

Curriculum Vitae : Amol Karandikar

Contact Information	Earth and Planets Laboratory Carnegie Institution for Science 5241 Broad Branch Road NW Washington, DC 20015	Phone: +1 (202) 478 8993 Email: akaran@carnegiescience.edu Webpage: https://epl.carnegiescience.edu/people/karandikar
Education	Goethe University, Frankfurt am Main, Germany <ul style="list-style-type: none">• Ph.D., Natural Sciences, Sept. 2016 (<i>Magna cum Laude</i>)• Thesis Title: 'Development of the Flash-heating Method for measuring Melting Temperatures in the Diamond Anvil Cell'• Advisor: Prof. Dr. Björn Winkler, Supervisor: Dr. Reinhard Boehler University of Pune, Pune, India : M.Sc., Quantum Physics, Sept. 2000 <ul style="list-style-type: none">• Project topic: Study of Quantum Gates in Quantum computing• Advisor: Dr. P. S. Joag University of Mumbai, Mumbai, India : B. Sc., Physics, June 1997	
Academic Positions	Laser-heating & Spectroscopy Lab Manager Earth and Planets Laboratory Feb. 2024 - current Research Scientist Earth and Planets Laboratory Feb. 2021 - Jan. 2024 Geophysical Laboratory Feb. 2019 - Jan. 2021 Carnegie Institution for Science, Washington DC, USA Supervisor: Dr. Michael Walter Postdoctoral Research Associate Feb. 2017 - Jan. 2019 Geophysical Laboratory Carnegie Institution for Science, Washington DC, USA Supervisor: Dr. Reinhard Boehler, Dr. Timothy Strobel Doctoral Research Associate March 2010 - Sept. 2014 Geophysical Laboratory Carnegie Institution for Science, Washington DC, USA Supervisor: Dr. Reinhard Boehler Doctoral student Aug. 2009 - Sept. 2016 Department of Geoscience Goethe University, Frankfurt am Main, Germany Advisor: Prof. Dr. Björn Winkler Doctoral student, research employee March 2009 - Nov. 2009 High pressure Mineral physics department Max Planck Institute for Chemistry, Mainz, Germany Supervisor: Dr. Reinhard Boehler Scientific Officer Sept. 2002 - Nov. 2008 High Pressure Physics Division Bhabha Atomic Research Centre, Mumbai, India Trainee Scientific Officer Aug. 2001 - Aug. 2002 Raja Ramanna Centre for Advanced Technology, Indore, India	

**Work Experience/
Technical Expertise** Studies of phase transitions, melting, and synthesis of materials under high pressure using Toroidal anvil apparatus (6 GPa-1200K), Bridgman anvil apparatus (8 GPa), and laser-heated diamond anvil cell (LHDAC) apparatus (1 Mbar-5000K).

Experienced in probing electronic / ionic conductivity properties of materials using Toroid and Bridgman anvil apparatus. Handled various DAC types: Boehler-Almax, Mao-Bell, and membrane DAC.

Conversant with preparing and assembling DACs for 4-probe electrical measurements, and resistive heating.

Expertise in design and set up of near/far IR LHDAC facility. Probes used: Raman, Brillouin, and IR-absorption spectroscopy. Synchrotron methods - X-ray diffraction (XRD), absorption spectroscopy (XAS), and inelastic scattering (IXS) for the DAC research. Involved in optical alignment and calibration for optimizing temperature measurement at 16 ID-B beamline dedicated to LHDAC research at APS (USA).

Experienced user of the XRD beamlines at synchrotron facilities - Elettra (Italy), ESRF (France), PETRA (Germany), and APS (USA).

Experienced in developing Graphic User Interface (GUI) in Labview for instrument control at the XRD1 beamline Elettra (Italy), and at the Earth and Planets Laboratory (USA).

Experienced in Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDX), and Focused Ion Beam Milling (FIBM) to prepare/characterize/analyze samples.

Software capability *Labview* for developing GUI for instrument control; *Autocad* for machine drawing; *Origin*, *Veusz*, *Igor-Pro* for plotting; *Dioplas*, *GSAS*, *fit 2d* for XRD analysis; *LaTeX* for manuscript editing. Currently learning *Python*.

Selective Research

- **Tunable thermal expansion materials**
Low/Negative thermal expansion (LTE/NTE) materials have potent use in synthesizing tunable thermal expansion materials. Under pressure, most of these materials (ZrW_3O_{12} , $NbOPO_4$, $HfMo_2O_8$, $ZrMo_2O_8$) amorphize, losing their NTE property. Using XRD, and Raman spectroscopy, I studied their compression-path through phase transitions to amorphization, and heating thereafter. The amorphization was attributed to kinetic hindrance to a phase transition/decomposition, in contrast to LTE ceramics having energetically favored amorphized state.

- **Development of flash-melting method**
Measuring melting temperatures (T_{melt}) in LHDAC is challenging due to difficulties like chemical reactions, sample instability, and thermal

runaway. Using rectangular shaped laser-pulses of milliseconds duration, with analysis using optical images, SEM, EDX, and FIBM techniques to characterize the melt texture, I developed 'flash-melting' method that circumvents these problems. Melting curves of Re, Mo, and Ta have been measured using this method. The method is robust, accurate within ± 100 K, with reproducible results.

- **Development of a novel encapsulation for melting experiments**

The ultimate method to measure T_{melt} at extreme pressures is to be able to contain the material in liquid state inertly and probe the structure. Using FIBM technique, I developed novel insulating, inert encapsulations for synchrotron XAS to measure T_{melt} of iron at Megabar pressures in LHDAC. These encapsulations maintain uniform sample thickness within the X-ray beam - a crucial requirement for XAS - during compression and heating, allowing very first of this kind of measurement.

Recent Research

- Using XRD to detect onset of melting from diffuse scattering signal and measure T_{melt} in a LHDAC is challenging due to sample dispersion and stringent alignment of X-ray, heating laser, and optical probe. I am using flash-melting synchronized with 0.1-10 ms XRD of samples (8-10 μm dia, 5-6 μm thin) contained in inert encapsulation to detect the melting onset. Beamlines used : 16 IDB and 13 IDD at APS (USA).

- Melting diamond at high pressure is challenging due its high thermal conductivity and predicted high T_{melt} . It is fundamentally interesting due to a maximum in its melting curve, and yet to be observed BC8 phase. The only available data is above 600 GPa from shock experiments. Using Re as a coupler and flash-melting method with SEM, EDS analysis using FIB, I have attempted to measure T_{melt} in 20-50 GPa range using LHDAC.

Development work

- Set up a user friendly, double sided LHDAC facility at the Earth and Planets Laboratory, DC, USA. It will facilitate CW and modulated laser heating, with 1 μm and 10 μm laser wavelengths. The temperature will be measured by spectroradiometry and 2-d temperature maps of the sample assembly will be created by 4-color method. The 10 μm laser-heating will be coupled with Brillouin Spectroscopy set up.

- Set up a user friendly facility to perform Raman spectroscopy for DAC research. The user can choose a combination of the laser excitation wavelengths (473 nm or 660 nm), and magnification (20x or 50x) as needed simply by pushing buttons.

- Set up a 'Laser levitation' facility that produces spheres (diameter < 2 mm) by homogeneously melting sample chunks levitating on a gas flow. Spheres thus produced are pure and are a prerequisite for elemental rock analyses, and experiments involving evaporation/reduction, metal-silicate partitioning, and solubility of metals in melt.

- I have set up a facility to measure pressure in DAC using Ruby fluorescence spectroscopy and diamond-edge Raman spectroscopy.

- Responsibilities**
- Set up optics needed for conducting research in collaboration or independently.
 - Train PhD/post doctoral fellows, collaborators in using existing laser-spectroscopy facilities and supervise laser-heating experiments.
 - Supervise, maintain, and improve safety protocols regarding research employing laser radiation, as a member of the safety committee.

- Research Grants**
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| Postdoctoral Research Associate | Feb. 2018 - Jan. 2019 |
| Washington Diamond® grant. Carnegie Institution for Science, DC, USA | |
| Postdoctoral Research Associate | Feb. 2017 - Jan. 2018 |
| U.S. Department of Energy, Office of Science under Award Number DE-SC0001057 EFree(I), Carnegie Institution for Science, DC, USA | |
| Doctoral Associate | July 2014 - Sept. 2014 |
| NSF grant (Dr. R. Boehler). Carnegie Institution for Science, DC, USA | |
| Doctoral Associate | April 2014 - June 2014 |
| Carnegie-DOE Alliance Center, Grant DE-NA0002006 | |
| Doctoral Associate | Oct. 2010 - March 2014 |
| U.S. Department of Energy, Office of Science under Award Number DE-SC0001057 EFree(I), Carnegie Institution for Science, DC, USA | |
| Doctoral candidate fellowship | March 2009 - Sept. 2010 |
| Max Planck Institut für Chemie, Mainz, Germany | |

Talks given

1. Methods for detecting metal melting in Diamond Anvil Cell
[2011 Jan 07, Geophysical Laboratory, Carnegie Institution of Science, Washington D.C., USA]
2. Phonon Dispersion Curves of Gadolinium at High Pressures from Single Crystal Inelastic Xray Scattering in Diamond Anvil Cell
[2011 Sept 28, AIRAPT - 23 International Conference, Mumbai, India]
3. Limits of material stability: melting of refractory materials
[2012 Apr 3, EFree mid-term review, Baltimore, USA]
4. Flash heating in diamond cell: *Melting curves of rhenium and molybdenum*
[2012 June 24-29, Gordon Research Conference, Biddeford, New England, USA]
5. Flash heating in diamond cells: Melting of refractory metals
[2014 Sept 24, EFree Highlight Talk, Carnegie Institution of Science, Washington D.C., USA]
6. Bonds to Bands
[2017 Dec 01, Geophysical Laboratory, Carnegie Institution of Science, Washington D.C., USA]

Publications

10. *Melting diamond in the diamond cell by laser-flash heating.*
[[High Pressure Research 43 \(2023\) 1](#)]
L. Yang, A. Karandikar, T. Shiell, B. Cook, S. Wong, M. Field, J. Bradby, B. Haberl, D. McCulloch, R. Boehler.
09. *Latent heat method to detect melting and freezing of metals at megabar pressures.*
[[Physical Review Materials 5 \(2021\) 033803](#)]
Z. Geballe, N. Holtgrewe, A. Karandikar, E. Greenberg, V. Prakapenka, A. Goncharov.
08. *Flash melting of tantalum in the diamond cell to 85 GPa.*
[[Physical Review B 93 \(2016\) 054107](#)]
A. Karandikar, R. Boehler
07. *Melting of iron determined by X-ray absorption spectroscopy to 100 GPa.*
[[Proceedings of National Academy of Sciences 112 \(2015\) 12042](#)]
G. Aquilanti, A. Trapananti, A. Karandikar, I. Cantor, C. Marini, O. Mathon, S. Pascarelli, R. Boehler
06. *High P-T Brillouin scattering study of H₂O melting to 26 GPa.*
[[High Pressure Research 34 \(2014\) 327](#)]
M. Ahart, A. Karandikar, S. Gramsch, R. Boehler, R. J. Hemley
05. *Flash Heating in the Diamond Cell: Melting Curve of Rhenium.*
[[Review of Scientific Instruments 83 \(2012\) 63905](#)]
L. Yang, A. Karandikar, R. Boehler.
04. *Microscopic evidence of a flat melting curve of tantalum.*
[[Physics of Earth and Planetary Interiors 181 \(2010\) 69](#)]
J. Ruiz-Fuertes, A. Karandikar, R. Boehler, D. Errandonea
03. *Amorphization and structural evolution of α -HfMo₂O₈ and its high density polymorph β -HfMo₂O₈ at high pressures.*
[[Journal of Physics and Chemistry of Solids 69 \(2008\) 35](#)]
G. D. Mukherjee, A. Karandikar, V. Vijayakumar, B. K. Godwal, S. N. Achary, A. K. Tyagi, A. Lausi, E. Busetto.
02. *Pressure evolution of resistance in framework structured materials α -ZrMo₂O₈ and α -HfMo₂O₈.*
[[Journal of Applied Physics, 100 \(2006\) 13517](#)]
A. Karandikar, G.D. Mukherjee, V. Vijayakumar, B.K. Godwal, S.N. Achary, A.K. Tyagi.
01. *Compressibility anomaly and amorphization in anisotropic negative thermal expansion material NbOPO₄ under pressure.*
[[J. Solid State Chemistry, 178 \(2005\) 8](#)]
G.D. Mukherjee, V. Vijayakumar, A. Karandikar, B.K. Godwal, S.N. Achary, A.K. Tyagi, A. Lausi, E. Busetto.

Academic personnel references

Dr. Michael Walter

Director
Earth and Planets Laboratory
Carnegie Institution for Science, USA
*Relation: Supervisor at work
(2019 - present)*

Dr. Timothy Strobel

Staff Scientist
Earth and Planets Laboratory Laboratory
Carnegie Institution for Science, USA
*Relation: Scientific colleague at work
(2010 - present)*

Dr. Reinhard Boehler

Staff Scientist
Spallation Neutron Source, Neutron Science
Oak Ridge National Laboratory, USA
Relation: Supervisor/collaborator (2009-present)

Prof. Dr. Björn Winkler

Abteilung Kristallographie, FE Mineralogie
Johann W Goethe-Universität, Germany
*Relation: Official Adviser/guide for the
doctoral thesis (2009 - 2016)*

Dr. Madduri Somayazulu

Group Leader
HPCAT, X ray Science Division
Advanced Photon Source, ANL, USA
*Relation: Scientific colleague at the
Geophysical Laboratory (2010 - 2017)*

Dr. Goutam Dev Mukherjee

Professor
Physical Sciences Department
IISER Kolkata, India
*Relation: Supervisor at work at
B.A.R.C., Mumbai, India (2002-2008)*
