High Pressure and Temperature Polymorphism of a Key Super-Earth Mantle Material: MgO

June Wicks, Johns Hopkins University
Thank you to previous NLUFs

Thank you to the continued support of the NLUF program to T. Duffy, Princeton University, DE-NA0002154 and DE-NA0002720. which launched my career.
Thank you to previous NLUFs

... the first preliminary data for the decaying shock experiments of MgO were collected during Prof. Tom Duffy’s NLUF experiments.
High pressure x-ray scattering techniques to better understand atomic mobility, electronic bonding changes in planet-forming materials.

Supported by NNSA:
Connor Krill, BS’19
Zixuan Ye, 2nd-year PhD student
Dr. Melissa Sims, postdoctoral scholar
Dr. Vinay Rastogi, postdoctoral scholar
The Wicks Lab . . . bringing extreme to the Hopkins Extreme Materials Institute (HEMI) since fall 2017.

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The Wicks Lab... benefits from national lab collaborations

Dr. Raymond Smith, LLNL
Dr. Martin Gorman, LLNL
Dr. Marius Millot, LLNL
Dr. Federica Coppa, LLNL
MgO: a building block of terrestrial planets

- B1-B2 transition at ~500 GPa
- Dissociation of MgSiO$_3$ into MgO + MgSi$_2$O$_5$ /SiO$_2$
- Viscosity changes?
- Clapeyron slope?
Constraints on MgO phase diagram
Two complementary shock studies of the MgO Hugoniot
Velocimetry comes in the following flavors:
- Photon doppler velocimetry (pdv)
- Point VISAR
- Line VISAR
- 2-d VISAR

VISAR diagnostic

(Velocity Interferometry System for Any Reflector)

Samples are accelerated to velocities up to 25 km/s

VISAR interferometer encodes Doppler shifted phase into fringe movement

Streak camera is used to resolved fringe movement in time

For more, see: Barker et al., JAP 1972; Celliers et al., RSI 2004
Streaked optical pyrometer (SOP) at the OMEGA laser

Dylan Spaulding, PhD thesis 2010

For more information on calibration, see Gregor et al., Rev Sci Inst 2016.
X-ray Diffraction

Access to *in situ* crystal structure information is revolutionizing the field of dynamic compression.


Tracy et al., 2018.
MgO as a fundamental solid, II

What makes an analog system useful? When do the periodic table trends stop working, and why?

NaCl

LiF

MgO

Li&Li, Am Min, 2015

Smirnov, 2011

Du and Lee, 2014
NaCl - our favorite low-pressure analogue of MgO
Paired X-ray diffraction and pyrometry measurement of the MgO shock Hugoniot

Preceding NLUF work on MgO [100]: A proof of B1-B2 transition behind this big temperature excursion on the Hugoniot.

Adapted from Wicks et al., in prep

442 GPa
Paired X-ray diffraction and pyrometry measurement of the MgO shock Hugoniot

Wicks et al., in prep
This NLUF cycle-- ¼ complete

Explore the orientation dependence of MgO phase transitions

FY 20 (2 days on Omega EP)
- Shock decay studies of MgO [110] and [111] single crystals.
- Combined steady-shock and nanosecond x-ray diffraction study of shock compressed MgO [111] and [110] single crystals, as a function of pressure.
- Detailed analysis of experimental data.
- Presentation of data at National Meetings.

FY 21 (2 days on Omega EP)
- Double-shock compression of MgO [100] to determine the B1-B2 Clapyron slope.
- Extended 30-ns laser drive to directly measure phase transformation kinetics within shock compressed MgO [100].
- Publication of the FY20 data in peer reviewed journals.
- Detailed analysis of FY21 data.
- Presentation of data at National Meetings. Preparation of FY21 data for publication within the following year.
MgO decaying shock studies - *Orientation dependence*

Observation of orientation-dependence of phase transitions observed in temperature measurements along the Shock Hugoniot.

See poster NLUF-6 on *Phase Transformations of MgO under shock compression*

Zixuan Ye, Phd student
Observation of orientation-dependence of phase transitions observed in temperature measurements along the Shock Hugoniot.

Zixuan Ye, Phd student
We are making changes to the x-ray illumination geometry to expand our azimuthal coverage and data access.

Preliminary experiments on MgO [110] at 530 GPa shows a difference in texture in the coexistence of B1 and B2 phase.

Lots to do before our next ½ day in July.
Thank you!

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Proxima Centauri b
M. Kornmesser