Laser Compression of Tantalum: Experiments, Analysis, and Simulation

Chia-Hui Lu

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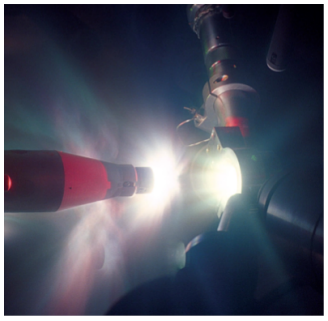

2nd Omega Laser Facility User Group Workshop

2010.4.29 Rochester, NY

Collaborators

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UC San Diego

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Outline

- Research objective
- Experimental Setup
- Characterization
  - Profilometry
  - Scanning Electron Microscope (SEM)
  - Transmission Electron Microscope (TEM)
  - Micro-Hardness test
- Simulation
- Conclusions and Future Work

Research objectives

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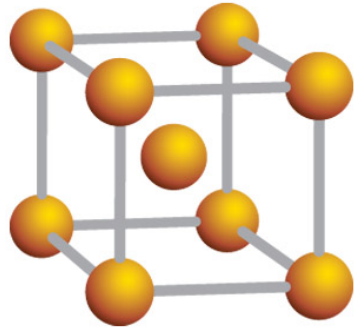
- **Investigate the response of laser compression BCC materials**
  - **Dislocation configuration and density**
  - **Transition pressure from dislocations to twinning**
  - **Microstructure and micro-hardness**



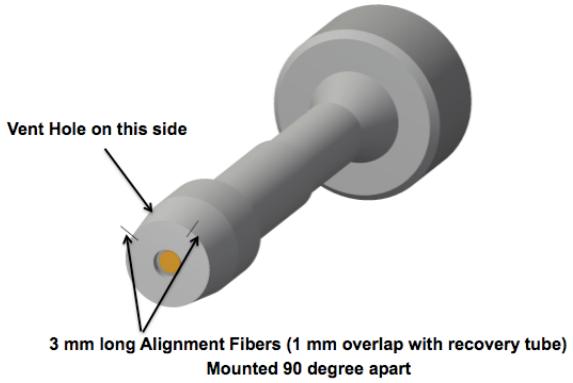
- **Take Tantalum as a model material**

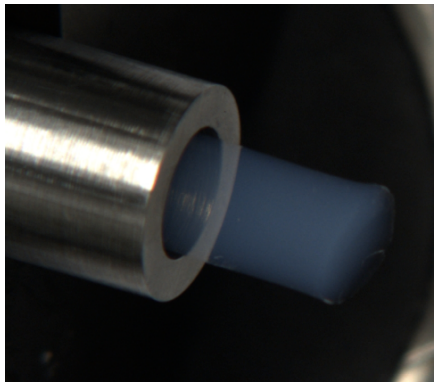
- **Laser source:**
  - **Laboratory for Laser Energetics (LLE), University of Rochester**

http://www.lle.rochester.edu/

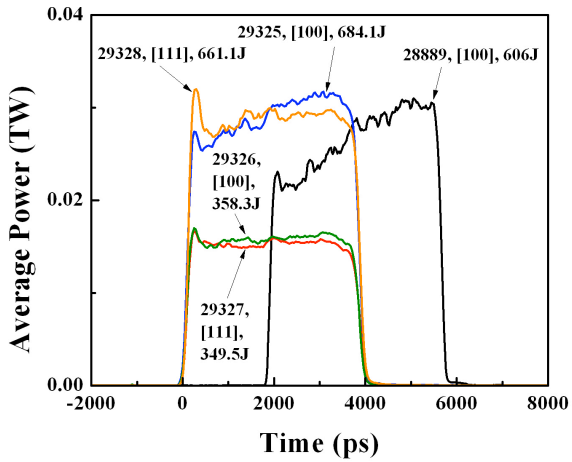
Experimental Setup

- **Experimental recovery setup for laser shock experiments**





RID	Crystal Orientation	Momentum Cap?	On-target energy (UV, recovery)
28889	100	No	606.0
29325	100	No	684.1
29326	100	Yes	358.3
29327	111	No	349.5
29328	111	No	661.1



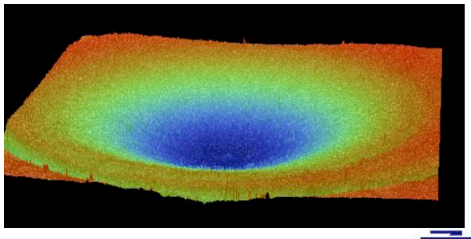
Pulse duration ~ 3.7 ns

VISAR measurements

B. R. Maddox, R. Luo

Characterization

Profilometry



Veeco

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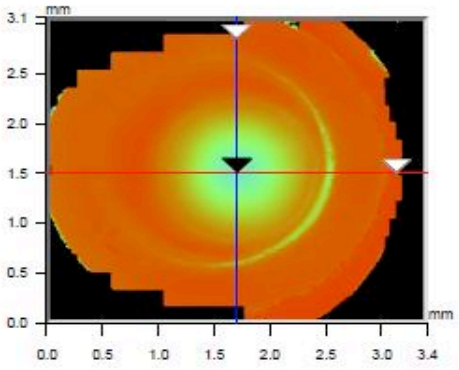
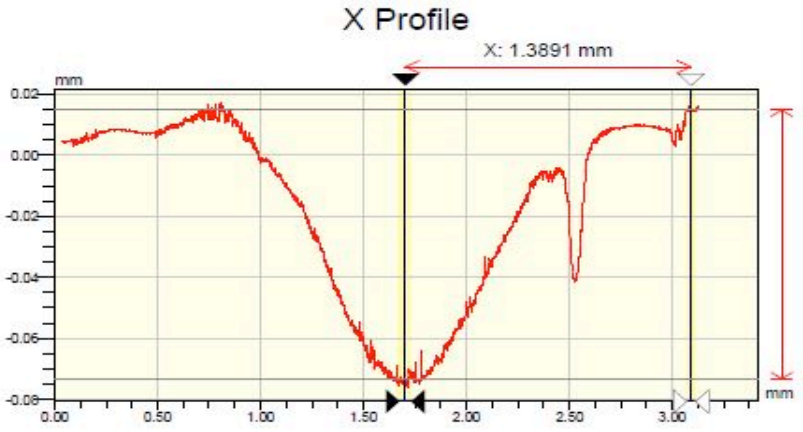
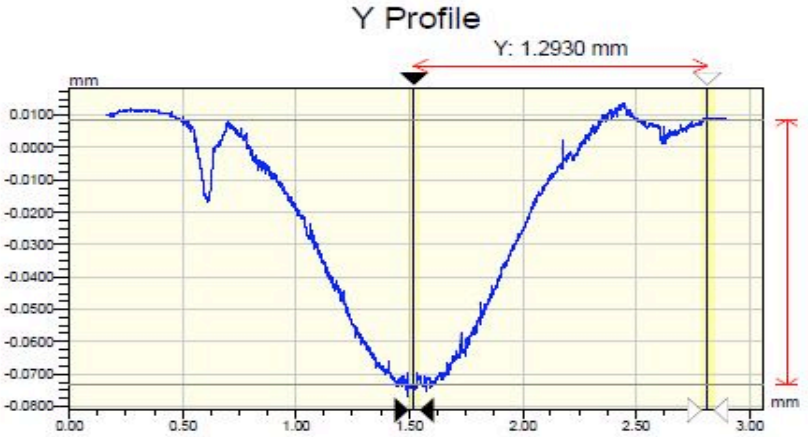
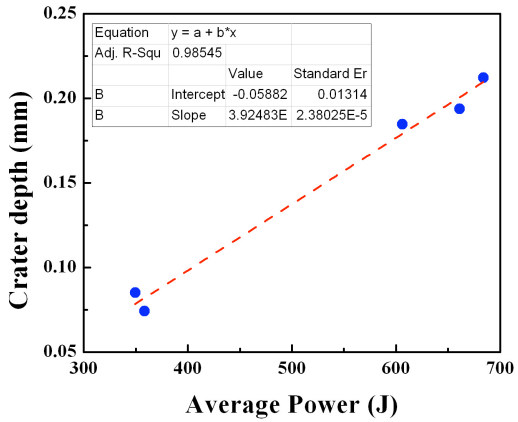


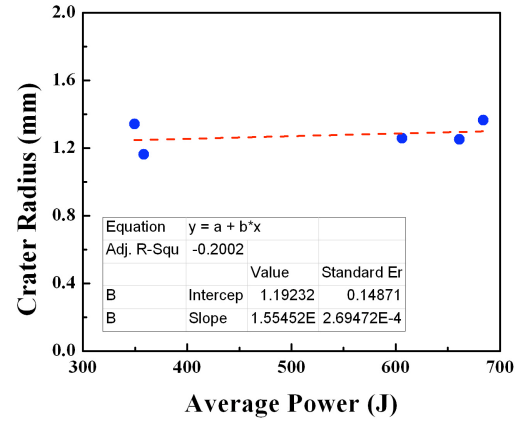
X	1.70	-	-	mm
Y	1.51	-	-	mm
Ht	-73.95	-	-	um
Dist			-	mm
Angle			-	°

Title:





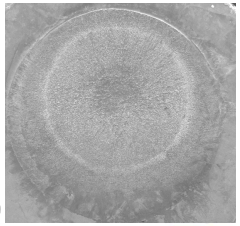




R. Luo, C. H. Lu

Characterization

Scanning Electron Microscope (SEM)



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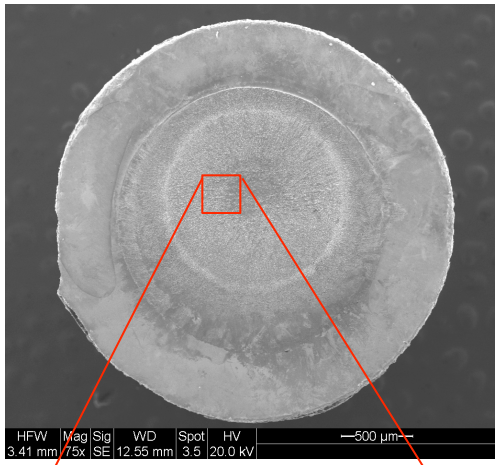
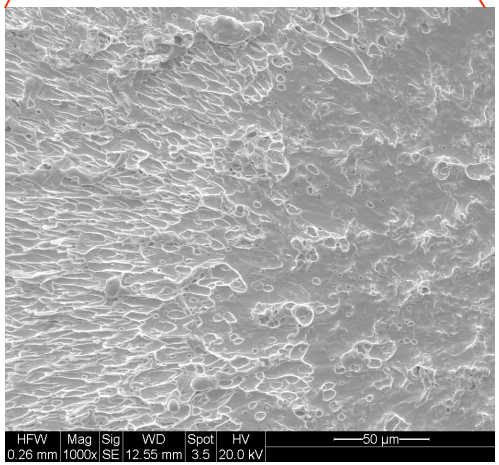
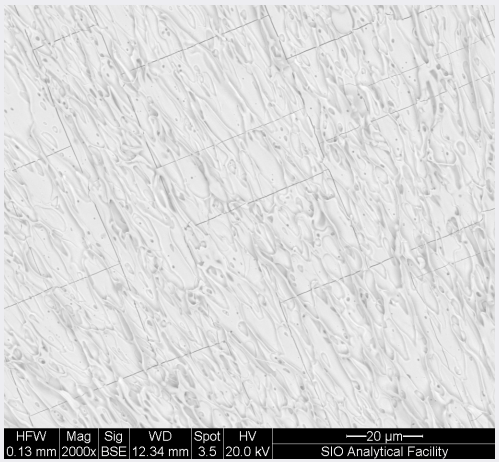
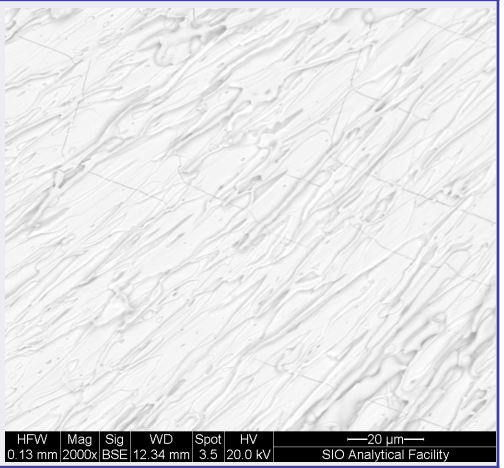
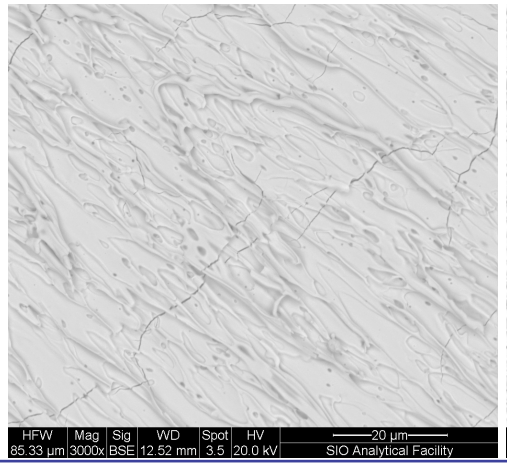
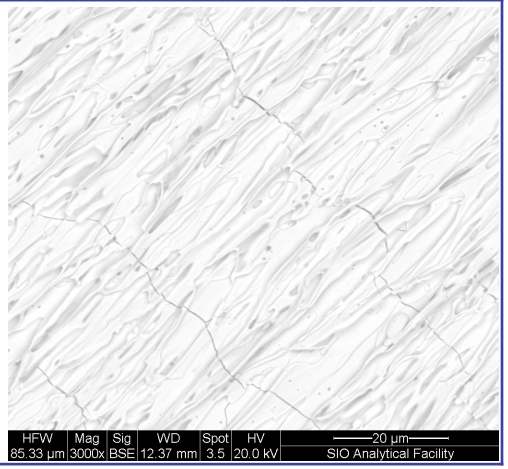
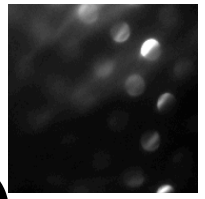




BSE	35 GPa	150 GPa
[100]		
[111]		

Characterization

Transmission Electron Microscope (TEM)



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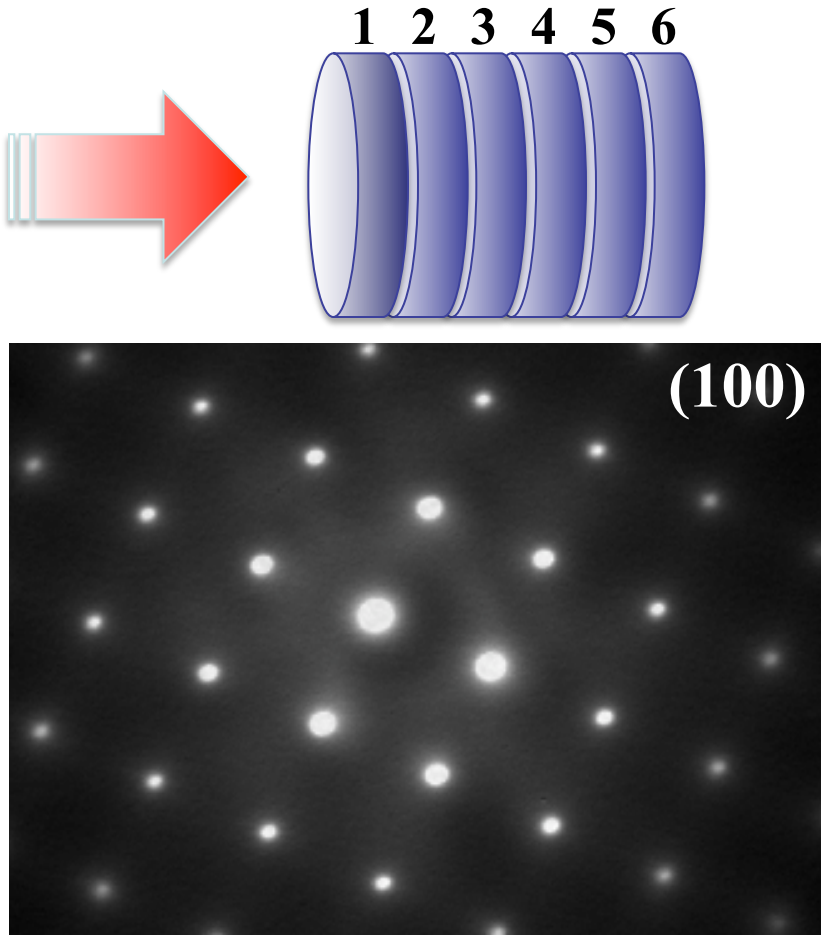
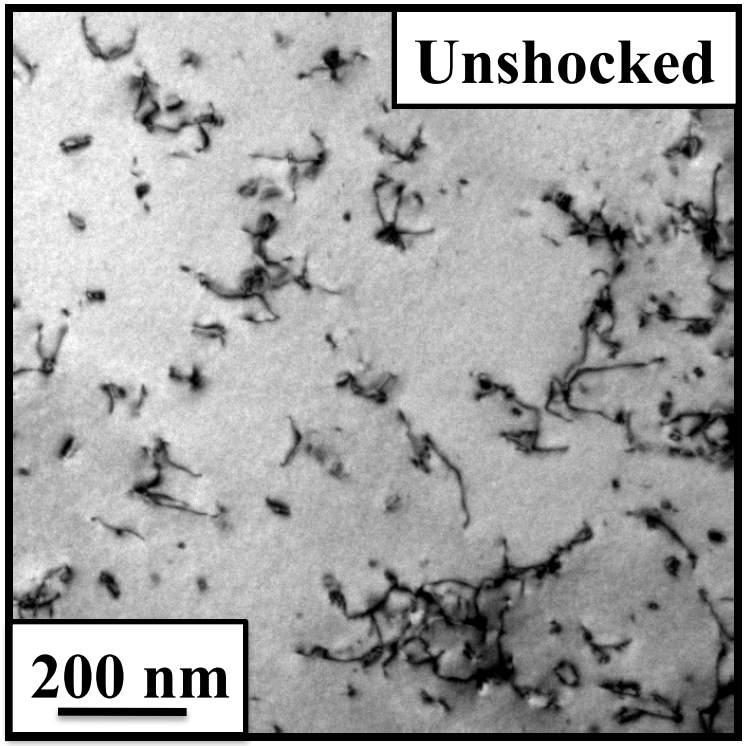
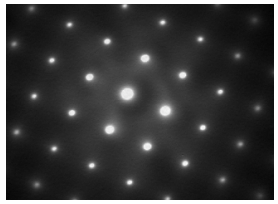




TEM Results



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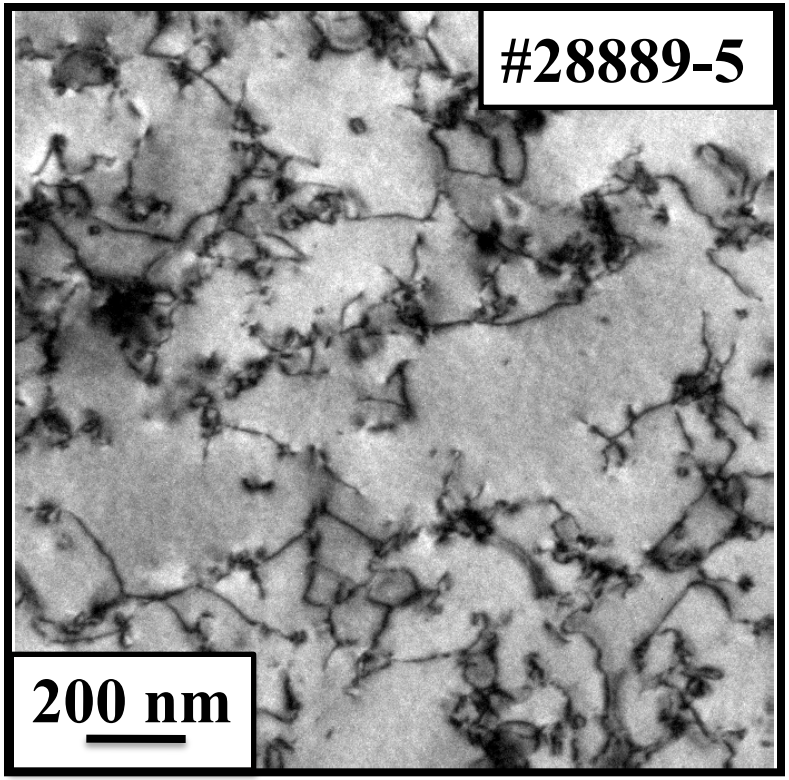
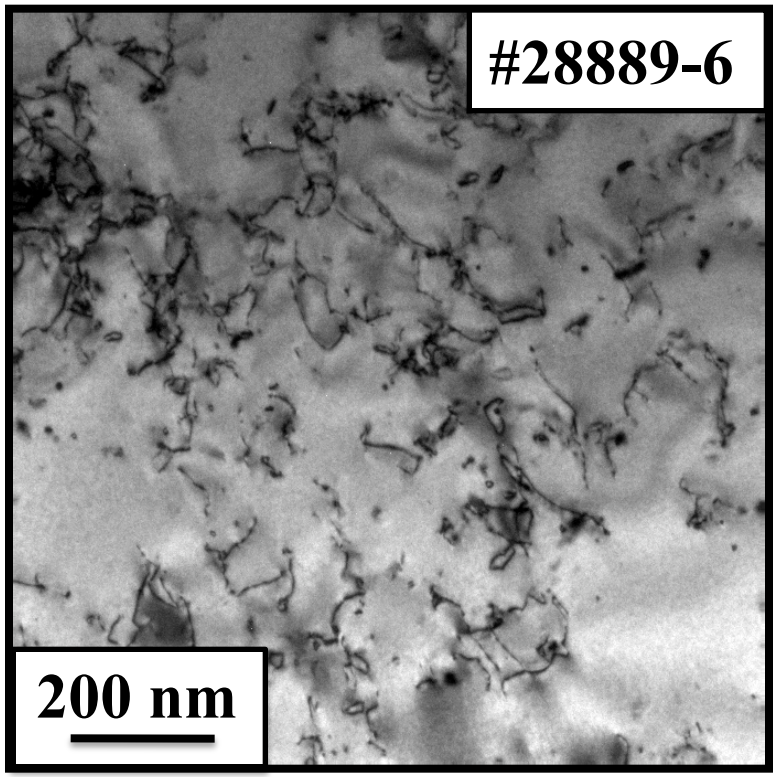
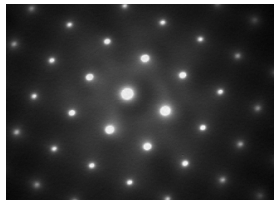




TEM Results



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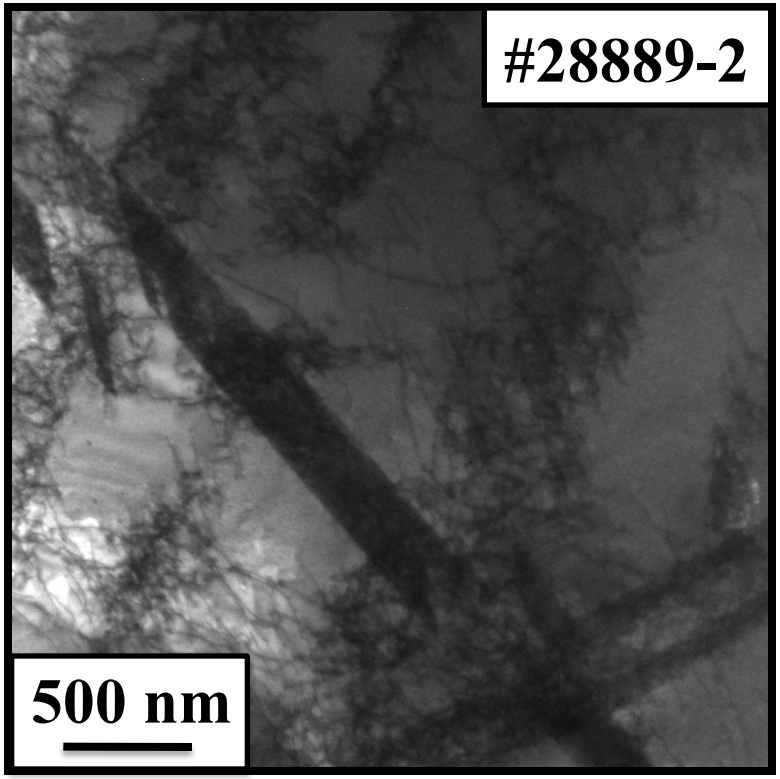
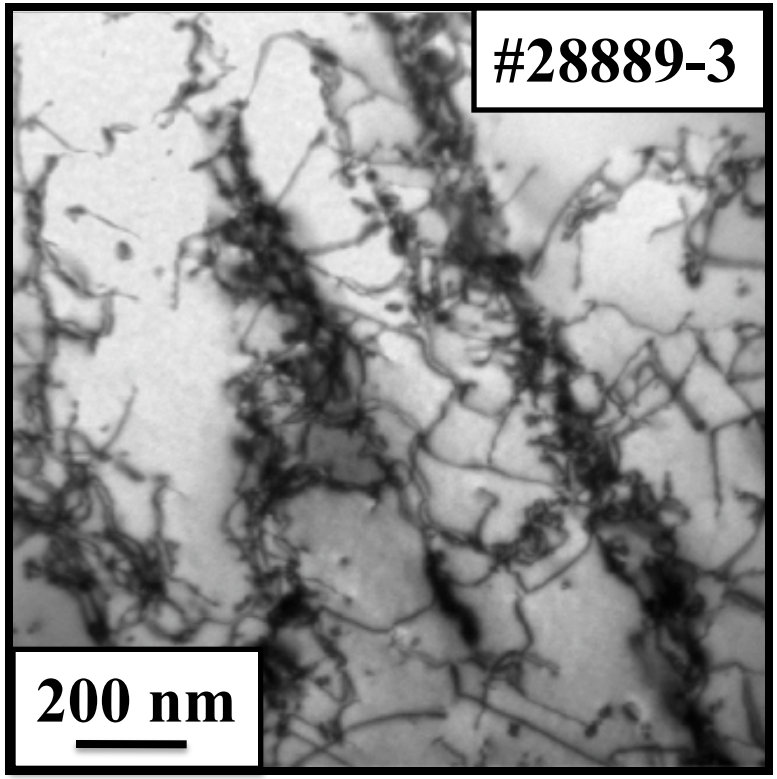
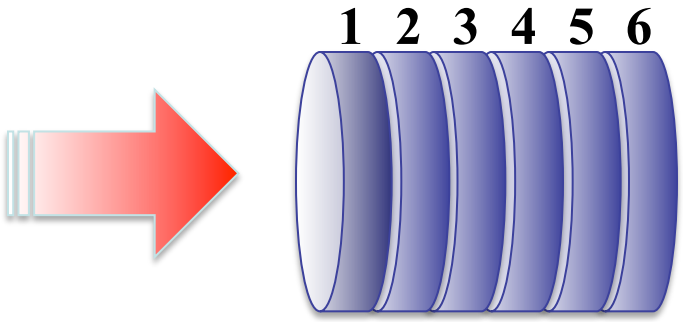
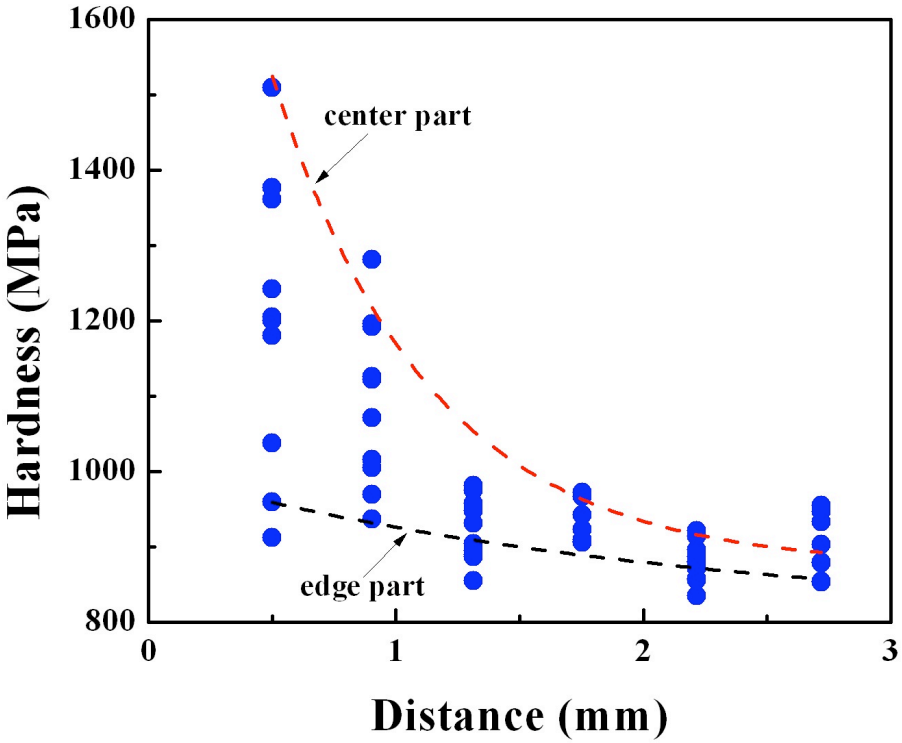


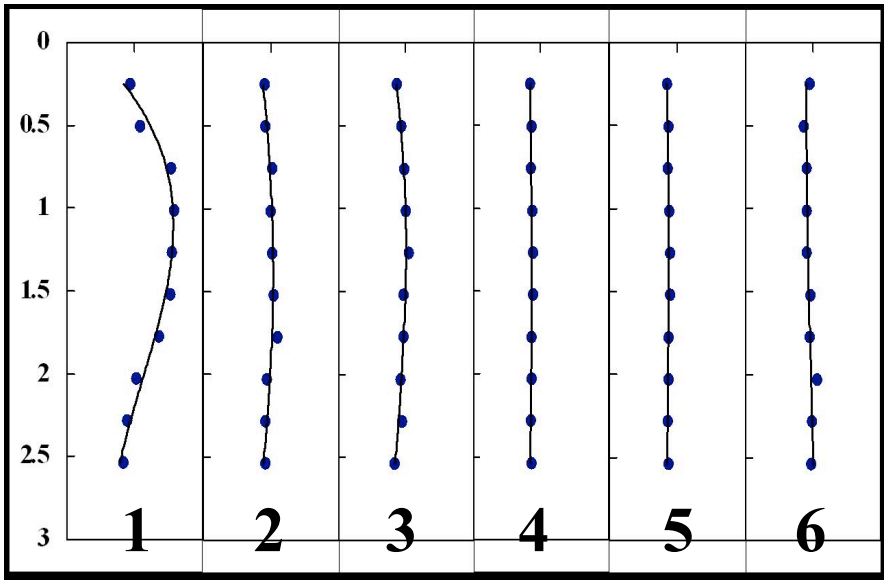


Characterization

Micro-Hardness

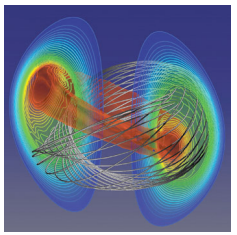






LECO DM-400 hardness tester was used

Analysis
Slip-Twinning Transition Pressure



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Swegle-Grady Relationship for Ta: $\dot{\varepsilon} = 27.34 \times 10^{-36} P_{Shock}^{4}$

Slip:

$$\sigma_S = \sigma_s^* + C_2 e^{-C_3 T} \dot{\varepsilon}^{C_4 T} + k_S d^{-1/2} = athermal \;\; stress + C_2 e^{-C_3 T} \dot{\varepsilon}^{C_4 T} + k_S d^{-1/2}$$

Shear Modulus:

$$G = G_0 \left(1 - \alpha \frac{T}{T_m}\right)$$

Temperature Rise function:

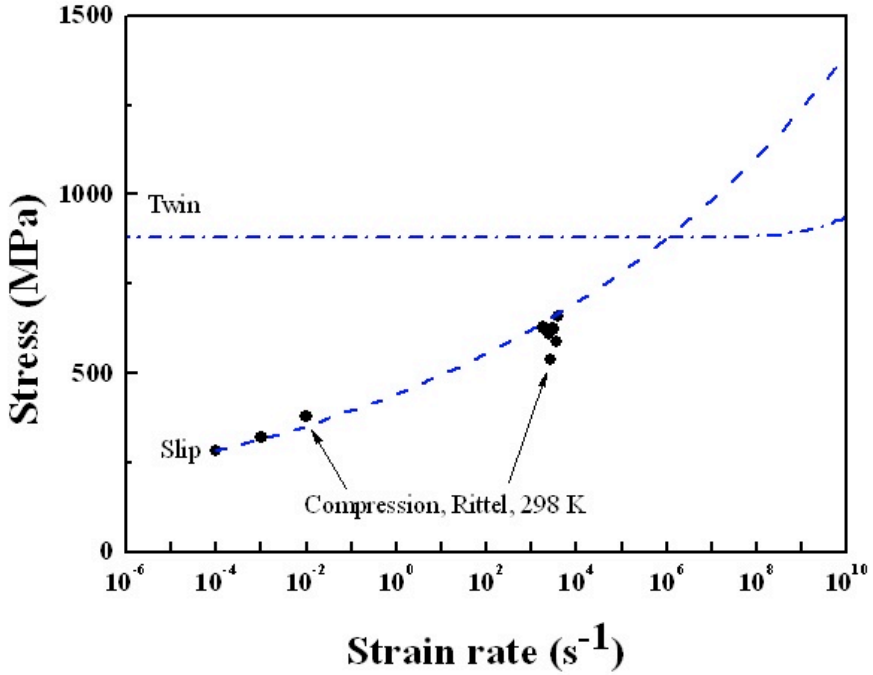
$$T_{Shock} = 1.007 \times 10^{-19} P_{Shock}^2 - 1.13 \times 10^{-9} P_{Shock} + 294.8$$

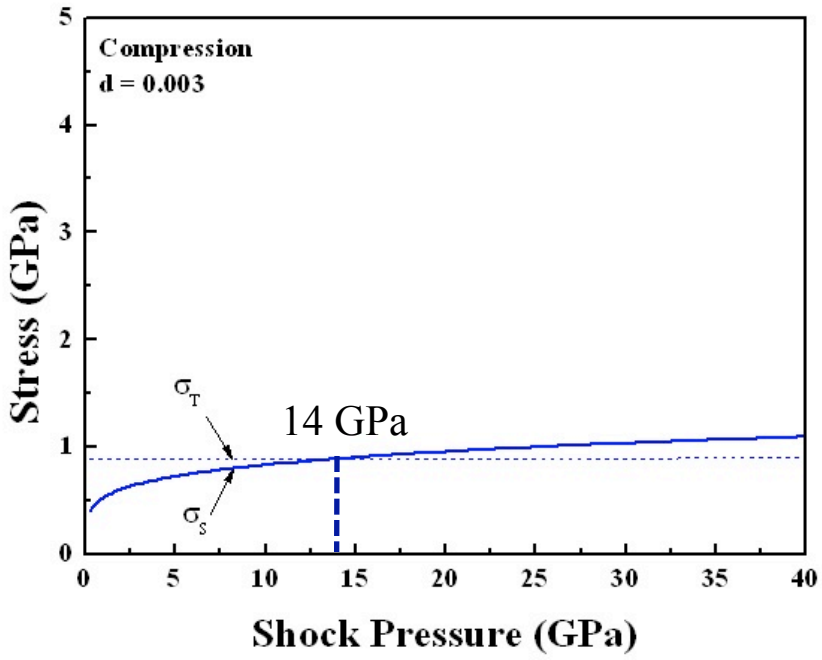
Twin:

$$\sigma_T = k \left(\frac{\gamma_{st}}{Gb}\right)^{1/2}$$

M. A. Meyers, Metallurgical & Mat. Trans. A, Vol. 39 A, Feb, 2008
L. E. Murr, Acta mater, Vol. 45, No. 1, pp. 157-175, 1997
D. L. Preston, Solid State Commun, Vol. 81, No. 3, pp.277-281, 1992

Modeling Results





D. Rittel, Mechanics of Materials 41 (2009) 1323-1329

Conclusions and Future Work

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- **Conclusions:**
  - Crater depth depends on laser energy while crater radius does not.
  - Dislocation activity decreases away from impact surface in all cases, in agreement with the hardness distribution.
  - Modeling revealed that the strain rate for slip-twinning transition is about 14 GPa for single crystal Ta.
- **Future work:**
  - Incorporate nanocrystalline Tantalum both experimentally and computationally. In depth dislocation analysis to be carried out to identify underlying mechanisms.

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~ Thank you ~

Questions & Discussion