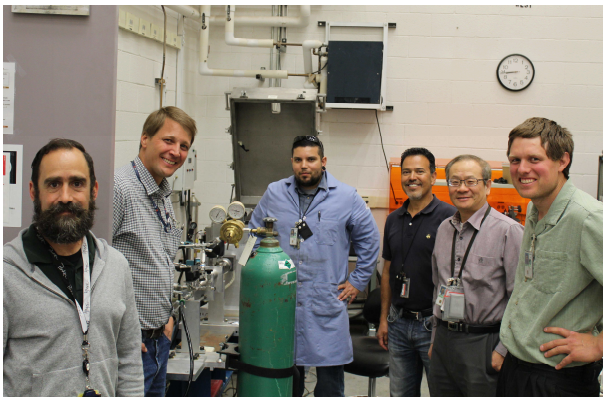


# Dynamic Impact Tests of Tantalum Single Crystals

Hojun Lim<sup>1</sup>, Jay Carroll<sup>1</sup>, Corbett Battaile<sup>1</sup>, Matthew Lane<sup>1</sup> and Shuh Rong Chen<sup>2</sup>



<sup>1</sup>*Sandia National Laboratories*

<sup>2</sup>*Los Alamos National Laboratory*

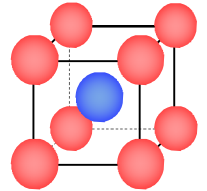
**APS March Meeting 2018**

March 7, 2018

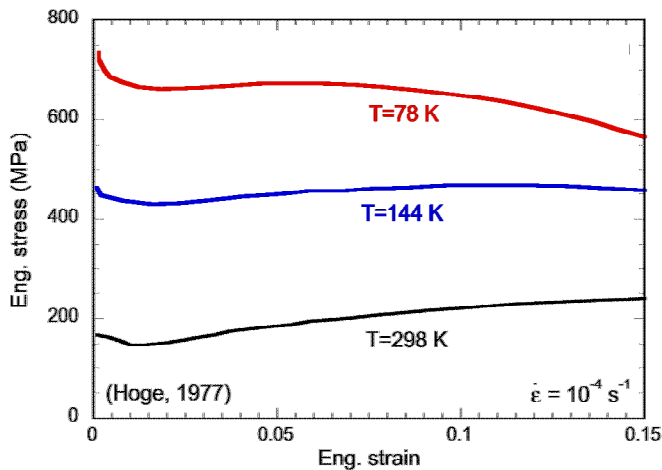
# Tantalum



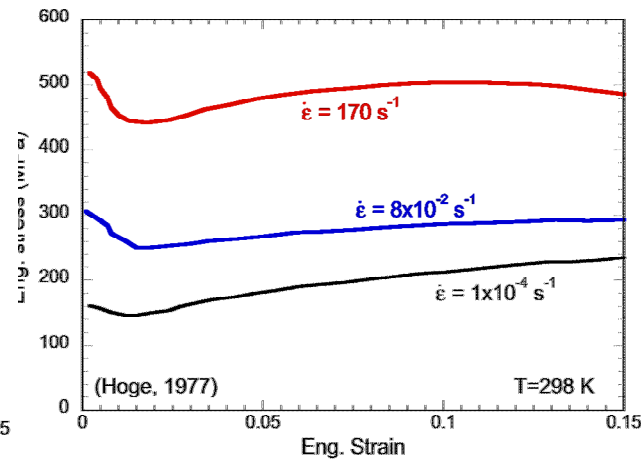
- BCC refractory metal
- High melting point (3290 K) & density (16.7 g/cm<sup>3</sup>)
- Strong, ductile, high corrosion resistance
- Nuclear / surrogate / ballistics applications.
- Electronic components (capacitors and resistors), alloying.
- Strong temperature and strain-rate dependent flow strength



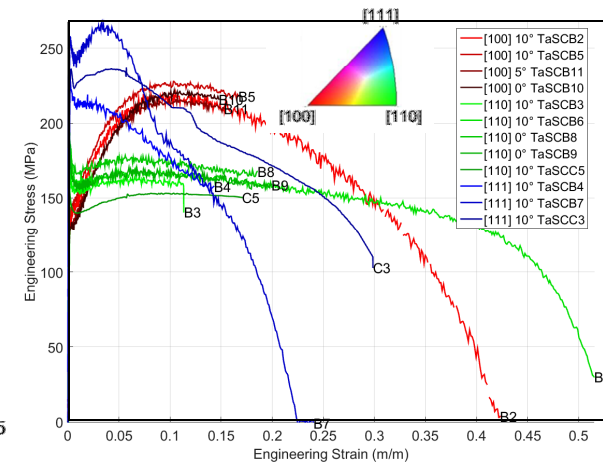
BCC structure



Polycrystalline Ta  
Temperature dependence



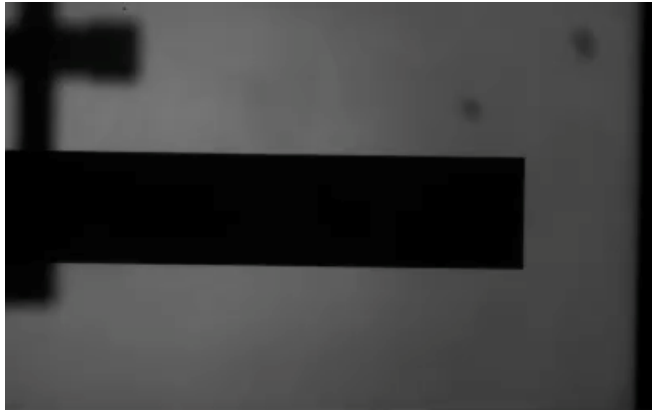
Polycrystalline Ta  
Strain rate dependence



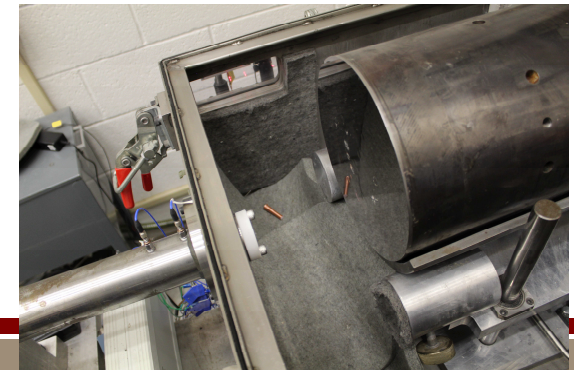
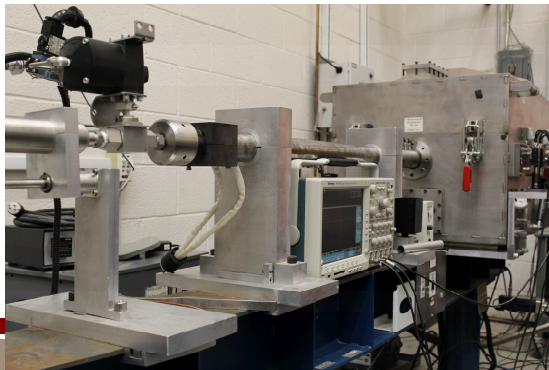
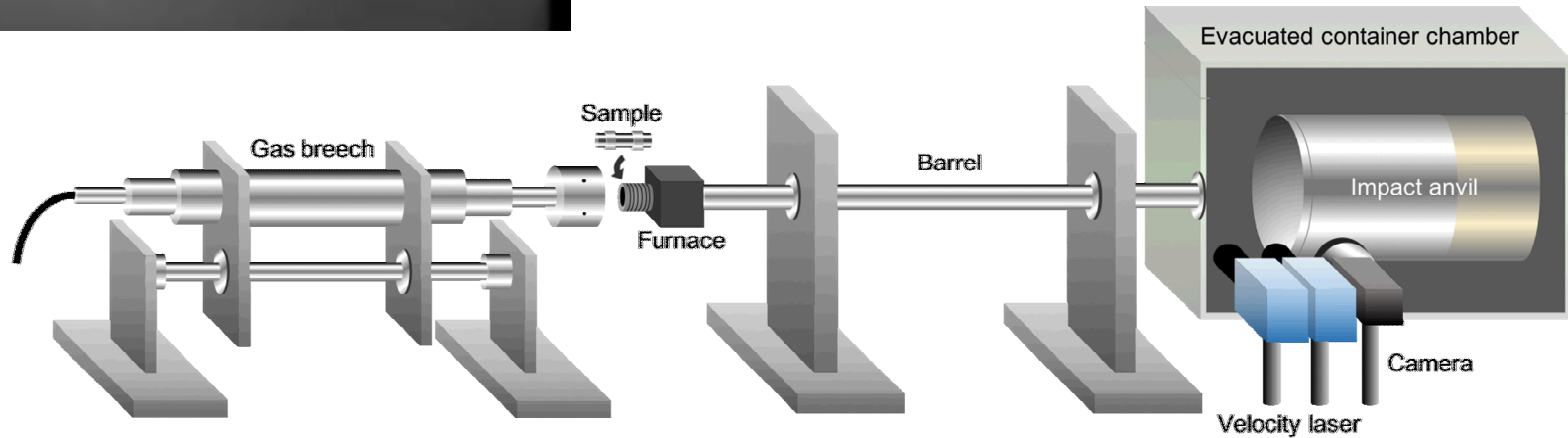
Single crystal Ta  
Crystal orientation dependence



# Taylor impact test

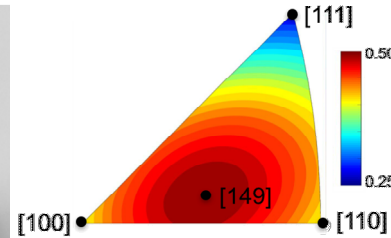
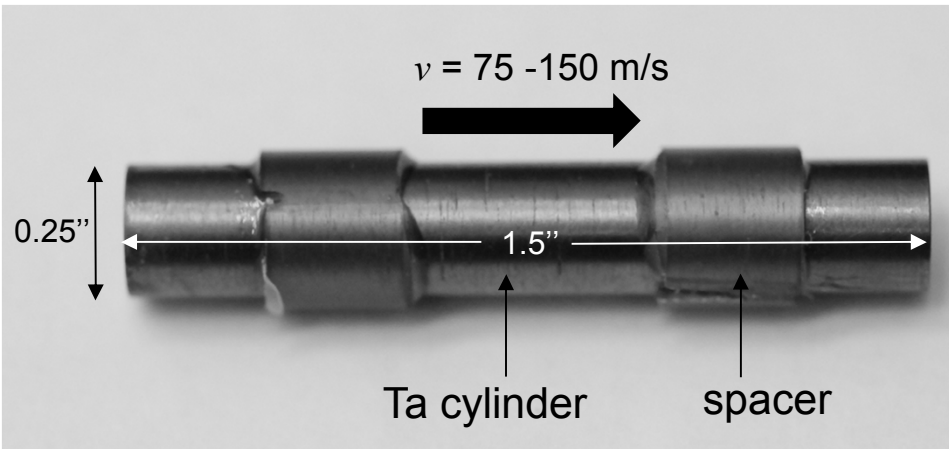


- Simple and robust technique to understand dynamic behaviors
- Large temperature & strain rate gradients  
 $\dot{\epsilon} < 5 \times 10^4 \text{ s}^{-1}$  and  $T < 1000 \text{ K}$
- Provides strength & plastic anisotropy
- Non-destructive technique



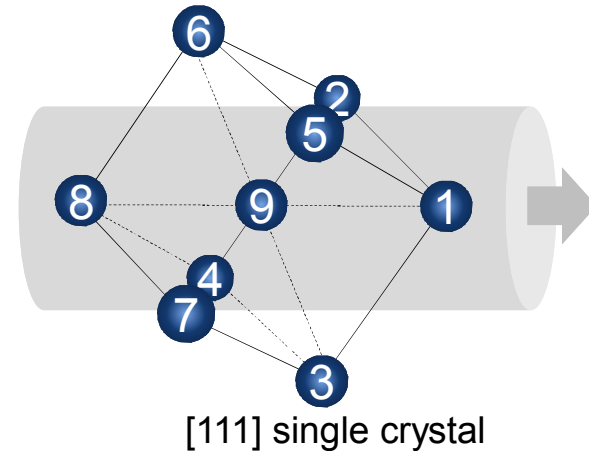
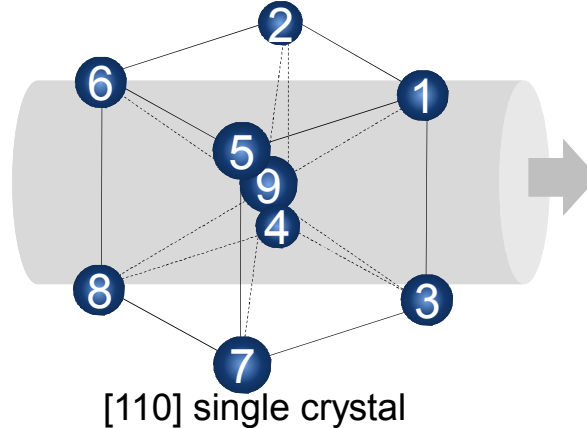
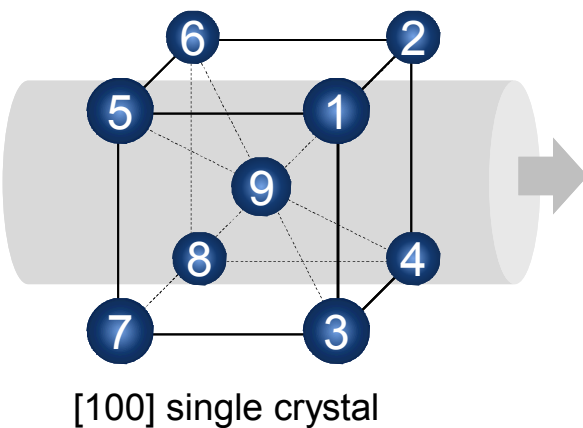
# Single crystal experiments

- Extreme anisotropy
- Understand single grain scale deformation at high rate
- Dynamic behaviors (rate < shock regime) less well-known – no Taylor results



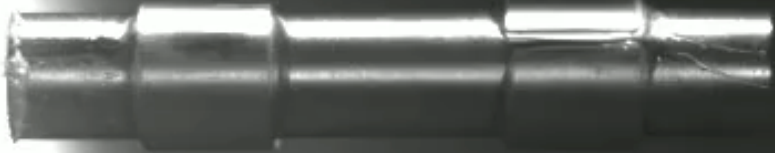
4 single crystal orientations:  
[100], [110], [111] and [149]

[100]	[110]	[111]	[149]
-	78.1 m/s	78.3 m/s	77.8 m/s
102.2 m/s	101.7 m/s	102 m/s	102 m/s
137.4 m/s	137.5 m/s	137 m/s	137 m/s
150.6 m/s	-	-	-

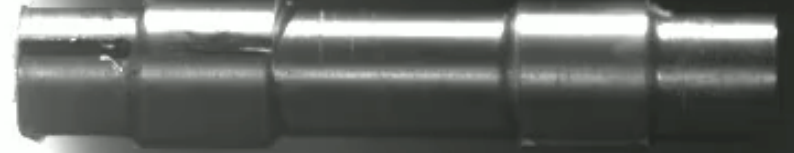


# *Single crystal Taylor impact shots*

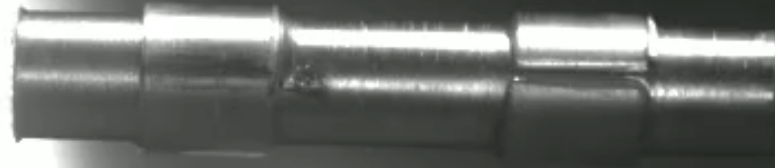
[100] 150.6 m/s



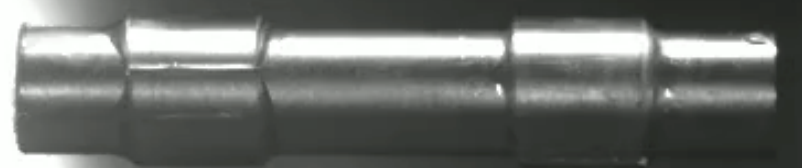
[111] 78.3 m/s



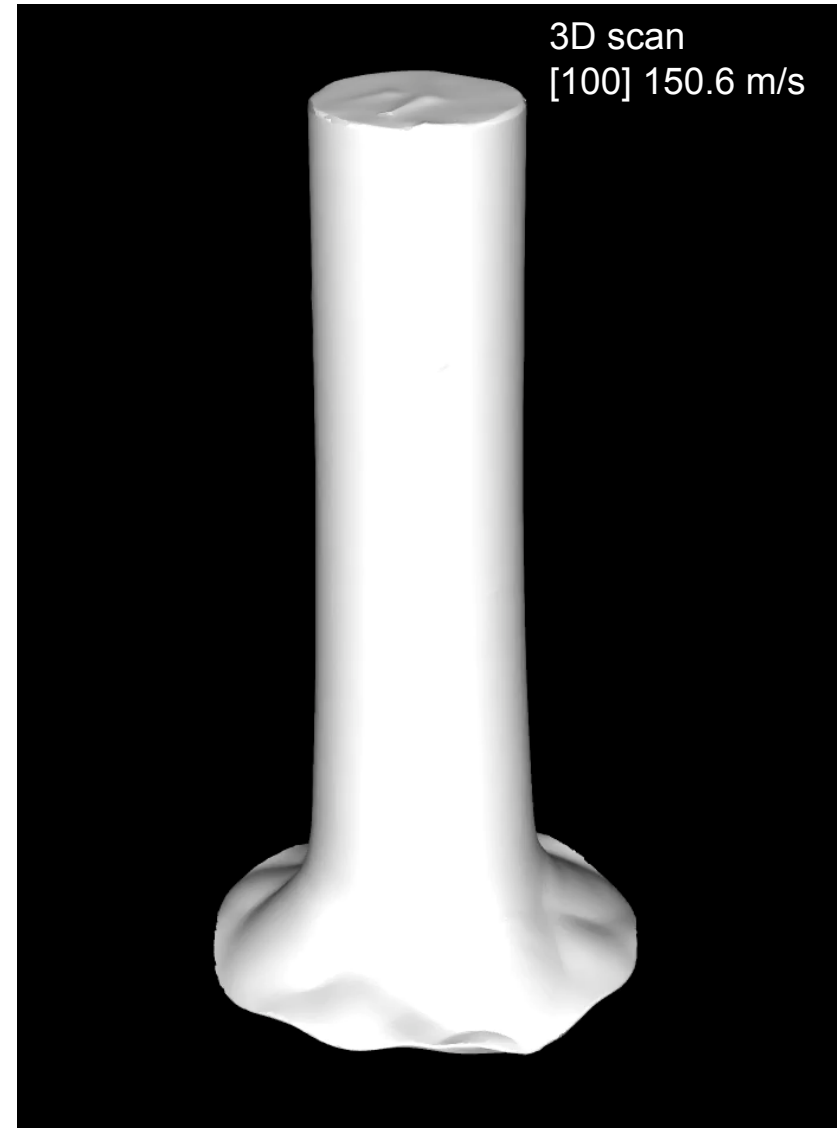
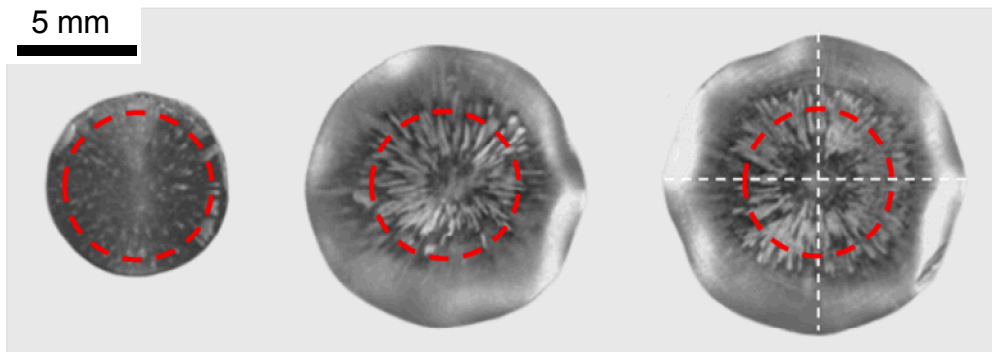
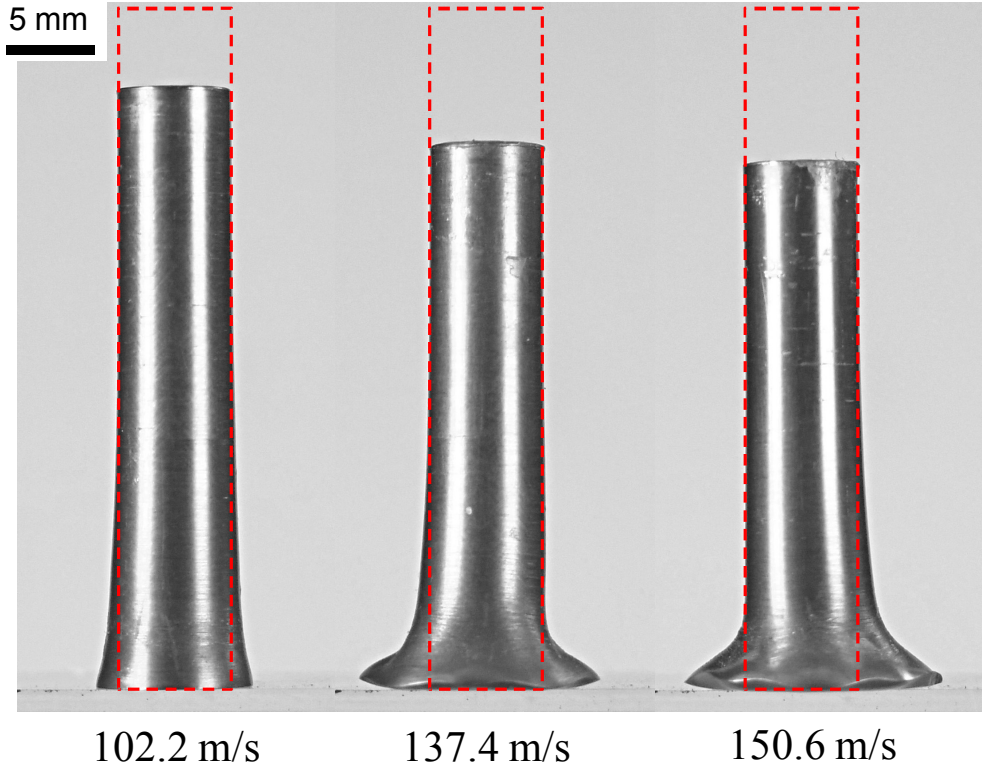
[110] 78.1 m/s



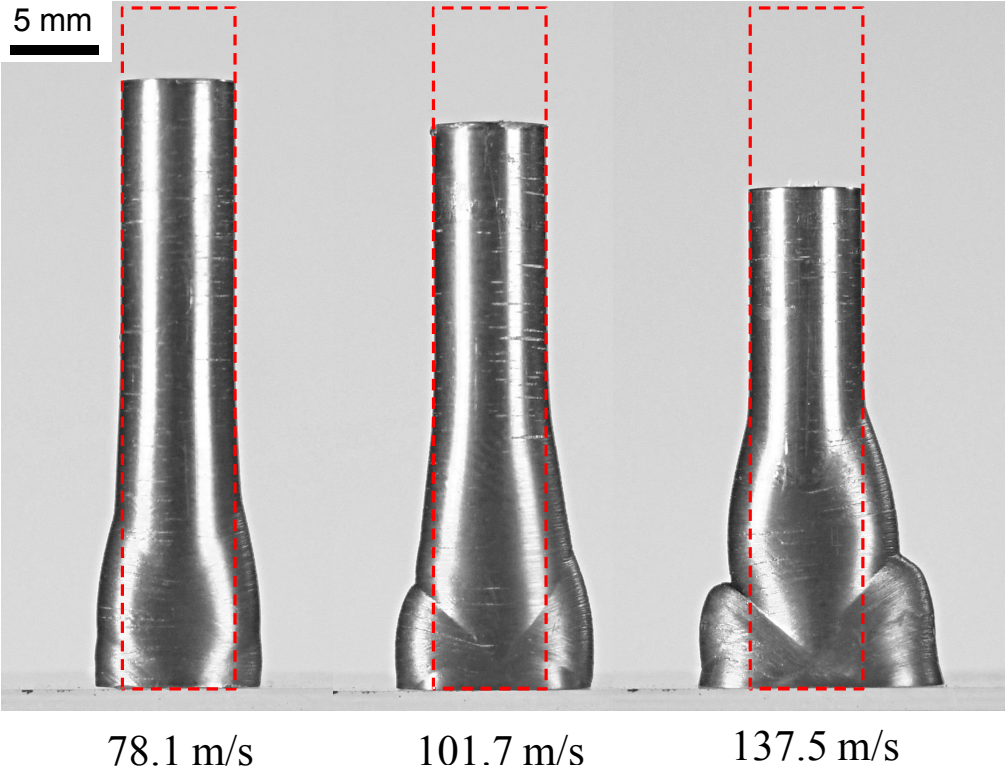
[149] 77.8 m/s



# *[100] single crystal specimens*

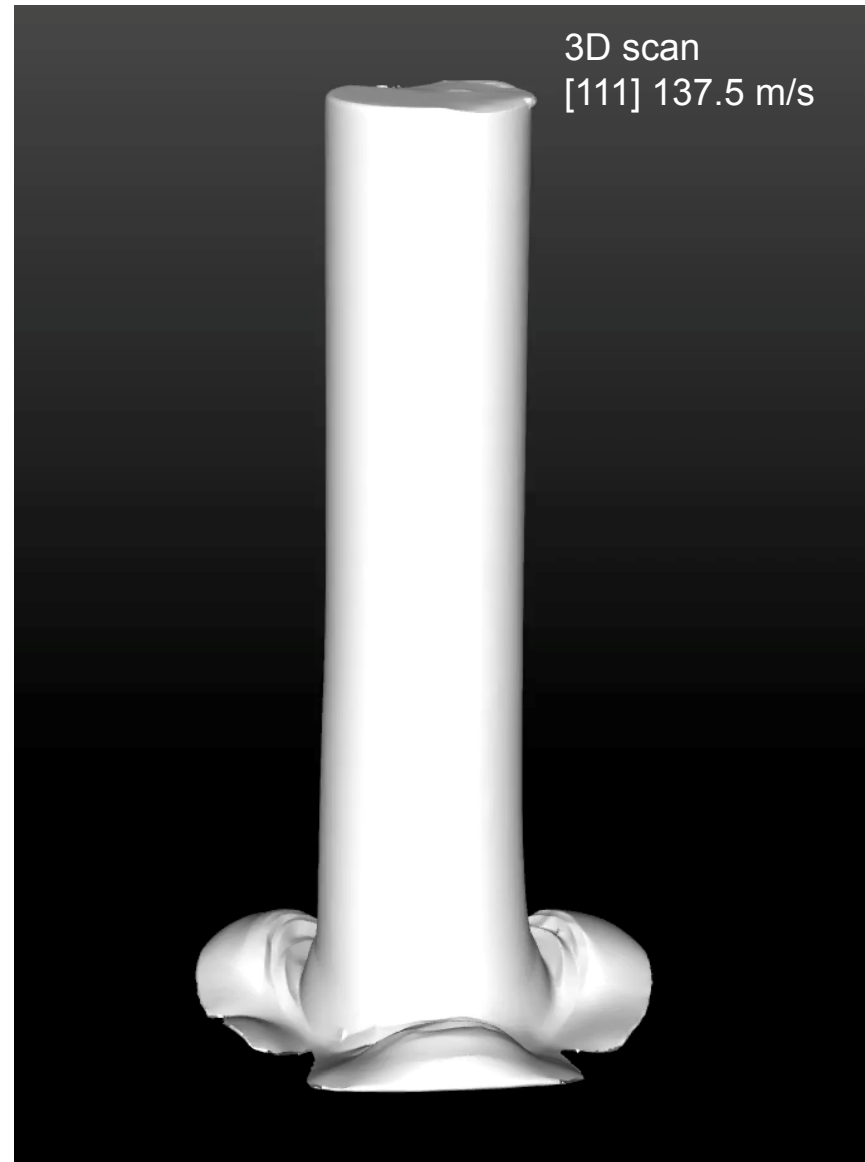
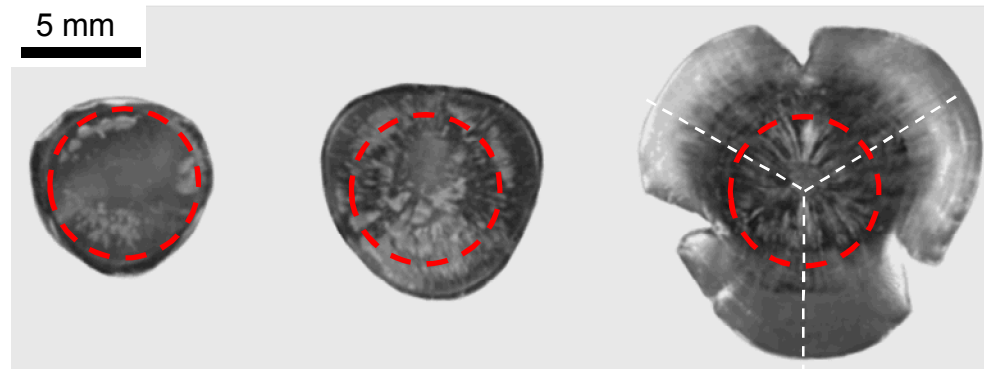
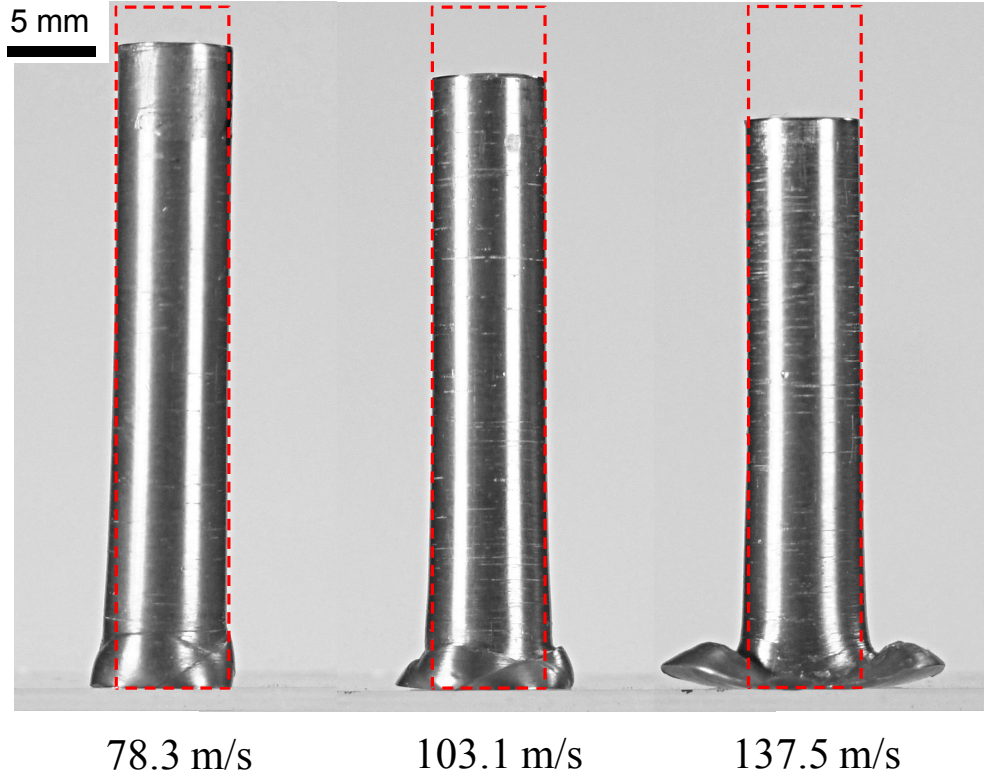


# *[110] single crystal specimens*

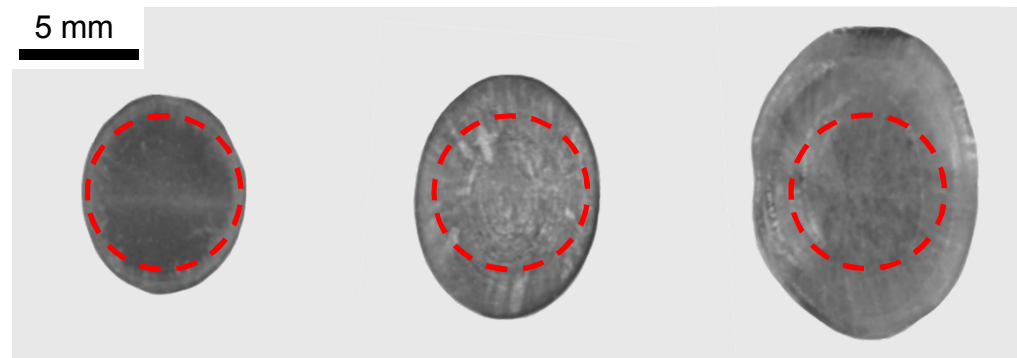
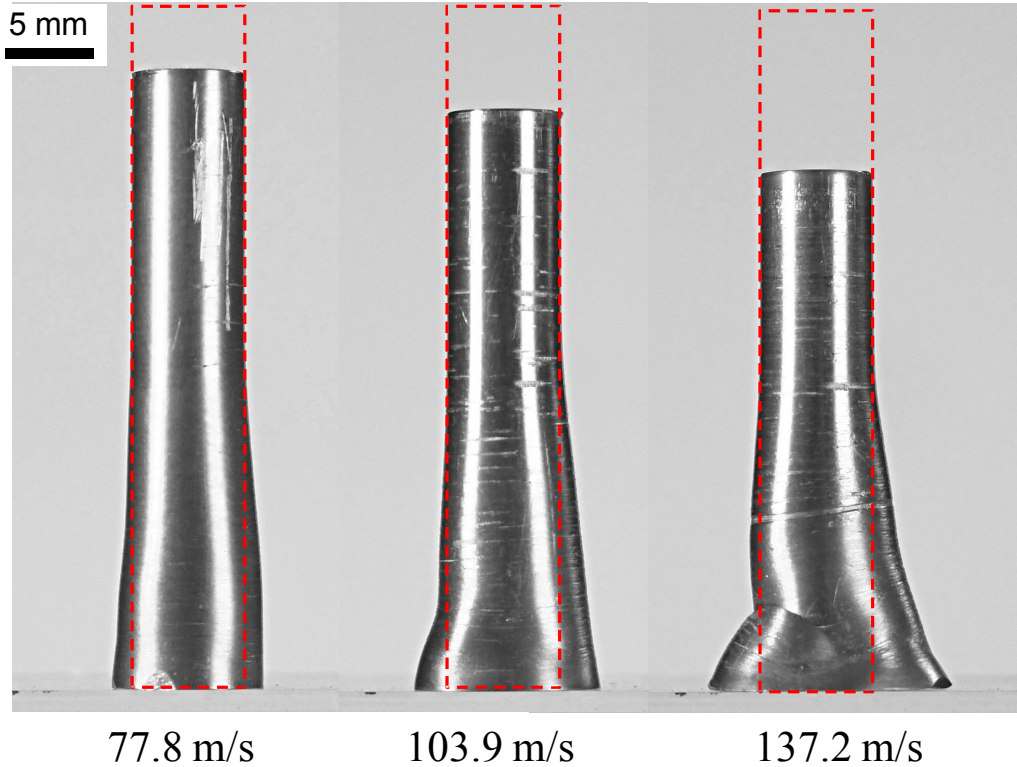




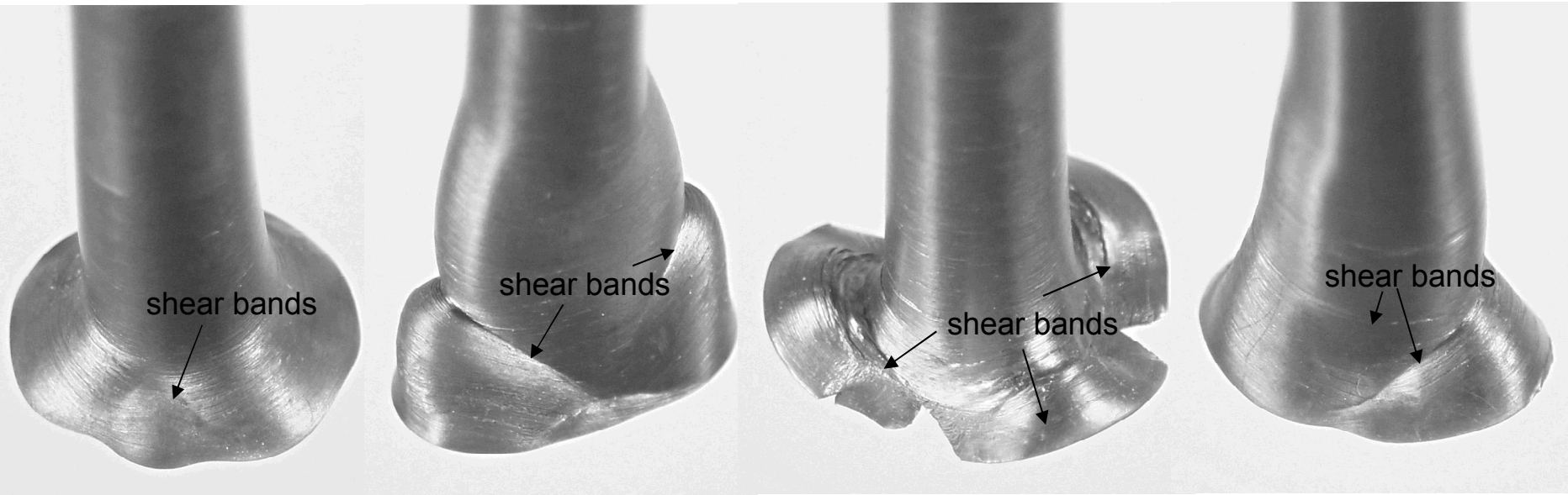
# *[111] single crystal specimens*



# $[\bar{1}49]$ single crystal specimens



# Strain localizations



[100] single crystal

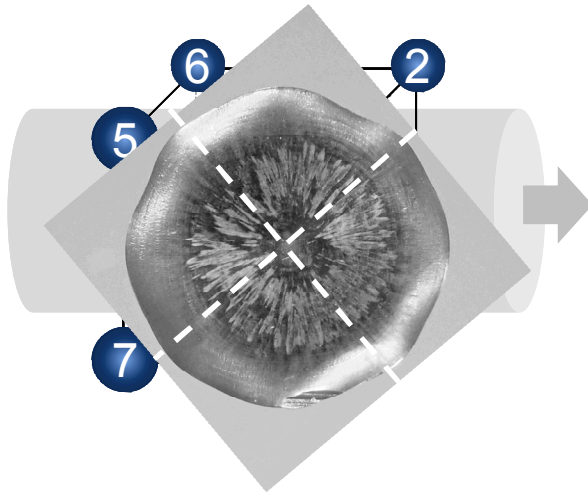
[110] single crystal

[111] single crystal

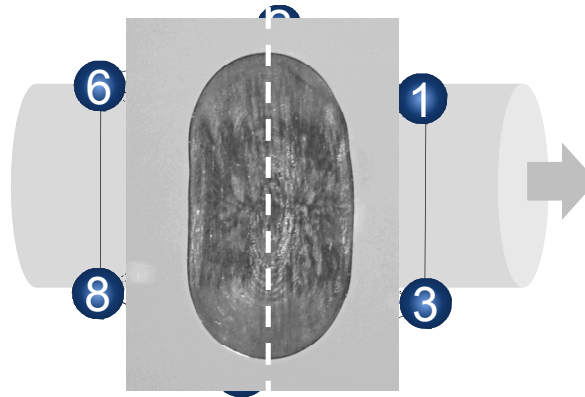
$\bar{1}49$  single crystal

# Crystallographic analysis

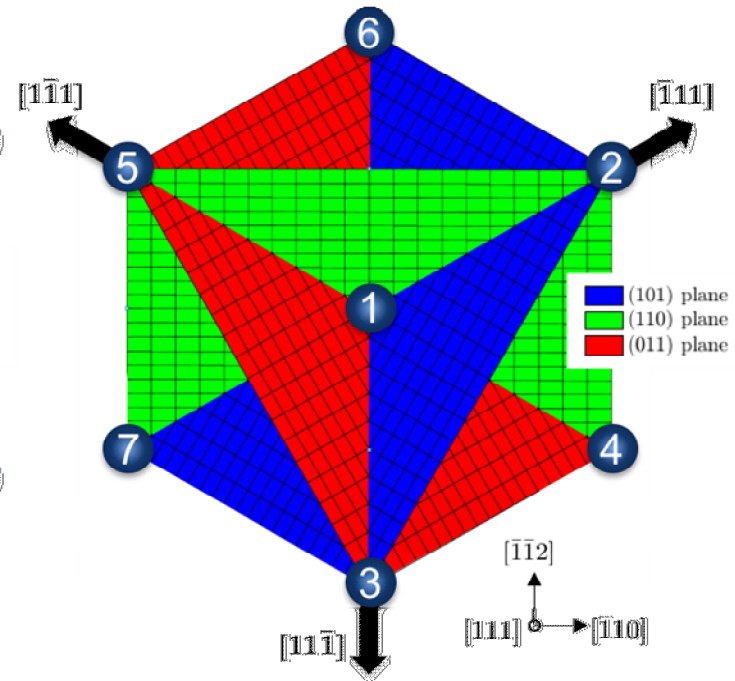
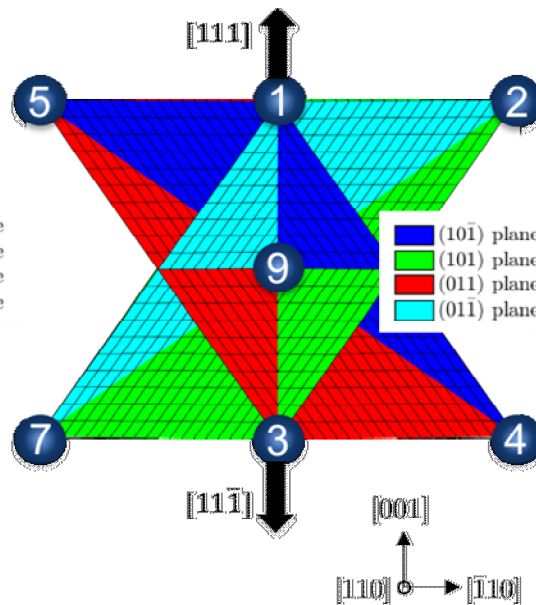
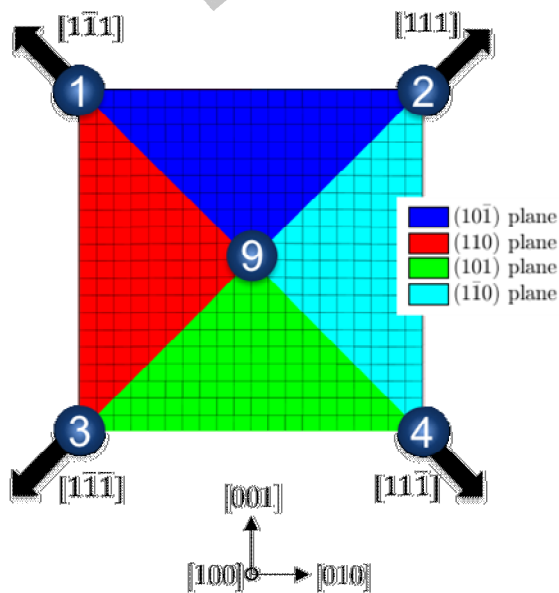
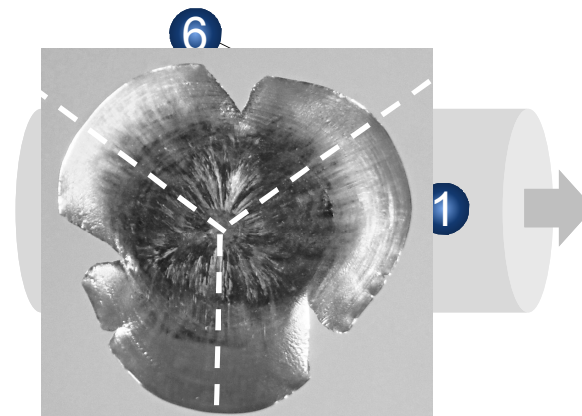
[100] single crystal



[110] single crystal

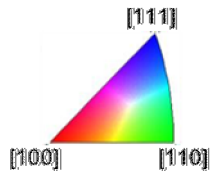


[111] single crystal

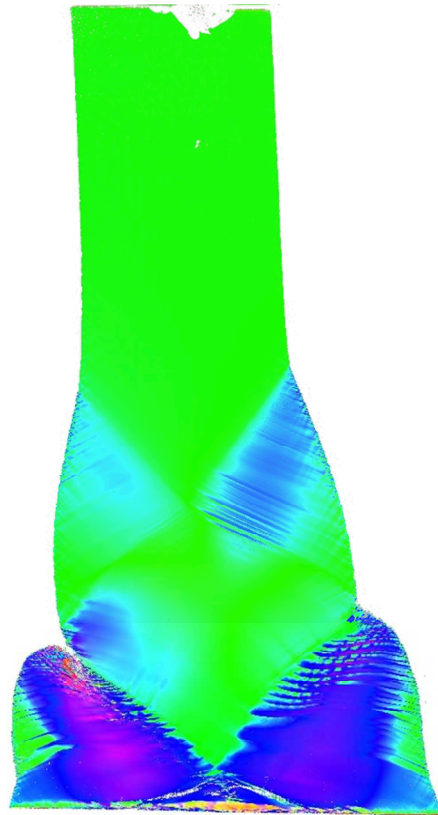




# EBSD images



$[100]$  single crystal



$[110]$  single crystal



$[111]$  single crystal

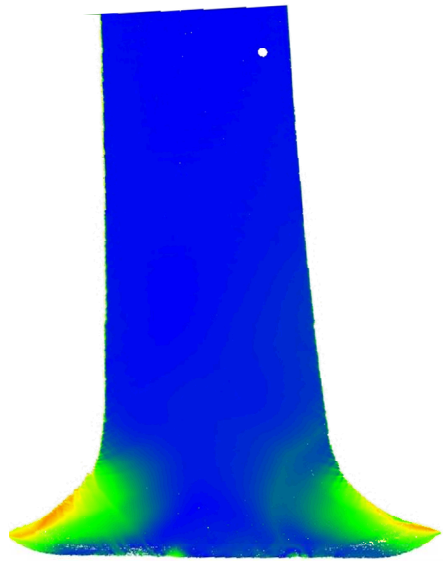


$[\bar{1}49]$  single crystal

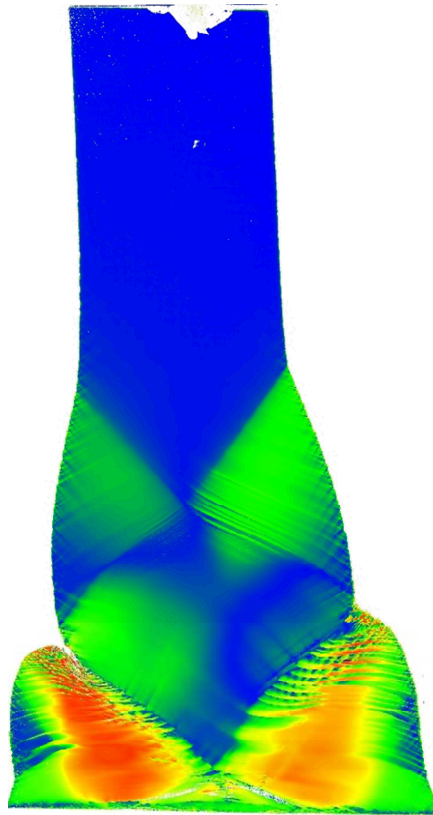


# Misorientation angles

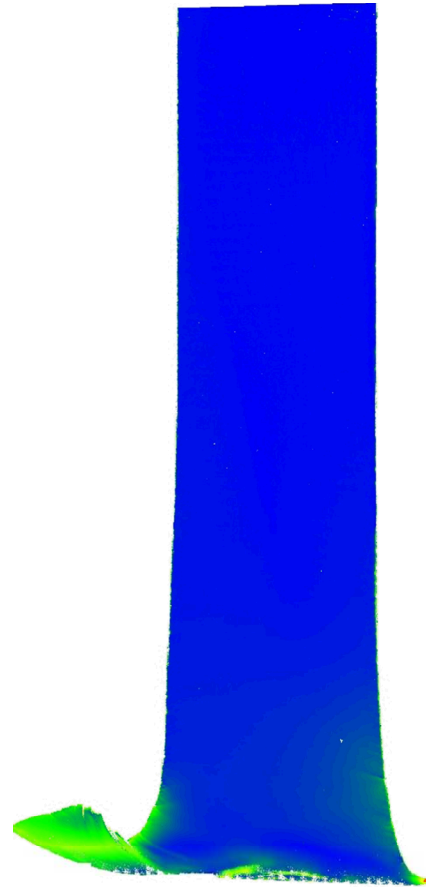
Misorientation angle  
(degrees)



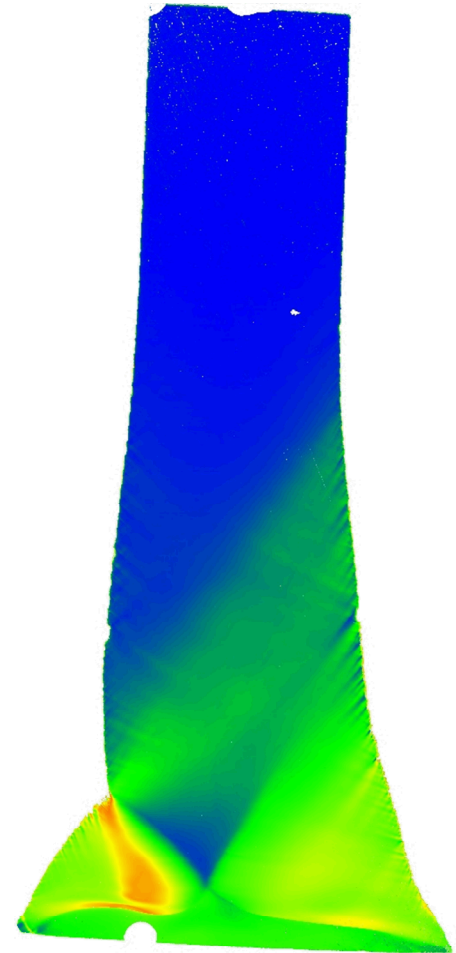
[100] single crystal



[110] single crystal



[111] single crystal



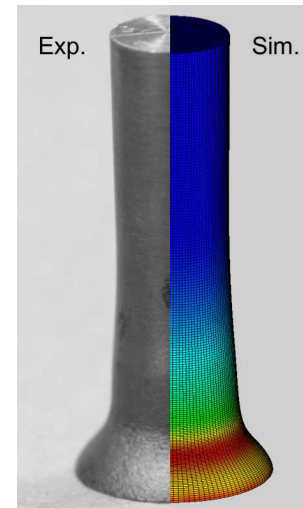
$[1\bar{1}49]$  single crystal

- **“Microstructure matters”**

- ✓ Conducted impact tests using single crystals
- ✓ Strong plastic anisotropy and strain localizations in single crystals
- ✓ 4, 2, 3 fold symmetries in foot shapes of [100], [110] and [111] single crystals
- ✓ Strong localization in [111] single crystals

- **Modeling challenges**

- ✓ Temperature/rate dependent strength model
- ✓ Dynamics/ explicit
- ✓ Crystal plasticity framework
- ✓ Thermo-mechanical coupling
- ✓ Contact/ friction



Polycrystalline Ta



*Thank you!*

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