Newsletter of the Global COE program

Deep Earth Mineralogy

Center for Advanced Experimental and Theoretical Deep Earth Mineralogy
先進的実験と理論による地球深部物質学拠点

No. 3, September 25, 2009

News & Events

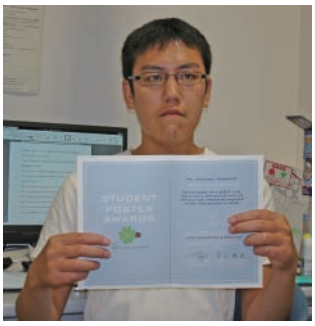
International awards to young scientists

Two young scientists of GRC received international awards during the 22nd general assembly of International Association for the Advancement of High-Pressure Science and Technology (AIRAPT) held in Tokyo on 26-31 July.

Dr. Yasuhiro Kuwayama, an assistant professor of GRC, received Jamieson award from AIRAPT, for his outstanding research achievements in high-pressure mineral physics using a laser-heated diamond anvil cell. The executive committee of AIRAPT selects one young scientist for Jamieson award mainly from research fields relevant to geophysics and high-pressure physics. This award is in memory of Prof. J.C. Jamieson of Chicago Univ., who greatly contributed to the invention and development of diamond anvil cell technology. Dr. Kuwayama is the second person who received this award from Japan, and gave a 40 minute award lecture.

Mr. Takehiro Kunimoto, a PhD student at GRC, received a Student Poster Award during this meeting, as one of seven outstanding poster presenters in three-day poster sessions. He presented some of the latest results on application of nano-polycrystalline diamond (NPD = HIME-Dia) to a 6-8-2 type multianvil apparatus, resulting in generation of pressures as high as 125 GPa, at 1000 K. This is the highest pressure ever reported in multianvil apparatus.

Dr. Kuwayama



Mr. Kunimoto

Hot discussion on novel pressure scales

Intensive discussion was made on existing and new pressure scales among ~40 participants in a summer school held at GRC on 3-5 August. Establishing practical pressure scales based on adequate P-V-T equations of state (EOS) is one of the major issues relevant to the deep Earth mineralogy. Prof. Taku Tsuchiya of GRC, whose pressure scale of gold is well cited and sometimes referred to as "Tsuchiya-scale", organized a summer school in Matsuyama for the satellite meeting of AIRAPT, held in Tokyo in the preceding week.

Some internationally well-acknowledged speakers in both theoretical and experimental studies were invited to GRC from various countries, and had intensive discussion with the participants for three days, focusing on the current status and future perspectives of the P-V-T EOSs suitable as pressure scales. One of the highlights of the summer school is a special lecture by Prof. W. B. Holzapfel, Univ. Paderborn in Germany, who is the authority of P-V-T EOS studies and made a comprehensive review talk on these topics. A new method of deriving a unified EOS utilizing available experimental data sets was proposed by Dr. Yoshinori Tange, an assistant professor of GRC, who gave a talk on the performance of a series of new EOSs, referred to as "EHIME-scale", based on this method.

Internship for crystal structure analysis

An internship for crystal structure analysis was held on 19-21 August, attended by PhD students and postdoctoral fellows, as well as some faculty members of GRC and GL. The lecturer, Dr. Kazuki Komatsu of GL, Univ. Tokyo, made a comprehensive lecture on the basics of crystal structure analysis, followed by some practice in using major software packages, such as VESTA and GSAS. Training of young scientists in applications of various "quantum beams", particularly X-ray and neutron, to deep Earth mineralogy is one of the purposes of the education program of the present global COE, and this internship offered an opportunity to learn practical method for analysis of crystal structures using observed diffraction data. The internship program will continue in laboratories related to the present COE program.

Global COE
DEEP EARTH MINERALOGY
EHIME UNIVERSITY JASRI, UNIV.TOKYO, SBU

Paper highlighted by Nature Geoscience

Dr. Steeve Gréaux, a COE postdoctoral fellow at GRC published his research paper entitled "Experimental high pressure and high temperature study of the incorporation of uranium in Al-rich $CaSiO_3$ perovskite" in Physics of the Earth and Planetary Interiors (vol.174, 254-263), which has been picked up in "Nature Geoscience" as one of the articles in Research Highlights (Nat. Geosci., vol.2, 5). Another paper by a COE postdoctoral fellow of GRC was also picked up by the same journal as a highlight (see, No.2 of this news letter) earlier this year, demonstrating high quality of researches conducted by the young scientists of GRC. Further details of Dr. Gréaux's work are summarized in this issue.

Awards to COE members

Two of the COE executive members, Profs. Tetsuo Irifune of GRC and Hiroyuki Kagi of Geochem. Lab. (GL), Univ. Tokyo, received the most prestigious awards of two major Japanese Societies relevant to high-pressure studies and mineral sciences, respectively. Prof. Irifune was selected as the winner of the Japan Society of High Pressure Science and Technology Award, and gave a plenary lecture during the joint meeting with AIRAPT-22 held in Tokyo in July. The Japan Association of Mineralogical Sciences Award was given to Prof.Kagi, who gave a special talk during the annual meeting of the association held in Sapporo in September. Meanwhile, Prof. Kiyoshi Fujino, also a staff member of GRC, received the Research Paper Award of the latter society during the meeting, as one of the co-authors. Moreover, Mr. Akihito Sogabe, a graduate student at GRC, and Mr. Toru Yoshino, also a student at GL received Outstanding Research Presentation Award in this meeting. Only three students were selected for this award.

Prof. Irifune

Prof. Kagi

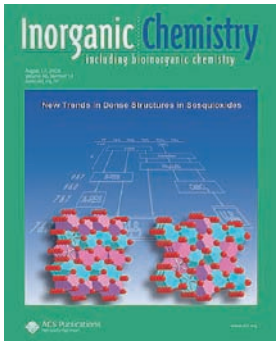
Prof. Fujino

Mr. Sogabe

Mr.Yoshino

A new high-pressure form of M_2O_3

A research team of Prof. Taku Tsuchiya of GRC and Dr. Hitoshi Yusa of NIMS (Guest Researcher of GRC) found a new high-pressure form with the Gd_2S_3-type structure as a result of a phase transition from Sc_2O_3 at about 20 GPa, using both diamond anvil cell experiments and first-principle calculations. The new structure was found to possess octahedrally coordinated cations and results in a quite large density increase by about 13% upon the transition. The same phase transition was also found in In_2O_3, suggesting that the new structure could also be important in deep Earth mineralogy. An illustration of the new structure and phase transition sequence was adopted as the cover page of the journal "Inorganic Chemistry", issued by the American Chemical Society.



Inter-institutional workshop in Bayreuth, Germany

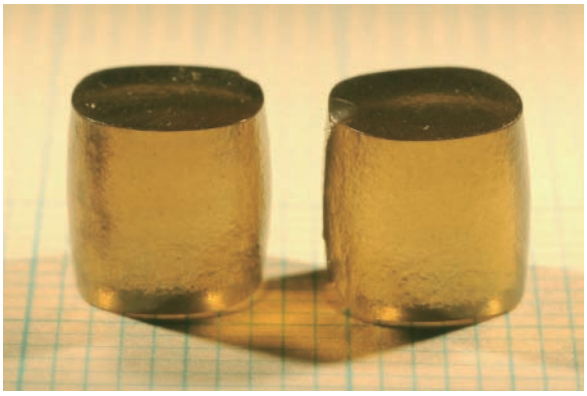
A workshop attended by the global COE members and the members at Bayeriches Geoinsitut (BGI), University of Bayreuth, was held on 17-19 June, at Eremitage old palace in the suburb of Bayreuth. About 70 people, 30 from the GRC side, gathered, and oral and poster presentations were made mostly by young scientists, such as PhD students and postdoctoral fellows.

The best presentation award was given to two presenters, Drs. Shinichi Machida, GRC, and Micaela Longo, BGI, with Germany wine and Japanese sake as supplementary prizes, respectively, by the selection committee made of 12 "senior" members from both sides. This workshop was held to improve ability of research presentations in English for young scientists, as well as to enhance mutual interactions and collaborations between the two institutes, who have an agreement on exchange of people and collaboration in research/education.

During the workshop in Bayreuth, participants from GRC side visited BGI for a lab tour, and also discussed with the people at BGI on details of the experimental techniques and facilities. After the lab tour, a BBQ party was held at BGI and all the participants enjoyed further discussion and communication with fine German Beer. At the end of the workshop, an excursion tour to an old castle and a limestone cave was arranged by BGI, where the participants learned some history and nature of this region in Bavaria.

Larger HIME-Dia now available with BOTCHAN

Up to about 7 mm "HIME-Dia" (or nano-polycrystalline diamond, NPD) rods in both diameter and length are now produced at GRC using a newly constructed large-volume multianvil apparatus (BOTCHAN) operated in a 6000-ton press. Thus synthesized HIME-Dia rods are processed with a pulse-laser to form various shapes and used as anvils for high-pressure apparatus. Press loads of only up to about 3000 tons have been used for synthesis of such HIME-Dia rods, and those exceeding 1 cm in dimensions are expected to be produced when the capacity of BOTCHAN is fully used.



Lecture & Seminar

International Frontier Seminer

8th (14 May)

"Experimental constraints on the chemistry and physical state of the terrestrial planetary cores"
Lecturer : Prof. **Yingwei Fei** (Geophysical Laboratory, Carnegie Institution of Washington, USA)

9th (28 May)

"Rheology of serpentines, seismicity and mass transfer in subduction zone"
Lecturer : Prof. **Bruno Reynard** (Laboratoire de Sciences de la Terre UMR CNRS 5570, Ecole Normale Supérieure de Lyon, France)

10th (22 July)

"Magma to Molecules: Simulation of Abiotic Organic Synthesis at Mid-Ocean Ridge Seafloor Hydrothermal Systems"
Lecturer : Prof. **John R. Holloway** (Institute for Geothermal Sciences, Kyoto University & Department of Chemistry & Biochemistry, and School of Earth and Space Exploration, Arizona State University)

11th (24 August)

"Laboratory-based Interpretation of Upper-mantle Seismic Tomograms: Progress and Prospects"
Lecturer : Prof. **Eiji Ito** (Institute for Study of the Earth's Interior, Okayama University, Japan)

12th (2 September)

"Water Distribution Across the Mantle Transition Zone in Earth and Its Implications for the Evolution of Ocean"
Lecturer : Prof. **Shun-ichiro Karato**
(Department of Geology and Geophysics, Yale University)

The 2nd International Special Lecture

Lecturer: Prof. **Shun-ichiro Karato**

(Department of Geology and Geophysics, Yale University)
Date: 2-3 September, Ehime Univ.

Lecture I : Some recent progress in the study of plastic deformation in minerals: Applications to the dynamics of Earth and other terrestrial planets
Lecture II : A new approach to the equation of state of liquids: Applications to the evolution of Earth and other terrestrial planets

The 2nd YESA Workshop

(YESA: Young Earth Scientist Association)
"Seismic observations for the deep Earth and the interpretation"
28-29 September, Ehime University

Takuto Maeda, Seismic Energy Radiation from low-frequency tremor

Youjiro Yamamoto, Seismic velocity structure off Miyagi forearc region, central part of NE Japan

Yoshihiro Yamamoto, Global P-wave tomography of mantle plumes and subducting slabs

Genchi Toyokuni, Efficient Computation of Seismic Wave Propagation through Whole Earth for Investigation of Deep Structures

Kensuke Konishi, Waveform inversion for seismic structure in D"

Yusuke Usui, Numerical modeling of D" anisotropy by the calculation for polycrystalline elasticity

Noriyoshi Tsujino, Equation of state of γ-Fe and γ-Fe_{64} Ni_{36} alloys

Hiroki Ichikawa, Thermal distribution resulting from planetary core formation by iron rain in a magma ocean

Yasuhiro Kuwayama, Phase relations of iron alloys and its implications for the structure of the Earth's inner core

Takako Satsukawa, Fabric Characteristics and Seismic Properties of Mantle beneath South Central North America: Constraints from Peridotite Xenoliths from Knippa and Kilbourne Hole

Ikuo Katayama, Where anisotropy is distributed in the mantle wedge?

Akihiro Yamada, Structural change in hydrous magma under upper mantle conditions

Forthcoming Events

Internship Program"Tutorial for Synchrotron in situ X-ray Diffraction Experiment under High Pressure and High Temperature"

Date: 30 November - 4 December, 2009, Venue: SPring-8
Lecturer: **Ken-ichi Funakoshi, Yuji Higo**
(Japan Synchrotron Radiation Research Institute (JASRI), SPring-8)

This is a practical internship program focused on a basic procedure for synchrotron in situ X-ray diffraction experiment under high pressure and high temperature. It would be particularly suitable for PhD students, Post-Doc and young scientists who are beginners for in situ X-ray diffraction experiment under high pressure and high temperature. The experiment will be conducted using a large volume high pressure apparatus (MA8-type (Kawai-type) apparatus), SPEED-1500 or SPEED-MkII in SPring-8. Anyone who would like to know how to conduct in situ X-ray diffraction experiments using a Kawai-type apparatus at SPring-8 or anyone who plans to do such an experiment at SPring-8 will be also welcome.

The internship will include the following programs.
1) Lecture for synchrotron in situ X-ray diffraction experiment under high pressure and high temperature,
2) Preparation of high pressure cell assembly,
3) In situ X-ray diffraction experiment under high pressure and high temperature,
4) Analysis for the obtained diffraction data

In this internship, we will observe olivine - wadsleyite transformation in Mg_2SiO_4, and then collect the P-V-T data of wadsleyite in wide pressure and temperature range. Using the data, we will determine the P-V-T equation of state for wadsleyite. The number of participants would be limited to 15.

Contact address: Geodynamics Research Center, Ehime University
2-5 Bunkyo-cho, Matsuyama 790-8577, JAPAN
Toru Inoue (Professor), Email: inoue@sci.ehime-u.ac.jp

New Members

Hiroki ICHIKAWA (COE Postdoctoral Fellow)

I moved to GRC from ENS Lyon in May. I was working on a development of a numerical method to calculate a metal-silicate separation process in the planetary core formation process and received Ph.D. from the university of Tokyo in 2008. I made 10cm length scale calculations of metal-silicate separation process in the magma ocean to estimate size or velocity of metal droplets. Throughout my research, my main tool has been computational fluid dynamics. I would like to contribute to the understanding of the core formation process and the mantle convection.

Li Lei (COE Postdoctoral Fellow)

I received my Ph.D from Sichuan University on June 2009. My doctoral dissertation was on investigating phase transitions of $LiMO_2$ (M=B, Al, Ga) compounds under high pressure as well as high-pressure synthesis of GaN crystals through solid-state metathesis reaction. GaN is considered as one of the most promising semiconductor materials for LEDs and LDs because of its wide-band gap as well as thermal and chemical stability. The newly found chemical reaction may imply an effective synthetic route to not only GaN but also other novel materials. I'd like to continue this interesting research at GRC. Geophysically, a minor fraction of borate component in silicate magma may affect the geodynamics in Earth's interior. Borate exhibits interesting behaviors at high pressure. Exploring the nature of borate at high pressure, therefore, is also my current research interest.

Tomohiro OHUCHI (COE Postdoctoral Fellow)

I have moved from Yale University in June. I majored in the experimental petrology, particularly microstructural evolution of rocks controlled by diffusion process, and got a PhD at Tohoku University in 2007. I have wanted to understand the evolution of the Earth from the viewpoint of "microstructure". Deformation is one of the most essential processes controlling the evolution of the Earth, and microstructure of rocks evolves during deformation. So, I started deformation studies when I moved to Yale, and I am now concentrating in it. I would like to contribute to GRC and the GCOE program by conducting my researches.

Matthew L. Whitaker (COE Postdoctoral Fellow)

I started working with the GRC at the beginning of September of 2009 after finishing my Ph.D. in Mineral Physics at Stony Brook University in August 2009. I have an extensive background in experimental mineralogy and petrology, and my dissertation research focused on examining the physical properties of iron/light-element alloys at high pressures and temperatures using synchrotron X-ray diffraction in Diamond Anvil Cells and a combination of synchrotron radiation techniques with ultrasonic interferometry measurements in the Multi-Anvil Cell. The information obtained from these experimental studies can be used to make some determinations about the composition of the Earth's core. I hope to eat some good sushi, sing some good karaoke, and contribute to the overall mission of the GRC and GCOE during my stay here by expanding our knowledge of the composition of planetary cores by using these experimental mineral physics techniques.

Phase relation of Ca-rich garnets under High-pressure and high-temperature

Steeve Gréaux
(COE Postdoctoral Fellow)

To understand the structure of the Earth's mantle transition zone has become a challenge for geoscientists in the past years. Main discontinuities in the upper part of the mantle are usually associated with the HP-HT polymorphism of olivine. However, in the lowermost part of the transition zone, this model cannot completely explain observed seismic variations (Irifune et al., 2008). Such variations could find an answer in chemical and/or structural transformations in non-olivine materials within the mantle's transition zone (Deuss et al., 2006). Majorite garnet is a major phase of the transition zone, whose behavior is of importance to explain the structure at the base of the transition zone (Irifune and Ringwood, 1993, 1995; Karato et al., 1995). Because of its complex nature and as the composition of garnets might significantly vary in the mantle, it is difficult to investigate majoritic garnet as a function of pressure, temperature and chemical composition. Therefore several experimentalists investigated the HP-HT phase relations of garnet endmembers (Irifune et al., 1996; Akaogi et al., 1998; Takafuji et al., 2002).

Unlike magnesian- and iron-rich garnets, the HP-HT behaviour of Ca-rich garnets is still poorly constrained. Grossular garnet is one of the most significant Ca-rich endmember of mantle garnets. In order to clarify the situation we investigated the HP-HT phase transitions in $Ca_3Al_2Si_3O_{12}$ using Kawai-type multi-anvil press apparatus coupled with in situ X-ray diffraction techniques at the synchrotron facility, Spring-8. Recovered samples were analyzed by micro-focused X-ray diffraction (μ-XRD) and transmission electron microscopy (TEM). Our experiments showed a transformation sequence at 20-30 GPa and ~800-1500 K. First, an Al-Ca-perovskite gets exsolved and coexists with grossular garnet. Second, grossular garnet completely transforms into a tetragonal "Grossular"-perovskite. As temperature increases, Gr-perovskite transforms to the cubic perovskite structure. Finally, at high temperature, $CaAl_4Si_2O_{11}$ CAS phase appears besides two compositionally distinct populations of Al-Ca-perovskites. These new results suggest a slow and progressive exsolvation of Al-Ca-perovskite from the garnet, with the occurrence of Gr-perovskite at intermediate temperature. It is also likely that an additional phase is required at high-temperature to accommodate the excess of Al in the Ca-perovskite (Saikia et al., 2008).

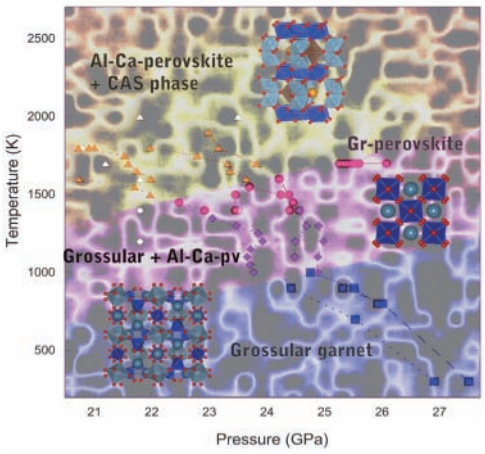


Fig. 1. Phase relations of $Ca_3Al_2Si_3O_{12}$ grossular garnet at HP-HT. Squares: grossular; diamonds: grossular + Al-Ca-perovskite; circles: Gr-perovskite; triangles: Al-Ca-perovskite + CAS phase. Plain and open symbols are in situ at HP-HT and recovered samples data, respectively. Crystal structure illustrations stand for CAS phase, $CaSiO_3$ perovskite and grossular garnet, up to down.

Technical development of a 6-8-2 type multianvil system with nano-polycrystalline diamond

Takehiro KUNIMOTO
(PhD student)

Kawai-type multianvil apparatus (KMA) and diamond anvil cell (DAC) have been widely used as the devices to study the Earth's interior. KMA has an advantage in producing homogeneous temperature and pressure in larger sample volumes compared with DAC. On the other hand, DAC has an advantage in generating higher P-T conditions equivalent to the Earth's core region, while the P-T conditions achievable with KMA have been limited to those of the middle region of the lower mantle. I have been developing the 6-8-2 type multianvil system (6-8-2 MA) toward higher pressure generation utilizing the advantages of KMA and DAC.

In situ X-ray diffraction experiments were carried out using a large volume KMA (SPEED-Mk.II) at BL04B1, SPring-8. We adopted nano-polycrystalline diamond (NPD or HIME-Dia) invented at GRC, as third-stage anvil material, which exhibited remarkable performance as anvil material in my preliminary experiments (Kunimoto et al., 2008). The generated pressure was calculated from several equations of state for MgO, while the temperature was measured with a W-Re thermocouple.

Using the present 6-8-2 MA, I successfully achieved the maximum pressure of 125.2 GPa by an EOS model of Jamieson et al. (1982), 124.4 GPa by Tange et al. (2009), under room temperature, at a press load of 5.0 MN. The sample was then heated at this press load, with a temperature fluctuation of less than 5 K. A slight increase of pressure from 125.2 to 125.9 GPa was noted with increasing temperature to 1000 K, where X-ray diffraction patterns of the sample were acquired. The pressure decreased significantly at higher temperatures, but was maintained at 83.7 GPa for two hours at 1300 K. The pressure at this temperature was almost constant within 0.5 GPa.

The P-T limits in multianvil apparatus with various techniques are shown in Fig. 1, which have been substantially expanded by the present technical development of 6-8-2 MA. With this new high-pressure system combined with NPD, I hope to accurately study the phase transitions at the P-T conditions of the Earth's lowermost mantle.

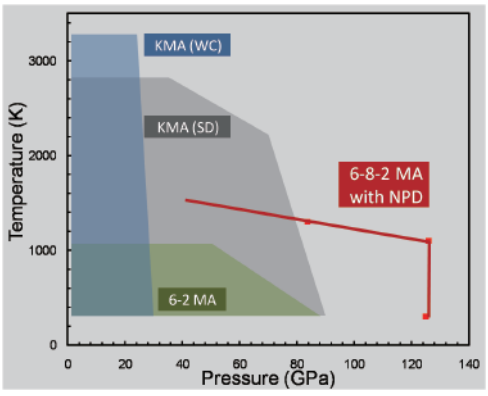


Fig. 1. Pressure-temperature limits in various types of multianvil apparatus. KMA (WC), Conventional Kawai type multianvil apparatus with tungsten carbide anvils (e.g. Irifune et al., 1992); KMA (SD), Kawai type multianvil apparatus with sintered diamond anvil (e.g. Ito, 2007); 6-2 MA, 6-2 type multianvil system (Utsumi and Aoki, 2003); 6-8-2 MA, 6-8-2 type multianvil system (present study).

News

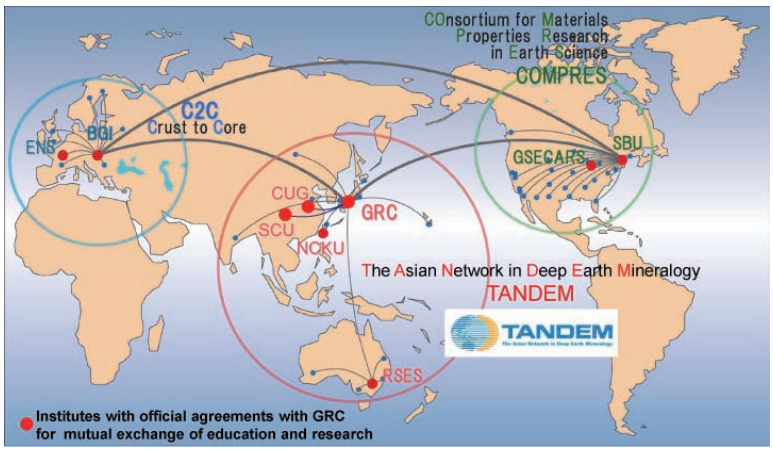
Internship students from CUG to GRC

Two master course students from China University of Geosciences (CUG, Wuhan) will attend a long-term internship from September for nearly 5 months. They will learn basics of high-pressure techniques and related analyses using quantum beams, and will engage in research relevant to phase transitions and P-V-T EOS at high pressure and high temperature during this period. This program is fully supported by GRC based on the TANDEM agenda in promoting exchange of young scientists and collaborative research in Asian countries. This long-term internship is closely related to the special PhD course for deep Earth mineralogy for Asian students, which has opened from this Autumn in Ehime University (see below).

Special course open to Asian students

A special PhD course in deep Earth mineralogy has been set up in the Graduate School of Science and Engineering, Ehime University, which annually invites two students from Asian countries with full financial supports from the University. The entrance exam will be made in May, and the successful candidates may enter the course from the end of September. The candidates should complete their master (or equivalent) thesis by the time of entrance. In this special course, GRC offers ideal environments for advanced experimental and/or computational studies on ultrahigh-pressure mineralogy and related sciences. Two students from the Institute of Atomic and Molecular Physics, Sichuan University are allowed to enter the course this year.

For more details on the application of FY2009, see
http://deep-earth-mineralogy.jp/g-coe2008/english/positions/index.html
Application information for FY2010 will be announced March or April, 2010.



Brief Communications

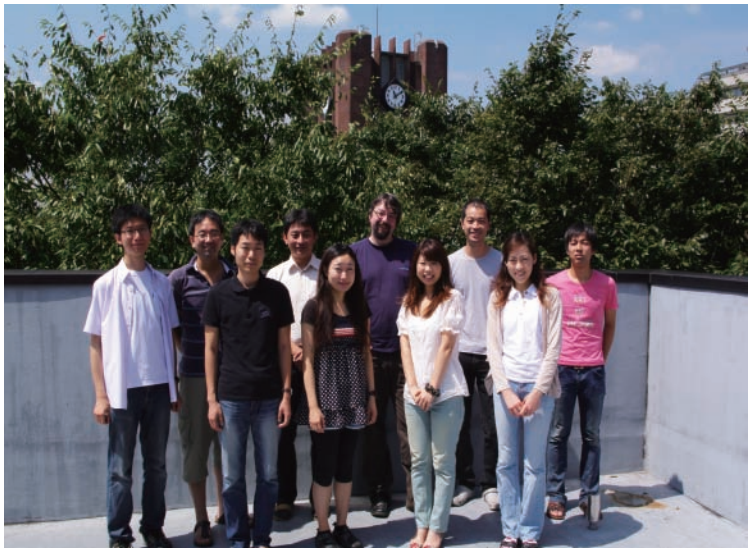
Advanced Crystallography at High Pressure

I had an opportunity to give a talk about current high-pressure techniques using multianvil apparatus in GRC, in an international conference "Advanced Crystallography at High Pressure" held as an activity of the International Union of Crystallography (IUCr) Commission on High Pressure on July 19-22, 2009 at Harbin Institute of Technology (HIT), China. This was the 9th meeting organized by the IUCr Commission on High Pressure since 1998. Harbin is a capital city in the northern part of China and located at a latitude of 45º45' north, which approximately corresponds to the northernmost region of Japan. About 80 participants (34 from Australia, Canada, France, Germany, Israel, Japan, Korea, Russia, Poland, UK, Ukraine, and USA; 48 from China) gave oral presentations (39) and poster presentations (36) on the high-pressure crystallography from various aspects such as geosciences and planetary sciences, materials sciences; amorphous, liquid, non-crystalline and nanocrystalline solids, biological solids, simple organic systems; magnetic and electronic phenomena, chemistry, theory, techniques, and so on. Some of the member of TANDEM gave contributions to the conference. The conference was started at the Science Park of HIT. From the second day, sessions were held in a conference room at the Songhuajiang Gloria Plaza Garden Hotel beside the Songhua River, and concentrated and hot discussions were made in a good atmosphere. In addition to the scientific sessions, a tour in Harbin and a conference banquet were planed in the afternoon of the third day, and we enjoyed the Tiger Zoo, the Sun Island Park which is famous for the Ice Sculpture Festival in the winter season, and the delicious Chinese food. Finally, I would like to thank the local organizer Prof. Haozhe Liu and his colleagues of HIT for their warm hospitality during the conference. The next year's meeting is locally organized by Dr. Chris Tulk, Oak Ridge National Laboratory, USA.

http://shp.hit.edu.cn/Meetings/2009IUCr_HP/Home.htm

(article by Y. Tange)

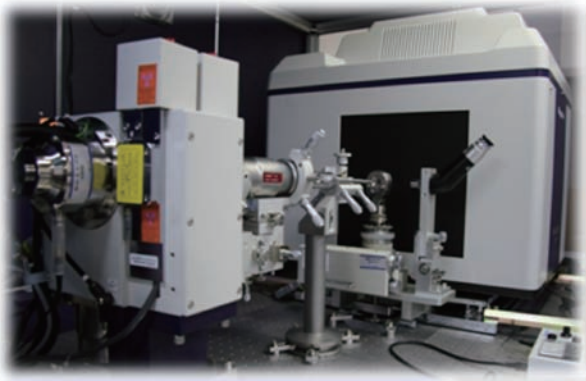
Geochemical Laboratory, Graduate School of Science, The University of Tokyo

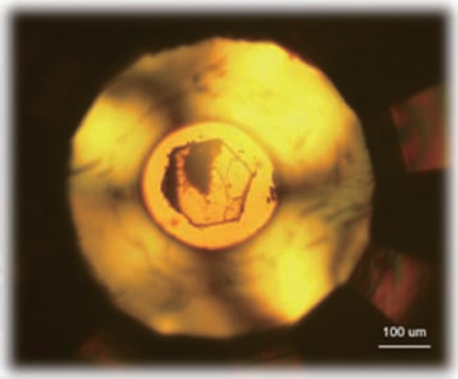


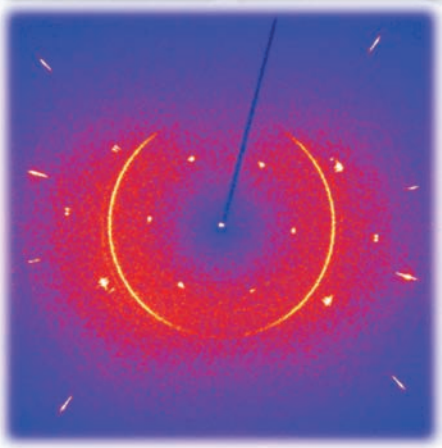
The Geochemical Laboratory at the University of Tokyo was originally founded as "Laboratory for Earthquake Chemistry" in 1978 for developing earthquake prediction from geochemical observations of groundwater. After a couple of decades from the foundation, the mission of the laboratory shifted gradually into fundamental geochemical researches for material science/chemistry of deep earth minerals, trace isotope geochemistry/cosmochemistry, spectroscopic observations of volatiles, etc. The Geochemical Laboratory currently has 7 faculty members, 3 post-docs, 3 supporting staffs, 8 PhD students and 6 master-course students. One of the marked features is that the laboratory belongs to the chemistry department and most of the graduate students majored in chemistry. We will contribute to the geoscience community by supplying people who have a background in chemistry.

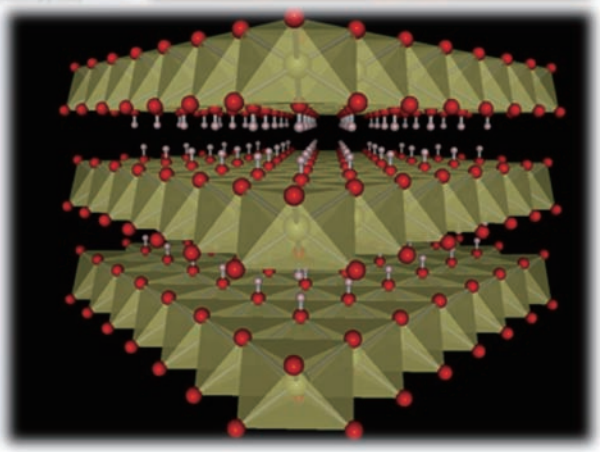
"Deep Earth mineralogy" group has two faculty members, Kagi and Komatsu, and 4 PhD students are studying under their supervision. We join with the GCOE program on deep earth mineralogy headed by Geodynamic Research Center, Ehime University and TANDEM. Our research group mainly focuses on the spectroscopic observations of deep earth materials and hydrous minerals at high pressure, crystallographic studies on minerals at high pressure using X-ray and neutron diffraction techniques, surface chemistry of crystal growth and dissolution, etc. Representative distinguishing instruments are three-dimensional Raman mapping system for imaging stress distributions around inclusions in diamonds, a high-intensity X-ray diffractometer with a fine-focused rotary anode, imaging plate and confocal mirrors for in-house X-ray diffraction measurements using DAC, IR and Raman microprobe for DAC, atomic force microscopes (AFM) for surface observations of crystal surface with the atomic scale, etc. These analytical tools have been improved from commercially available instruments with our original idea. Collaborations with people who are not familiar with these measurements are strongly welcomed and many geologists/petrologists visit the laboratory for collaborative works.

It is also worthwhile to note that we are leading the high-pressure neutron diffraction project at J-PARC by collaborating with many colleagues all over Japan headed by Professor Takehiko Yagi at the Institute for Solid State Physics, University of Tokyo. Neutron scattering experiments under high pressure will be one of the strongest tools for studying water in the earth's interior. In 2007, JSPS funded us the Grant-in-Aid for Creative Scientific Research entitled "Material sciences at ultra-high pressure using the strongest spallation neutron source". We are trying to apply HIME-DIA (nano polycrystalline diamond developed at GRC) as a new high-pressure generating device for neutron scattering. The construction of the high-pressure beamline at the pulsed neutron facility in J-PARC (Japan Proton Accelerator Complex) will be completed in a couple of years. Complementary studies using these measurements will shed light on material science of deep earth minerals. We strongly hope for further collaborations and exchanges of knowledge and people to further develop the sciences in TANDEM.









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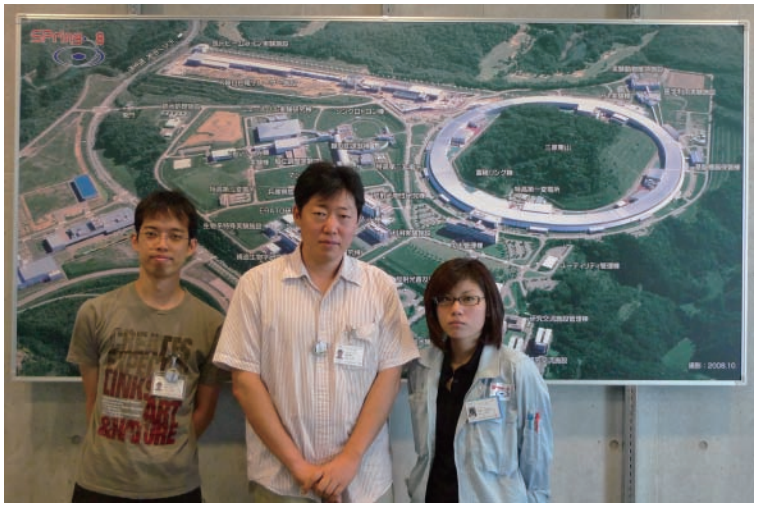
Japan Synchrotron Radiation Research Institute (JASRI, SPring-8)

SPring-8 (Super Photon ring-8 GeV) is a large third-generation synchrotron radiation facility which delivers the most powerful synchrotron radiation currently available in the world. SPring-8 has been in operation for users since October 3, 1997. Consisting of narrow, powerful beams of electromagnetic radiation, synchrotron radiation is produced when electron beams, accelerated to nearly the speed of light, are forced to travel in a curved path by a magnetic field. The research conducted at SPring-8, located in Harima Science Park City, Hyogo Prefecture, Japan, includes nanotechnology, biotechnology and industrial applications. The electron storage ring of the SPring-8 accelerator complex can potentially accommodate 62 beamlines (34 insertion devices, 4 long undulators, 23 bending magnets and 1 infrared). Currently, 49 beamlines are operational.

The "Material Structure Group I" / "Extreme structure team" has 6 researchers, and 3 beamlines are used for high pressure and high temperature experiments.

One of the beamline BL04B1, "High Pressure and High Temperature Research beamline" is a white X-ray beamline from a bending magnet. The use of high energy X-ray (20 - 150 keV) is suitable for energy-dispersive diffraction experiments using a solid state detector (SSD) and X-ray radiography experiments using a CCD camera. This beamline is designed to conduct research on the materials in the Earth's interior, and many studies concerning the phase relation, equation of state, structure, kinetics, viscosity, elastic wave velocity etc., have been conducted under high pressure and high temperature conditions. High-pressure and high-temperature experiments are performed using two large-volume presses: SPEED-1500 and SPEED-Mk.II, both of which are installed in the tandem experimental stations (Experimental hutch 1, hutch 2). These large-volume presses are constructed by double-stage (Kawai-type) high-pressure vessels with three kinds of the anvils; the tungsten carbide (WC), the diamond/SiC composite (RDC) and the sintered diamond (SD). 30 GPa or 90 GPa has been reached with the WC ($26 \times 26 \times 26$ mm^3)/RDC ($14 \times 14 \times 14$ mm^3) or the SD ($14 \times 14 \times 14$ mm^3) over 2500 K, and this high pressure and high temperature condition corresponds to the lower mantle region in Earth's interior. Recently, the monochrometer was installed into BL04B1. The white X-ray from a bending magnet source was monochromatized by a water-cooled Si (111) monochromator, which is capable of selecting monochromatic energies 30 ~ 60 keV. The lattice strain is measured using X-ray diffraction data collected at different azimuth angles by a two-dimensional X-ray detector (Imaging Plate or X-ray CCD Camera).



In this G-COE program, Practical internship program, which focused on a basic procedure for synchrotron in situ X-ray diffraction experiment under high pressure and high temperature, is held at SPring-8.

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