for example, to direct nerve repair, and muscle and cornea regeneration. Recently we have used this technique to create 3D scaffolds of orthogonal lamellae of aligned collagen fibrils to mimic the structure of corneal stroma. In vitro studies show that keratocytes align by contact guidance along the direction of collagen fibrils and respect the orthogonal design of the collagen template as they penetrate into the bulk of the matrix. These corneal substitutes have been implanted into rabbit eyes by lamellar keratoplasty. Preliminary results are very encouraging but need to be consolidated by further trials.

## Effect of Static Magnetic Fields on Firefly Bioluminescence

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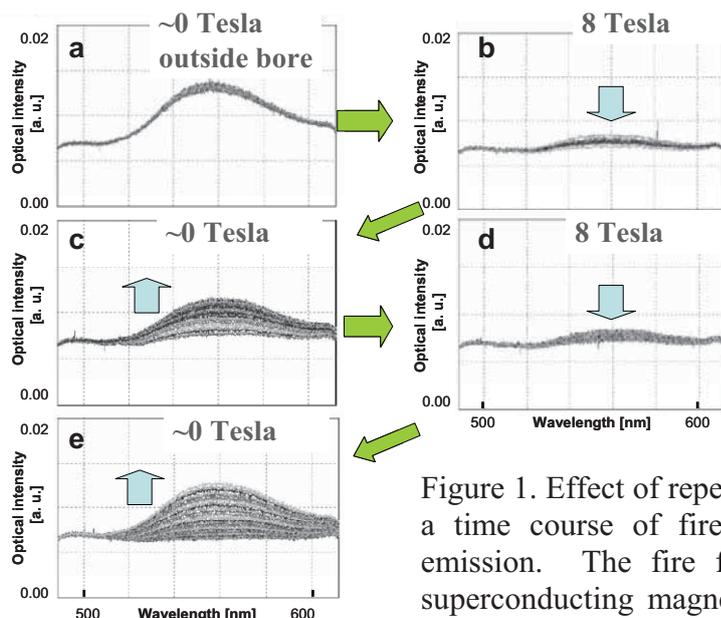
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Bioluminescence is a unique system utilized by living creatures, such as fireflies and lightning bugs, for the purpose to communicate with each other. The system can provide a highly sensitive evaluation system for biomagnetic studies because it enables direct investigation of the effects of magnetic fields on living systems by measuring light emissions in real time. The bioluminescence of firefly is a kind of photochemical reaction that involves a substrate, luciferin, and an enzyme, luciferase. In the previous studies, we observed the enzymatic reaction of luciferin and luciferase both *in vitro* and *in vivo*, and the results showed that the emitted light intensity of 560nm decreased and the peak wavelength slightly shifted to higher wavelengths by the magnetic field exposure of up to 14 Tesla [1]. In the present study, we investigated the effects of magnetic fields of up to 8 T on the emission spectra of firefly, *Luciola lateralis*, for the purpose of checking the reproducibility of the phenomena.

An optical measurement system with cooled CCD type of optical photometer was introduced for the real-time measurement of firefly's emission under the strong static magnetic fields. The firefly light organ was fixed at the edge of an optical fiber, and the emitted light was introduced into the CCD photometer system. We measured both the spectrum of a light emission and the time course of bioluminescence.

First, pulsed emission spectra in the range of 540 nm to 580 nm were collected every two seconds, and an averaged spectrum was obtained. Immediately after placing the light-emitting organ of the firefly at the end of an optical fiber, the optical emission peak at 560 nm gradually shifted to higher wavelengths as the magnetic field was applied, and shifted to a lower wavelength when the firefly was moved away from the 8 T. In the next study, a time course of bioluminescence during a static emission was measured. The intensity of emission decreased under 8-T magnetic fields; it was observed to be reversible as shown in Fig. 1.



It was speculated that the oxygen molecules transport in/around the firefly light-emitting organ was influenced by the magnetic fields. The specific mechanism, such as magnetic force, magnetic orientation or radical pair mechanisms, was not determined at the present study.

Figure 1. Effect of repeated exposure at 8-T magnetic fields on a time course of fire fly bioluminescence during a static emission. The fire fly was moved between the bore of superconducting magnet and its dummy bore which had the same condition except the magnetic fields.

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## Orientation Growth of Pollen Tubes in Vertical Strong Magnetic Fields

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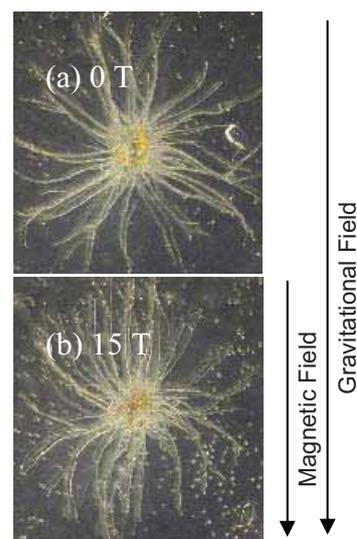
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Influence of strong magnetic fields on plants or their organs is an attractive subject in view of not only magneto-science of the living plants but also their agricultural application using the magnetic field.[1] Recently, attention has been paid for the phenomena of plants in the presence of strong magnetic force[2-4] since the vertically-operating force can simulate the microgravity and hypergravity. We and Takahashi et al. have demonstrated effects of a vertical strong magnetic field itself and the magnetically-simulated gravity on the germination and growth of Japanese radish and thale-cress seeds, respectively.[3,4] Interestingly, an effect of a strong magnetic field on the radish growth was opposite to that on the cress while an effect of the magnetically-simulated gravity was similar to each other. However, the mechanism of these effects remains unresolved since they might include effects on biological phenomena characteristic of multicellular systems such as cell divisions in addition to effects on the component single cell. In this study, therefore, a unicellular system of pollen tube was utilized to elucidate responses to a vertical magnetic field which is peculiar to a unicellular system although the response to a horizontal field was reported.[5] Pale yellow lines in Fig. 1 show individual pollen tubes of camellia in the absence and presence of a homogeneous vertical magnetic field of 15 T. The tubes geminate toward all direction from a central spot seeded, and subsequently tend to align in a direction of the field together with their elongation. This result indicates magnetic field-induced orientation growth of a unicellular system of pollen tubes. Further results and discussion will be presented in the conference.[6]

This work was financially supported by both JSPS Asian Core Program “Construction of the World Center on Electromagnetic Processing of Materials” and Hiroshima University Foundation.

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**Fig.1.** Optical microscope photos of pollen tubes in each magnetic field.

## Chemical Self-assemblies in High Magnetic Fields

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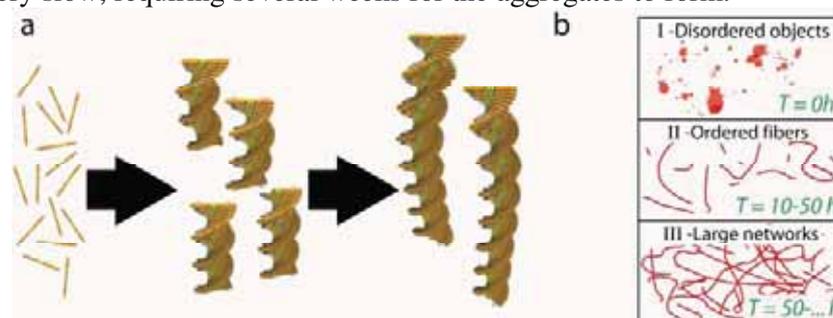
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The fabrication of functional nanostructures by using self organizing systems has been a fascinating research area for several years. Among these systems, the use of organic  $\pi$ -conjugated molecules is a very successful approach, given their promising electrical and optical properties and the large variety of possible nanostructures. To better understand the self-assembly process, it is important to measure the time and temperature dependency of aggregate formation in solution. Due to the magnetic- and optical anisotropies of most conjugated molecules, magnetic field induced birefringence is a very suitable technique, enabling an accurate measurement of the *size* and *internal order* of the aggregates.

We have applied magnetic birefringence on two different one dimensional aggregates. First, we have studied the thermally induced growth of chiral oligo(p-phenylenevinylene) (OPV) aggregates (Figure 1a)[1]. Although the aggregate alignment is not complete at  $B=20\text{T}$ , the induced birefringence clearly shows aggregate growth at decreasing temperature. Second, we have followed the time dependent aggregation process of macrocycle molecules[2]. We have found that the aggregation consists of three stages (see figure 1b), and that the aggregation process is very slow, requiring several weeks for the aggregates to form.



**Figure 1.** (a) Schematic representation of the formation of chiral OPV aggregates. (b) The three aggregation stages of the macrocycle. We have used magnetic birefringence to study the aggregation kinetics.

In both cases, magnetic birefringence is a valuable tool, revealing the time- and temperature dependence of aggregate formation. A better understanding of the formation process is a crucial step towards the use of organic molecules as nano-sized building blocks in future devices.

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## Magnetic field effect on chiral symmetry-breaking induced by stirring in supramolecular porphyrin aggregates

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The expression of chirality has been intensely studied especially in the field of supramolecular chemistry: chiral transfer, amplification and memory[1] has attracted interest since the close relationship with biological systems. In this respect the role of achiral building blocks, that can self-assemble onto homochiral templates mainly exploiting non-covalent interactions, thus yielding highly ordered and chiral aggregates, has received a lot of attention.[2] Anyway, much more intriguing is the case of “spontaneous” symmetry breaking in racemic mixtures induced by weak chiral perturbations. The resolution of NaClO<sub>3</sub> crystals into optically pure species has been reported as a consequence of the stirring sense imposed to the solutions during the crystallization process.[3] Apart from very recent controversial examples dealing with dynamic chirality induced at supramolecular level by the flow,[4] Ribò et al. described a very nice example of statistical symmetry breaking during the formation of aggregates of the anionic tri(4-sulfonatophenyl)phenylporphyrin (TPPS<sub>3</sub>) induced by rotation during the aggregation kinetics.[5] Under the conditions used to perform these experiments, AFM investigations revealed the occurrence of quite large helical ribbon-like structures, whose handedness has been explained in terms of the vortex flow and related to the gravity induced diffusion (barodiffusion).[6]

In order to disentangle the combined results of vortex and the unavoidable alignment effect of barodiffusion on mesoscopic aggregates, we have decided to investigate the role of rotation in a high magnetic field on aggregates of TPPS<sub>3</sub> smaller than those reported by Ribò and coworkers. We anticipate that in the absence of applied magnetic field this system does not evidence any chiral symmetry breaking induced by the rotation, while it exhibits an impressive correlation with the stirring sense when the initial aggregates are rotated and aligned by an intense magnetic field during the early stage of aggregation.

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## Controlling magnetic interactions in Mn<sub>4</sub>-clusters via carboxylate ligands

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Current material science is aiming to understand and control magnetism on the scale of a molecule. This research has recently focused on the emerging field of single-molecule magnets such as Mn<sub>12</sub>-, Fe<sub>8</sub>- and V<sub>15</sub>-clusters [1,2]. Serendipity has led to the discovery of most of these compounds and so far their magnetic properties have never been predicted nor designed. We, however, have synthesized a novel type of Mn<sub>4</sub>-cluster that allows controlling the magnetic inter-ion interactions via carboxylate and pyridine-diimine type ligands. Upon exchange of the carboxylate ligands from acetates to benzoates or trifluoroacetates, electrons are withdrawn from the cubic Mn<sub>4</sub>O<sub>4</sub>-core, which results in a decreased antiferromagnetic coupling between the manganese ions in the cluster. We will present magnetization data that have been measured over a wide temperature (2...300 K) and magnetic field range (0...30 T). Modelling these results provides a quantitative insight into the magnetic inter-ion coupling mediated by carboxylate ligands, which is further supported by density-functional calculations. In this way our investigations provide a promising starting point to a-priori predict magnetic interactions in newly designed molecules.

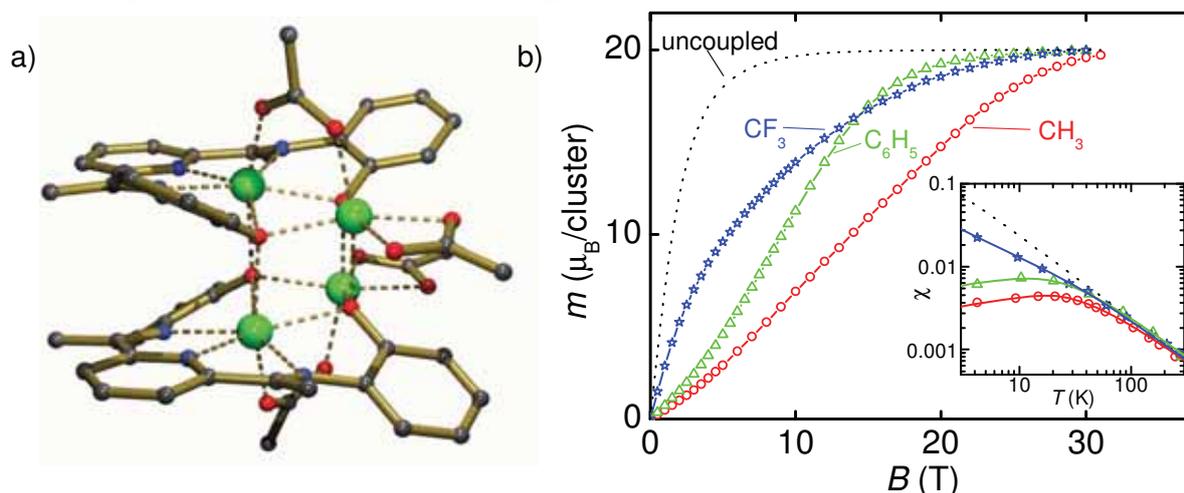


Figure 1: a) Crystal structure of the Mn<sub>4</sub>OAc<sub>4</sub> cluster, all four acetates can be exchanged with other carboxylates. b) Magnetic moments of the synthesized Mn<sub>4</sub>-clusters at 4.2K:

○: Mn<sub>4</sub>-acetate, △: Mn<sub>4</sub>-benzoate, ☆: Mn<sub>4</sub>-trifluoroacetate, dotted line: S = 5/2 Brillouin paramagnet. Inset: Volume magnetic susceptibility at low magnetic field.

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## Effect of Strong Magnetic Field on Inhomogeneous Chemical Reactions

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It is wellknown that a strong magnetic field influences various chemical and physical processes<sup>1</sup>. Inhomogeneous chemical reactions where mass transport is the rate determining step could be drastically affected by the magnetic field, as the magnetic force and/or Lorentz force affect a mass transport process remarkably. In this paper<sup>2</sup>, we studied effect of *vertical* magnetic field (max. 4 T) on the anodic oxidation of thiophene. A polythiophene deposit with a twisted shape is obtained by the application of the magnetic field. It is succeeded to induce 3D-morphological chirality on the shape of the polymer deposit using a magnetic field.

An electrolysis cell containing a 10 ml acetonitrile solution of thiophene and lithium perchlorate was placed in a bore tube of a superconducting magnet (vertical field). The electrolysis was carried out at room temperature under a galvanostat mode.

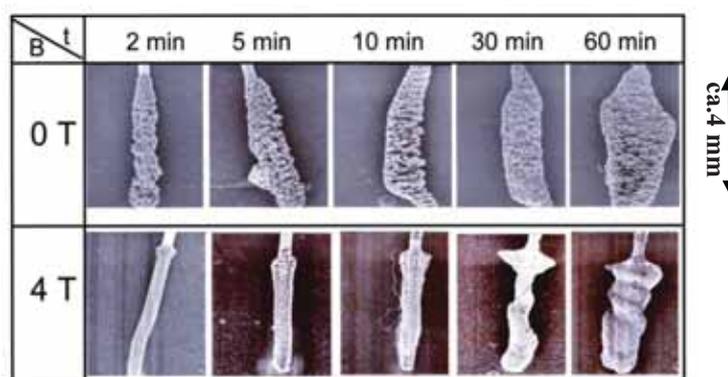
Figure 1 shows the magnetic field effect on the polymer deposit as a function of time. At 0 T, a deposit with an uncurved and bulky surface is obtained regardless of the reaction time. At 4 T, a deposit with a dense surface is obtained at a short reaction time. After prolonged reaction time (60 min), a left-handedly twisted deposit is formed.

Upon electrolysis, anions move to anode and cations move oppositely due to the electric field. Because of collision, the force acting on ions is transferred to the solvent and solute molecules surrounding them. As a result, bulk acetonitrile solution containing thiophene is transported to anode where oxidation takes place. In a magnetic field, magnetohydrodynamic (MHD) convection induced by the Lorentz force affects motion of ions in solution, resulting in the twist of polymer deposit. Indeed, *in situ* observation of the solution motion confirms that the solution undergoes MHD circular convection to the left-handed direction with the speed of 10-15 mm s<sup>-1</sup> during oxidation when an upward magnetic field of 4 T is applied.

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**Figure 1.** SEM images of polythiophene polymer deposit in the absence and presence of a 4-T field as a function of reaction time ( $t$ ).

## Author Index

- A**
- Abe, H. .... 51  
 An, Wei ..... 96  
 Ando, T. .... 70  
 Anthony, P. .... 101  
 Aogaki, R. .... 38  
 Aoyama, M. .... 109  
 Arakawa, T. .... 52  
 Ardavan, A. .... 94  
 Asanuma, M. .... 38
- B**
- Basu, S. .... 75  
 Baumgarten, M. .... 40  
 Beaugnon, E. .... 34, 45, 86  
 Berdinsky, V. .... 99  
 Bleichrodt, R. .... 100  
 Boonstra, J. .... 100  
 Borozdina, Y.B. .... 40  
 Boukhvalov, D.W. .... 112  
 Bras, W. .... 62, 105  
 Broer, D.J. .... 69  
 Bruin, B. de ..... 112  
 Bund, A. .... 36
- C**
- Cavaillé, J.Y. .... 86  
 Cheng, Chunxia ..... 54  
 Chiriac, A.P. .... 64  
 Chopart, J.P. .... 35  
 Chouchane, S. .... 35  
 Christianen, P.C.M. ....  
 ..... 62, 69, 100, 110, 111, 112  
 Coey, J.M.D. .... 42, 66
- D**
- Daltin, A.L. .... 35  
 Davey, M. .... 101  
 Deng, K. .... 54  
 Deryabin, D. .... 99  
 Dey, D. .... 75  
 Di, S. .... 63  
 Diguët, G. .... 86  
 Dijk, N.H. van ..... 31  
 Dijkstra, C. .... 101  
 Dunne, P. .... 66
- E**
- Eaves, L. .... 50, 101  
 Eckert, K. .... 41, 79, 95  
 Engelkamp, H. .... 111  
 Esling, C. .... 43, 84
- F**
- Fautrelle, Y. .... 32  
 Feyter, S. De ..... 110  
 Fröhlich, J. .... 36  
 Fu, Hengzhi ..... 96  
 Fujita, A. .... 33  
 Fujiwara, M. .... 59
- Fujiwara, Y. .... 53, 59, 109
- G**
- Gao, X. .... 58  
 Garcin, T. .... 45  
 Garrido, L. .... 61  
 Gebert, A. .... 41, 78, 79  
 Gelder, R. de ..... 112  
 Gerasimenko, Y.A. .... 94  
 Gerbeth, G. .... 73  
 Gerritsen, J.W. .... 68  
 Gielen, J.C. .... 62, 69, 100, 110  
 Groot, R.A. de ..... 68  
 Guo, Y.-Z. .... 47  
 Guo, Yonxing ..... 106
- H**
- Hamasaki, A. .... 51, 67, 85  
 Han, Jing ..... 63  
 Hayashi, H. .... 71  
 He, Ji-Cheng ..... 92, 93  
 Hein, C. .... 98  
 Herranz, R. .... 101  
 Hess, A. .... 36  
 Hest, J.C.M. van ..... 69  
 Heuvel, M. van den ..... 69  
 Heyers, D. .... 98  
 Hill, R.J.A. .... 50  
 Hirota, N. .... 70  
 Hisayoshi, K. .... 48, 72  
 Hore, P.J. .... 74  
 Hu, Li-Fang ..... 58  
 Huang, Yongping ..... 63
- I**
- Ikehara, Y. .... 44  
 Iles, A. .... 30  
 Iwasaka, M. .... 57, 65, 108
- J**
- Janssen, F.F.B.J. .... 112  
 Jia, Bin ..... 60  
 Jiménez-Melero, E. .... 31  
 Jin, Hongmin ..... 83  
 Jin, Huang ..... 83  
 Juan, E. de ..... 101
- K**
- Kalneus, E.V. .... 77  
 Kampert, E. .... 31, 112  
 Kanou, S. .... 48, 72  
 Kato, T. .... 29  
 Katsnelson, M.I. .... 112  
 Katsuki, A. .... 59  
 Kawamata, K. .... 71  
 Kimura, T. .... 102  
 Kipriyanov, A.A. .... 77  
 Klehe, A.K. .... 94  
 Koltover, V. .... 99  
 Kono, J. .... 104  
 Kornilov, A.V. .... 94
- Koyama, K. .... 33, 44  
 Koza, J. .... 41, 78, 79, 80  
 Krause, A. .... 80  
 Kubota, K. .... 51  
 Kurita, S. .... 65  
 Kurosaka, D. .... 56
- L**
- Lang, M. .... 40  
 Larkin, O. .... 101  
 Latyshev, A.Y. .... 89  
 Latyshev, Y.I. .... 89  
 Levesque, A. .... 35  
 Li, Baokuan ..... 87, 88  
 Li, Gui-mao ..... 92  
 Li, Tingju ..... 81  
 Li, Xi ..... 32  
 Li, Yibing ..... 83  
 Li, Ying ..... 83  
 Lipiec, W. .... 97  
 Liu, Lin ..... 96  
 Liu, Tie ..... 93  
 Liu, Yifeng ..... 106  
 Liu, Yin ..... 93  
 Loon, J.J.W.A. van ..... 100, 101  
 Loosdrecht, P.H.M. van ..... 46  
 Lou, Changsheng ..... 93  
 Löwik, D.W.P.M. .... 69  
 Lu, Q.Q. .... 47  
 Lummen, T.T.A. .... 46  
 Luo, Mingzhi ..... 63
- M**
- Maan, J.C. .... 62, 110, 111, 112  
 Marco, R. .... 101  
 Margaron, O. .... 30  
 Martyanov, O. .... 82  
 Matsushita, T. .... 67  
 Mazza, L. .... 66  
 Medina, J. .... 101  
 Meng, Rui ..... 49, 58  
 Micali, N. .... 111  
 Mitsui, Y. .... 33, 44  
 Miyamoto, K. .... 90  
 Mizuno, T. .... 71  
 Moes, M.J.A. .... 100  
 Mogi, I. .... 37  
 Molin, Y.N. .... 77  
 Monsù Scolaro, L. .... 111  
 Monzon, L. .... 66  
 Morgunov, R. .... 76  
 Morimoto, R. .... 38  
 Morimoto, S. .... 53  
 Mouritsen, H. .... 98  
 Mühlhoff, S. .... 79, 80, 95  
 Mutschke, G. .... 36
- N**
- Nicholas, A. .... 104  
 Nishikiori, R. .... 53  
 Nita, L.E. .... 64  
 Nugroho, A. .... 46



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