Laser Induced Spall in Tantalum

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Research Motivation

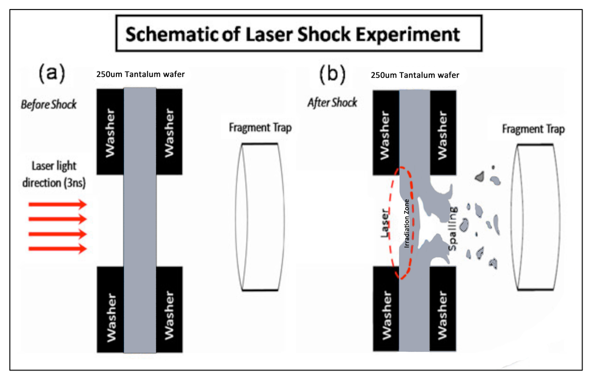
- Tantalum is used in the NIF targets and diagnostics (pinhole substrates, filters, shields, etc)
  - Important to study spall to know the potential effects it can have on the optics, diagnostics, and shields
- Tantalum is also used in military defense applications
  - Need to understand how the strength of tantalum differs in shock compression and release, between nano, poly and single crystal
  - Can assess the strength of the crystals by studying spall

Sample Preparation and Experimental Process

Mechanically polished tantalum samples on one side to a thickness of 250 um. Glued 20 um of polystyrene as a heat shield onto the polished side of the sample.

20 um Polystyrene +/- 2 um

3 mm diameter 250 um thick Ta single xtal, polycrystal, nanocrystal (UCSD)



Laser shocked samples at Janus over a range of shock strengths to create a series of spall results in the samples progressing from incipient to complete spall

Example of Laser Shock Experiment Conditions

Ta Sample Type	Thickness (um)	Laser Area (mm^2)	Pulse Length (ns)	Laser Energy (J)
nano	248	1.69	3	112.8
nano	254	1.69	3	73.7
poly	245	1.69	3	60.3
single (111)	253	1.69	3	60.1

SEM image and CT scan all samples after laser shock to examine grain and void growth

Determine spall strength in the nano, poly and single crystals using the VISAR pull-back signals and spall thicknesses

Surface Morphologies

Nanocrystalline

Laser energy at 112 J:

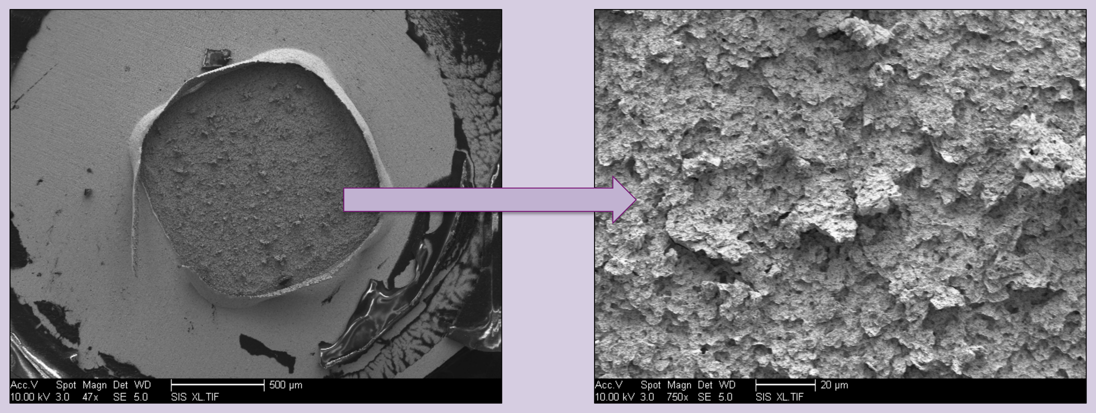


Fig 1. At high laser energy the nanocrystalline sample completely spalled. Grain size in the region of spallation could not be determined due to the large dimpling size on the surface.

Laser energy at 75 J:

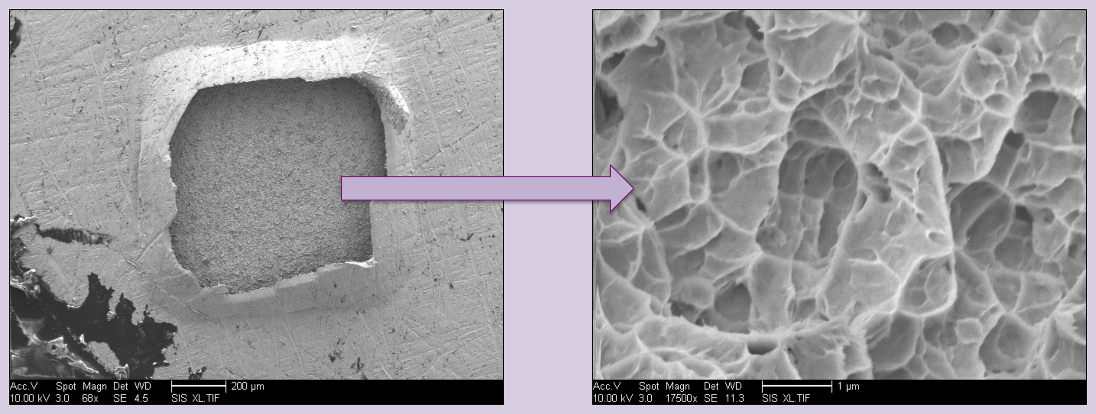


Fig 4. The nanocrystalline completely spalled at 75 J. The SEM image on the right shows dimpling around the same size expected of the nano grains.

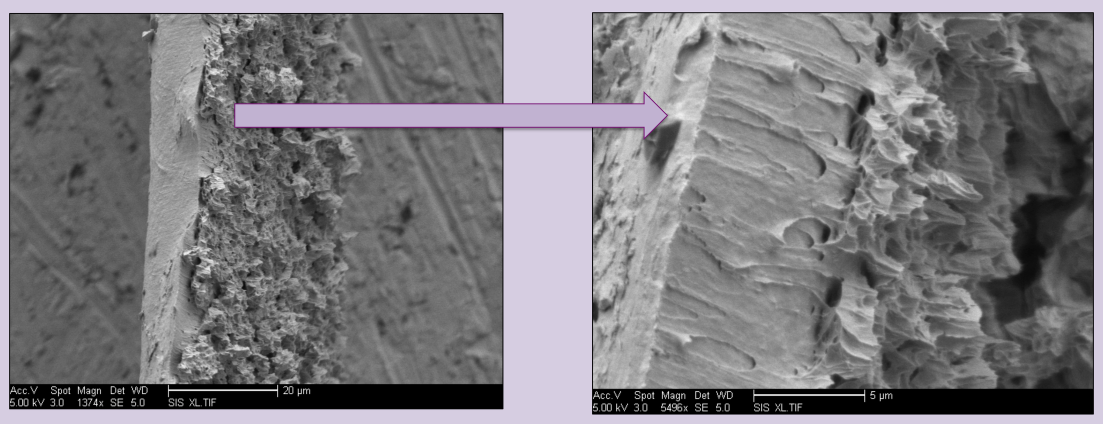


Fig 7. The lip of the spall crater from the nanocrystalline sample shocked at 112 J shows signs of shear.

Polycrystalline

Laser energy at 112 J:

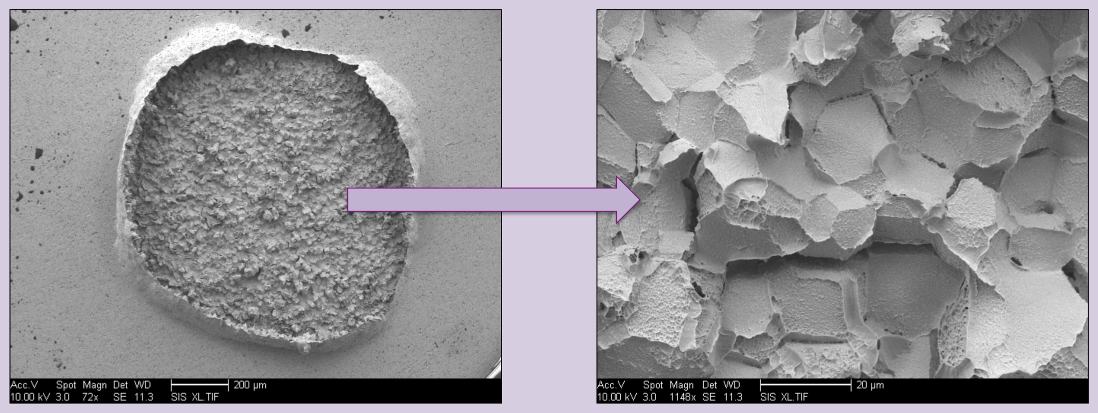


Fig 2. At high energy the polycrystalline sample completely spalled. The grain size was determined using SEM to be ~20 um after laser shock.

Laser energy at 75 J:

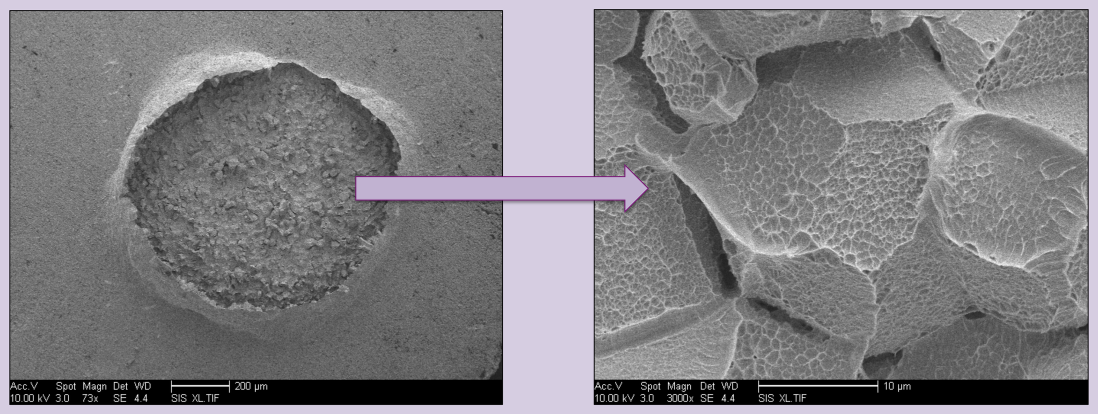


Fig 5. The polycrystalline sample completely spalled at 75 J and separation at the grain boundaries can clearly be seen.

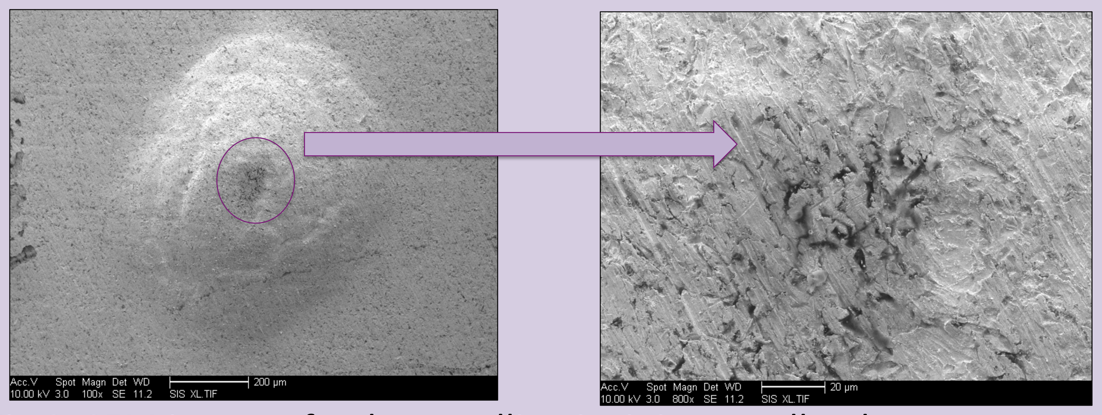


Fig 8. SEM image of polycrystalline incipient spall at laser energy of 60 J. The bulge shows the sample on the verge of complete spall with cracks and voids on the top of the spall bubble.

Monocrystalline (111)

Laser energy at 112 J:

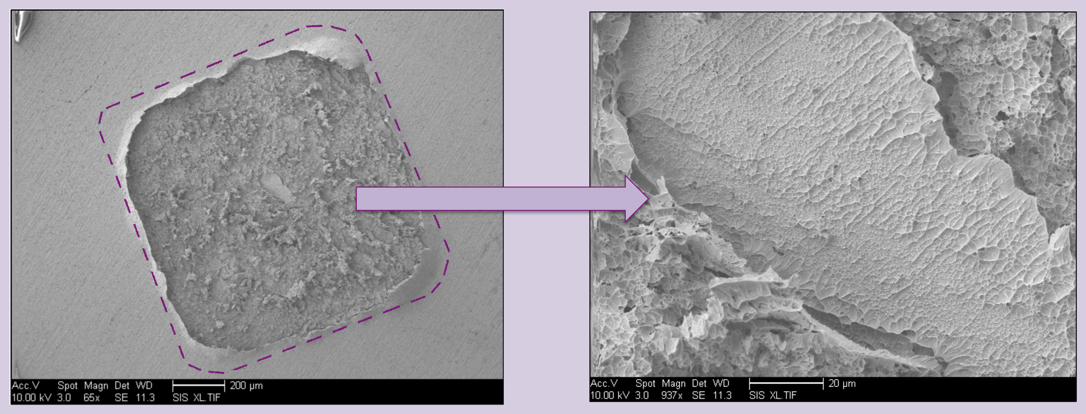


Fig 3. At high energy the monocrystalline sample completely spalled. The sample at such a high energy displayed signs of shear. Dashed line around spall crater represents laser spot.

Laser energy at 75 J:

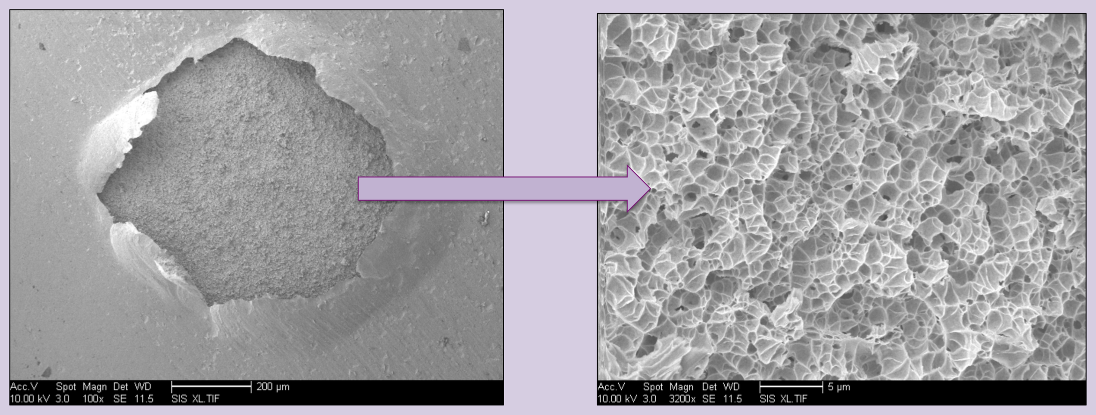


Fig 6. The single crystal completely spalled at 75 J showing dimpling in the crater area of the sample.

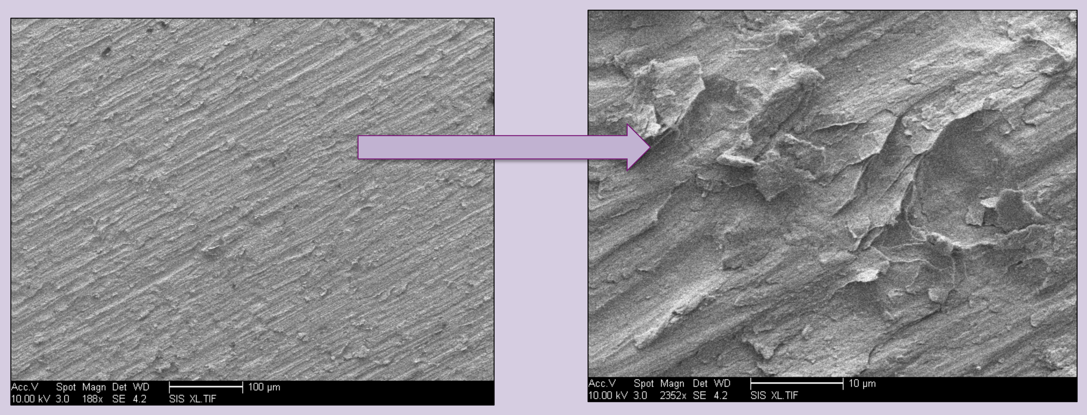


Fig 9. The single crystal shocked at 52 J did not produce a spall bubble that could be directly imaged using SEM. However, CT scans may show void formations under the surface.

Summary and Future Work

- Grain sizes of the nanocrystalline samples shocked at high energies cannot be clearly determined with direct imaging. The dimpling on the surface of the spall crater is on average the same size as the nano grains. This would suggest that the grain boundaries of the nanocrystalline sample are concealed by the dimpling. The original grain size of the nanocrystalline samples were 100 nm.
- The lip of the spall crater on the nanocrystalline sample shocked at 112 J show indications of shear.
- The nanocrystaline samples have the most amount of grain boundaries, so there are more initiation sites for voids to grow and coalesce. This would suggest that the nanocrystals will have the lowest spall strength. The VISAR data analysis is in progress to infer spall strength.
- CT scans are required to identify void sizes and locations in the nano, poly and single crystalline samples.
- Following future work also includes measuring spall thicknesses in the samples.
- Need to analyze the VISAR pull-back signals to extract the pressures and the spall strength of the materials.
- Compare spall strength from tension with material strength from compression.

Acknowledgements

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