New Directions in Mineral Physics: Multidisciplinary High Pressure Science

Russell Hemley and Ho-kwang Mao

2005 Balzan Prize for Mineral Physics

Balzan GPC Adviser: Enric Banda
Researchers: Pierre Beck, Lin Wang, Charles Qiaoshi Zeng, Claire Barkett, Daniel Cohen, Maura James (post-doctoral fellows and doctoral students); Andrew Kung, Alexander Levedahl, Manchali Madurri, Jaqueline Rivera, Ari Benjamin, Kevin Hernandez, Tao Liu, Louis Loubeyre, Juliana Mesa, Viktor Rozsa, Brandon Wilfong, Keenan Brownsberger, Anne Davis, Reed Mershon (high school students)
Affiliated Institution: Carnegie Institution of Washington, Geophysical Laboratory

Period: 2006-2016

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With the second half of their Balzan Prize, Hemley and Mao implemented a project focused on bringing bright young people from diverse backgrounds into the multidisciplinary field of High Pressure Science. Research in this new field is expected to bring about breakthroughs in applications to mineralogy, geophysics, geochemistry and bioscience, as well as specific areas such as hydrogen storage, superhard materials and superconductivity. The project was focused on training and its goal was the exploration of the new high-pressure dimension in multidisciplinary physical sciences. The fellowships encouraged the development, design, and fabrication of new instrumentation that exploited the CVD diamond technology developed by Professors Hemley and Mao. Publications and dissemination of results have also been financed.

The following post-doctoral fellows and doctoral students received Balzan support: Pierre Beck (Balzan Prize post-doctoral associate from 2006-2007): development of time-resolved (i.e., dynamic) high pressure-temperature phenomena with diamond

anvil cells; Lin Wang (Balzan Prize post-doctoral associate): development of a new method for the synthesis of controlled shape C60 fullerene nanorods, development of a new technique to integrate the high-pressure diamond anvil cell with the high brilliance x-ray beam focused down to 50-200 nm size at the Advanced Photon Source, and work at the High Pressure Synergetic Consortium (HPSynC) at the Advanced Photon Source (APS), Argonne National Laboratory (ANL) in 2008; Charles Qiaoshi Zeng (Balzan Prize support, 2008): x-ray diffraction experiments at the APS synchrotron facility and discovery of a new type of alloy and a new phenomenon in metallic glass that have far-reaching impact in fundamental physics as well as materials applications.

The following high school students also received Balzan Award support: Andrew Kung: to develop a high-pressure project studying the pressure, temperature and temporal effects on a newly discovered O_2-H_2 alloy; Daniel Cohen: to study novel electronic phenomena in diamond, in particular, to produce a new material with metallic electrical conductivity, and possibly superconductivity; Alexander Levedahl: to investigate the high pressure-temperature behavior of hydrogen-containing ice materials known as hydrogen clathrates; Claire Barkett: follow-up on the earlier work of Jaqueline Rivera by synthesizing several solid solutions in the Fe_2O_3-Al_2O_3 system very close to the 1:1 $FeAlO_3$ composition; Maura James: to investigate high pressure clathrate formation in the H_2O-NH_2-H_2 ternary system with Stephen Gramsch and Maddury Somayazulu in an exploratory project to work out special techniques for sample loading and mapping the composition of the mixture inside the diamond anvil cell; Manchali Madurri: a study of H_2-crown ether complexes at high pressure that led to his being named a semifinalist in both the Intel and Siemens national science fair competitions; Jaqueline Rivera: development of a new room-temperature, solution-based synthesis method for solid solutions in the Fe_2O_3-Al_2O_3 solid solution system; Ari Benjamin: Equation of state of the fluorinated copolymer Kel-F 800 to near megabar pressures; Kevin Hernandez: Raman spectroscopy studies of e carbon dioxide-water system at high pressure; Tao Liu: Optical emission spectroscopy studies of MPCVD diamond growth; Louis Loubeyre: heterogeneity in the dynamics of methanol under high pressure; Juliana Mesa: Geochemistry of Fe stable isotopes – from planets to minerals; Maimon Rose: Investigating the electrocaloric piezoelectric effects in $LiNbO_3$ and PMN-PT using MD simulations; Viktor Rozsa: Pressure studies of hydrogen-loaded hydroquinone clathrate; Nichole Valdez: High pressure synthesis of Fe_2SiO_5; Kevin Hernandez (second internship): Reactivity at high pressure and temperature; Olivia Reyes-Becerra: Synthesis of single-crystal Na_4Si_{24} clathrate; Brandon Wilfong: In-situ

Raman spectroscopic investigation of relaxor multiferroic $Pb(Fe_{0.5}Nb_{0.5})O_3$ under high pressure and temperature conditions; Keenan Brownsberger: Synthesis of palladium hydrides at extreme conditions; Anne Davis: Phase transitions in silicon quantum dots for solar energy conversion; Reed Mershon: The role of oxygen fugacity in elemental fractionation between basaltic and sulfidic liquids.

Publications

The most recent publications are listed below. For a complete list of publications, see http://www.balzan.org/en/prizewinners/russell-j--hemley-and-ho-kwang-mao/research-project-russlel-mao and previous editions of the *Overview*.

Beck P, Goncharov AF, Montoya JA, Struzhkin VV, Militzer B, Hemley RJ, Mao HK. 2009. Response to "Comment on 'Measurements of the thermal diffusivities at high-pressure using a transient heating technique'." Applied Physical Letters. Volume 95, Issue 9.

Goncharov AF, Beck P, Struzhkin VV, Haugen BD, Jacobsen SD. 2009. Thermal conductivity of lower mantle minerals. Phys. Earth Planet. Inter. 174: 2432.

Liang Q, Chin CY, Lai J, Yan CS, Meng YF, Mao HK, Hemley RJ. 2009. Enhanced growth of high quality single crystal diamond by MPCVD at high gas pressures. Appl. Phys. Lett. 94: 024103.

Liang Q, Yan CS, Meng Y, Lai J, Krasnicki S, Mao HK, Hemley RJ. 2009. Recent advances in high-growth rate single-crystal CVD diamond. Diamond and Related Materials. Volume 18: 698-703.

Liang QC, Yan S, Meng YF, Lai J, Krasnicki S, Mao HK, Hemley RJ. 2009. Enhancing the mechanical properties of CVD single-crystal diamond. Journal of Physics: Condensed Matter. Issue 36.

Sun L, Yi W, Wang L, Shu J, Sinogeikin S, Meng Y, Shen G, Bai L, Li Y, Mao HK, Mao WL. 2009. X-ray diffraction studies and equation of state of methane at 200 GPa. Chem. Phys. Lett. 473: 72-74.

Wang L, Pan Y, Ding Y, Yang W, Mao WL, Sinogeikin SV, Meng Y, Shen G, Mao HK. 2009. High-pressure induced phase transitions of Y_2O_3 and Y_2O_3:Eu^{3+}. Appl. Phys. Lett. 94: 061921.

Wang L, Ding Y, Yang W, Mao WL, Liu W, Cai Z, Shu J, Shen G, Mao HK. 2009. Application of nano/submicron-focused x-ray probe for ultrahigh-pressure studies. High Pressure Synchrotron Science Workshop (Argonne IL, 6-8 May 2009).

Zeng QS, Ding Y, Mao WL, Luo W, Blomqvist A, Ahuja R, Yang W, Shu J, Sinogeikin SV, Meng Y, Brewe DL, Jiang JZ, Mao HK. 2009. Substitutional alloy of Ce and Al. Proc. Nat. Acad. Sci. 106: 2515-2518.

Zha CS, Krasnicki S, Meng YF, Yan CS, Lai J, Liang Q, Mao HK, Hemley RJ. 2009. Composite chemical vapor deposition diamond anvils for high pressure/high temperature experiments. High Pressure Research. Volume 29, Issue 2.