X-ray diffraction measurements of shocked and shock-ramped platinum

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Summary

X-ray diffraction is used to measure the phases and constrain the melt curve of Pt shock- and ramp- compressed to ~500 GPa

- We investigate both a predicted phase transition and the melt curve of platinum
- Pt remains in the face-centered cubic (fcc) phase when ramp compressed to 530 GPa (with initial shocks between 72 – 250 GPa)
- The melt line is constrained with an observation of liquid platinum at 490 GPa on the principal Hugoniot

Work shown on title slide:
S. Crockett, LANL
We investigated two aspects of the platinum phase diagram: the melt curve and a possible solid-solid phase transition.

**Motivation**

We will be exploring the Pt melt curve up to 490 GPa.

**Previous work**

- Hugoniot
- Observed dispersion feature
- Predicted melt curves

**Z-machine velocity history**

- Initial shock compression to 85 GPa
- Velocity dispersion and a decrease in contrast suggest a phase transition at 150 GPa

**Graphs**

- Temperature vs. Pressure
- Velocity vs. Time

-a. Liquid
-fcc: face-centered cubic
-rhcp: randomly oriented hexagonal close packed

1. S. Crockett, LANL
2. C. Seagle, SNL
Precursor shocks are used to bring Pt into the region of interest of the SNL experiments.

First shock sets the system entropy.

The ramp sets the final pressure.

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Shock-ramp technique

S. Crockett, LANL
R. Kraus, LANL, pulse design
SNL: Sandia National Laboratory
The powder x-ray diffraction image plate platform (PXRDIP*) records the diffraction pattern of the compressed sample.

VISAR* tracks a particle or free surface velocity to infer the pressure in the sample at the time it is probed with x-rays.

**Target Package**

- Ablator (Be or CH)
- Pusher (Al or none)
- Platinum
- Window (LiF or diamond)

**VISAR/SOP**

**Shock – Ramp Technique**

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<th>Be</th>
<th>Pt</th>
<th>LiF</th>
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<th>CH</th>
<th>Pt</th>
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**Shock Technique**

- Laser drive (TW)
- Interface velocity (km/s)
- Time (ns)

**X-ray source (TW)**

*Velocity Interferometer System for Any Reflector*
The crystal structure and density of the compressed solid platinum is obtained from the diffraction pattern.

- Ambient Pt diffraction from the pinhole provides geometric calibration of the image plates.
- Compressed Pt that remains solid produces a shift in the fcc pattern.

Temperature is obtained from the SESAME EOS isentrope at the pressures inferred from velocimetry measurements.

fcc: face-centered cubic
We observed face-centered cubic platinum in the region of the Sandia experiment and no evidence of other solid structures.

Shock-ramp Results

![Graph showing Shock-ramp Results](image)

1. S. Crockett, LANL
A single broad diffraction line, seen among the ambient platinum, is the signature of diffuse scattering from a liquid.

- Analysis of the liquid structure will provide density and coordination number of the liquid phase.

fcc: face-centered cubic
The data was fit to a series of Gaussian functions to quantify liquid scattering

\[ I = a_1 e^{-(x-a_2)^2/2a_3^2} + 0.2a_1 e^{-(x-a_2)^2/2(0.5)^2} \]

- Each solid peak can be described as two Gaussians with three free parameters: amplitude, centroid location, and width.
- A single Gaussian is used to fit the liquid scattering feature

Strong shocks (~500 GPa) were used to observe melting along the Hugoniot.
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Melt curves

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- rhcp: randomly oriented hexagonal close packed

Experiments
- Strong and Bundy (1959)
- Mitra, et al. (1967)
- Kavner and Jeanloz (1998)
- Boehle (1992)
- Errandonea (2013)
- Liu, et al. (2010)
- Geballe (2021)

Theory
- Belonoshko and Rosengren (2012)
- Kavner and Jeanloz fit
- Burakovsky (2014)
- Jeong & Chang (1999)

 predicted melt curves

Pressure (GPa)

Temperature (K)

Hugoniot
The crystal structure of the compressed platinum is inferred from the diffraction pattern.