RESEARCH HIGHLIGHT

Nanometal group – Xinghang Zhang

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In summer 2016, Professor Zhang joined the School of Materials Engineering at Purdue University after serving at Texas A&M University for 12 years. His research group has expertise on synthesis of nanotwinned metals, metallic multilayers, bulk nanocrystalline metals; radiation damage in nanostructured metals; *in situ* mechanical testing of nanomaterials inside a scanning electron microscope and in a transmission electron microscope.

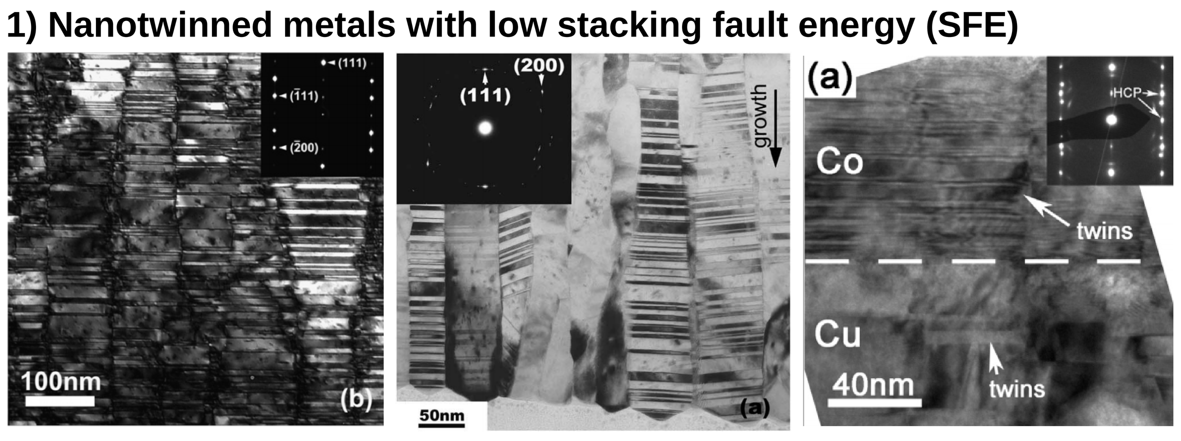
Nanotwinned metals

Nanotwinned metals have shown high strength and ductility. Our research started in 2004 focuses on understanding the fundamental strengthening and deformation mechanisms of nanotwinned metals with various stacking fault energy. Recently we show that nanotwinned Al and its alloys have high strength and work hardening capability.

Synthesis of nanotwinned (NT) metals

Metals	Ag	Au	Cu	Ni	Al
Stacking fault energy (mJ/m^2)	16	32	45	**125**	**166**

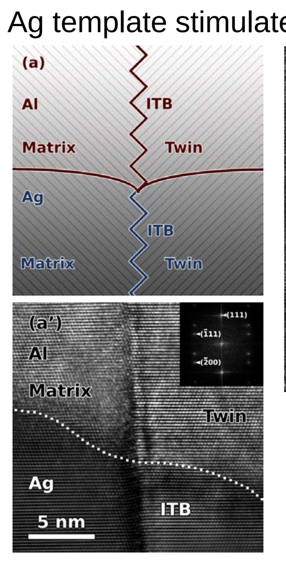
1) Nanotwinned metals with low stacking fault energy (SFE)

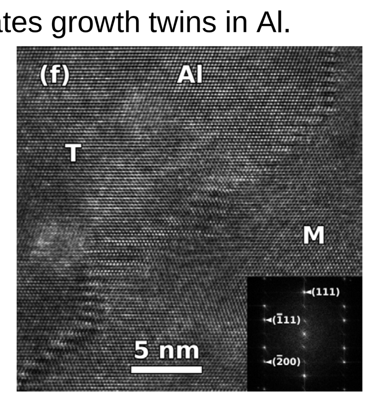


Nanotwinned Ag Bufford *et al*., Acta Mater., 2011 | *Nanotwinned Cu* Zhang *et al*., APL 2006. | *Twinned Cu/Co multilayers* Liu *et al*., Int. J. Plast., 2013

2) Twinned metals with high stacking fault energy

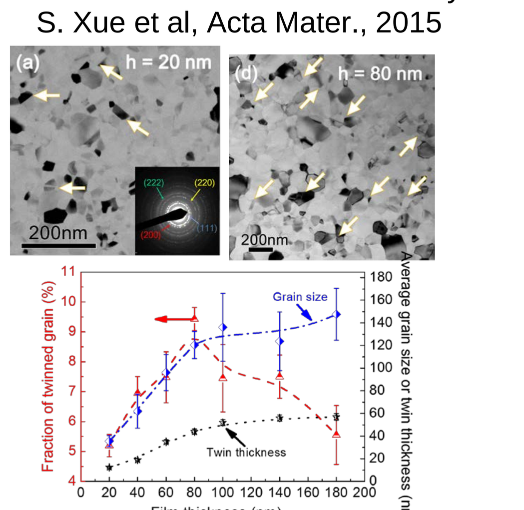
Ag template stimulates growth twins in Al.





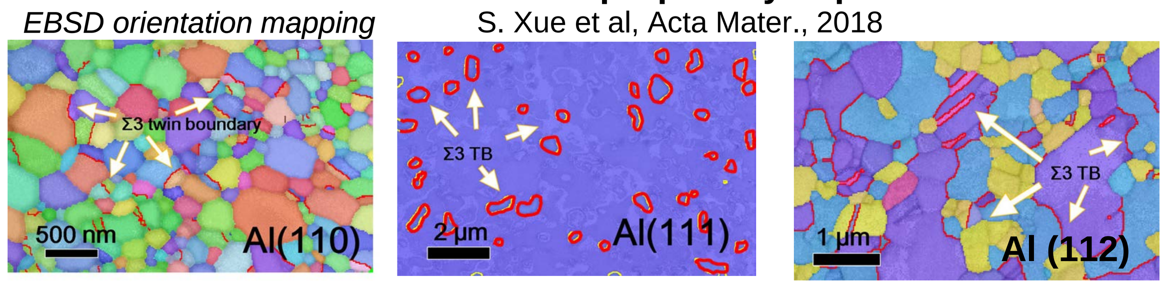
Bufford et al, MRL, 2013.
Patent pending

Film thickness tailors twin density in Al.
S. Xue et al, Acta Mater., 2015



Texture-directed twin formation propensity in pure Al

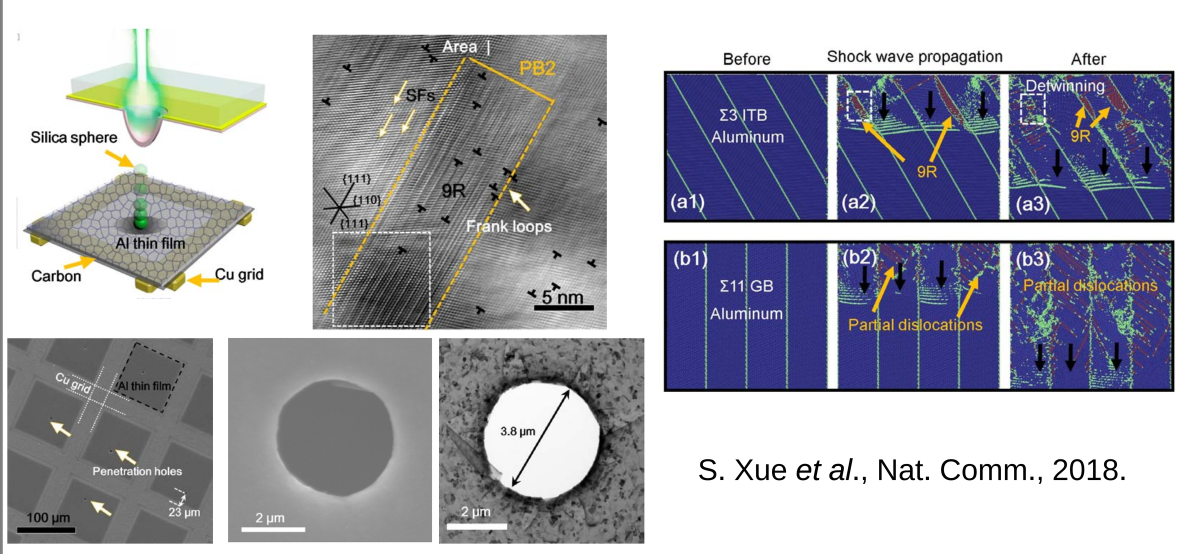
EBSD orientation mapping S. Xue et al, Acta Mater., 2018



(110) Al on Si (110) has low twin density. | Epitaxial Al (111) on Si (111) has twinned islands. | Epitaxial Al (112) on Si (112) has high density twins.

Projectile impact induces 9R phase and deformation twins in Al

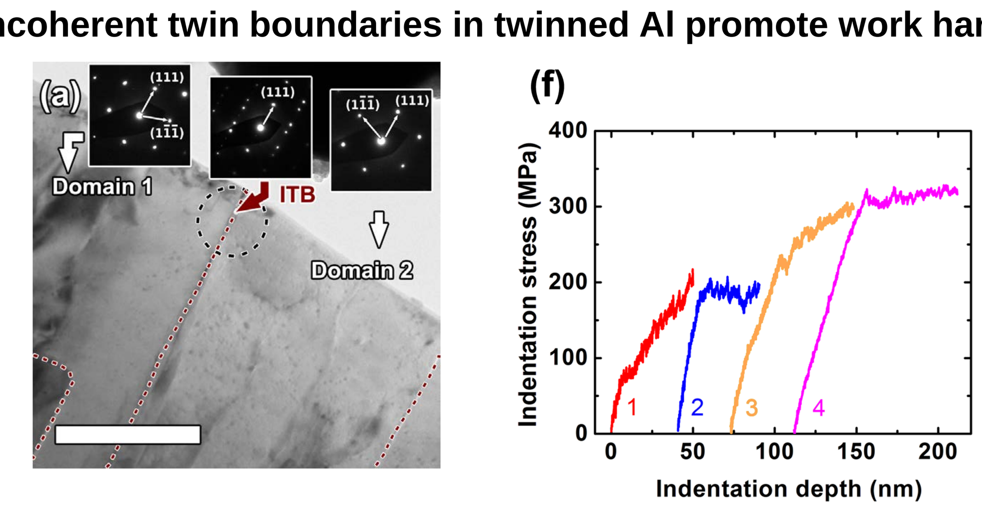
(In collaboration with Edwin Thomas (Rice University) Jian Wang, U. Nebraska, Lincoln



S. Xue *et al*., Nat. Comm., 2018.

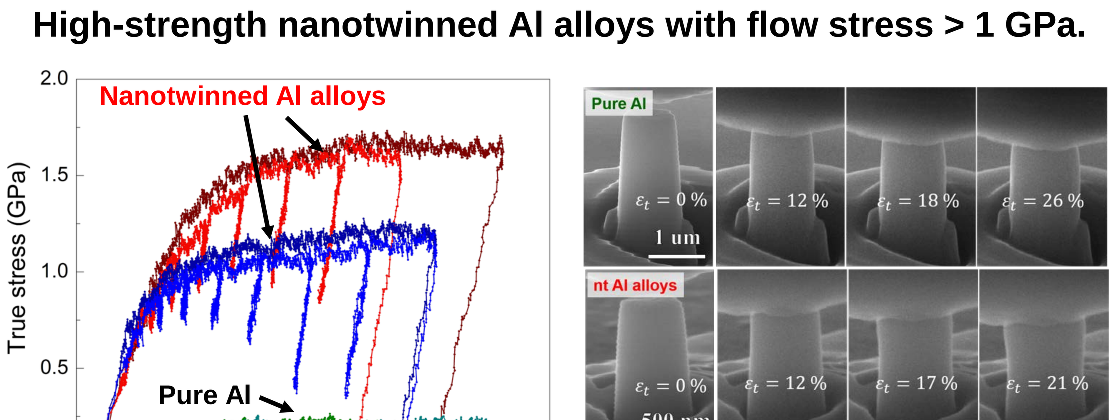
Mechanical properties of nanotwinned metals

Incoherent twin boundaries in twinned Al promote work hardening.

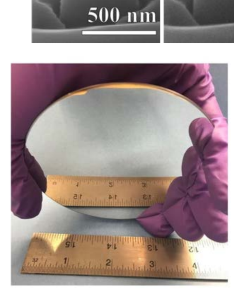


D. Bufford *et al*., Nat. Comm., 2014.

High-strength nanotwinned Al alloys with flow stress > 1 GPa.



Qiang Li, et al, submitted

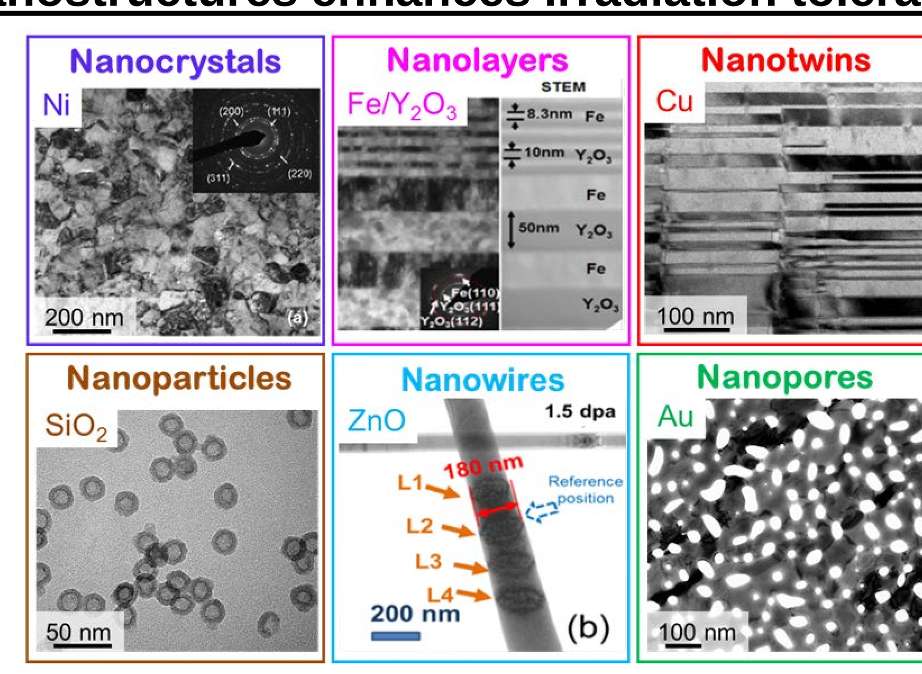


High-strength Al alloys coated on an entire Si wader

Irradiation damage

Our research of irradiation damage focuses on the fundamental aspects of defect-sink interactions as well as defect kinetics in various nanostructured metallic materials. The goal is to facilitate the design of irradiation-tolerant materials for advanced nuclear reactors.

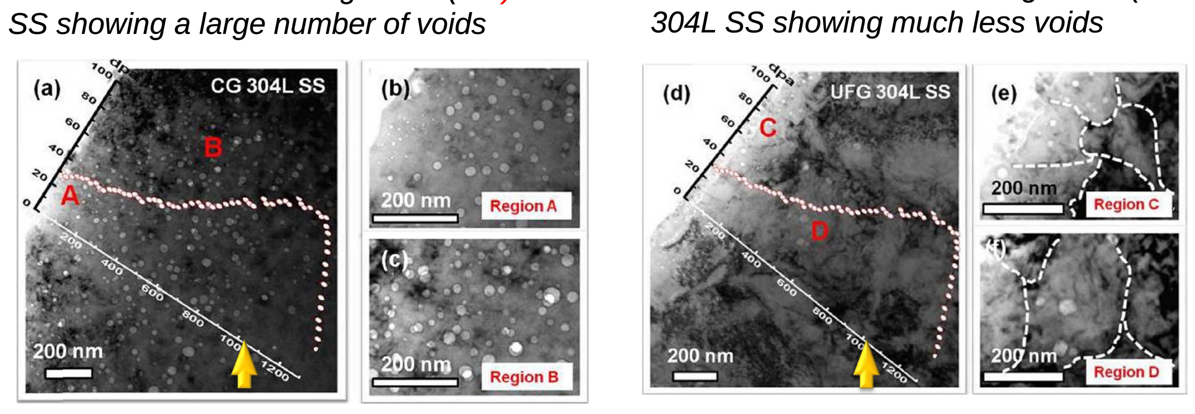
Nanostructures enhances irradiation tolerance[1-5]



C. Sun *et al*., Metall. Trans. A, 2013, Acta Mater., 2015; Y. Chen *et al*., J. Nucl. Mater., 2014; Nat. Comm., 2015; Jin Li et al., Sci. Rep., 2017; Zhang *et al*., Prog. Mater. Sci. 2018

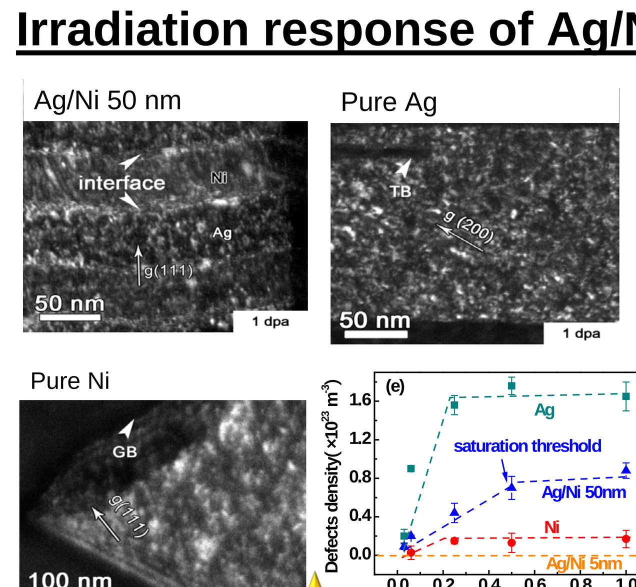
Irradiation response of ultra-fine grained 304L SS

Fe ion irradiated coarse-grained (CG) 304L SS showing a large number of voids | *Fe ion irradiated ultra-fine grained (UFG) 304L SS showing much less voids*



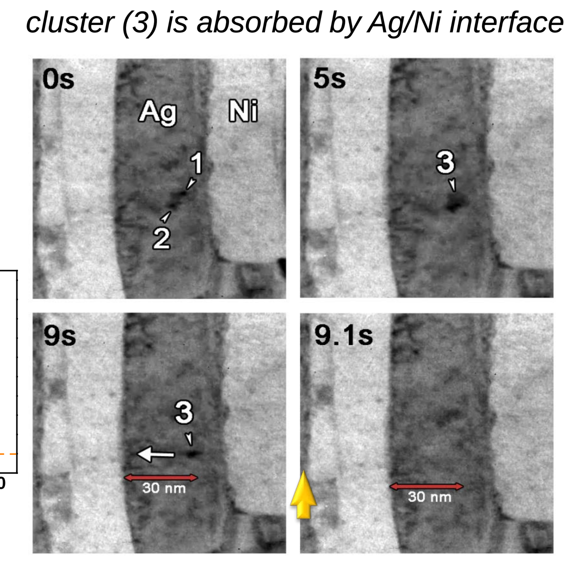
C. Sun et al., Sci. Rep., 2015

Irradiation response of Ag/Ni nanolayers



Defect density is much higher in pure Ag compared to pure Ni and Ag/Ni nanolayers

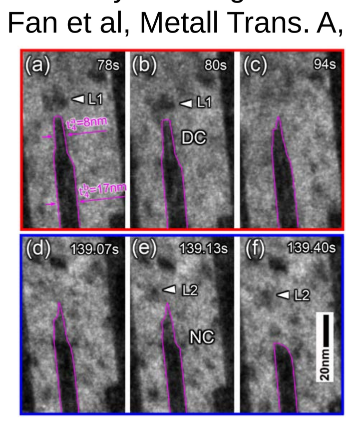
Defect-interface interaction: a defect cluster (3) is absorbed by Ag/Ni interface



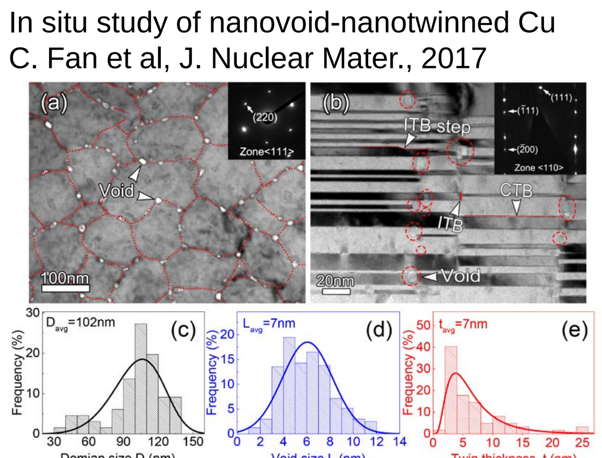
K.Y. Yu *et al*., Phil. Mag., 2013

Kr ion irradiation response of nanotwinned Cu

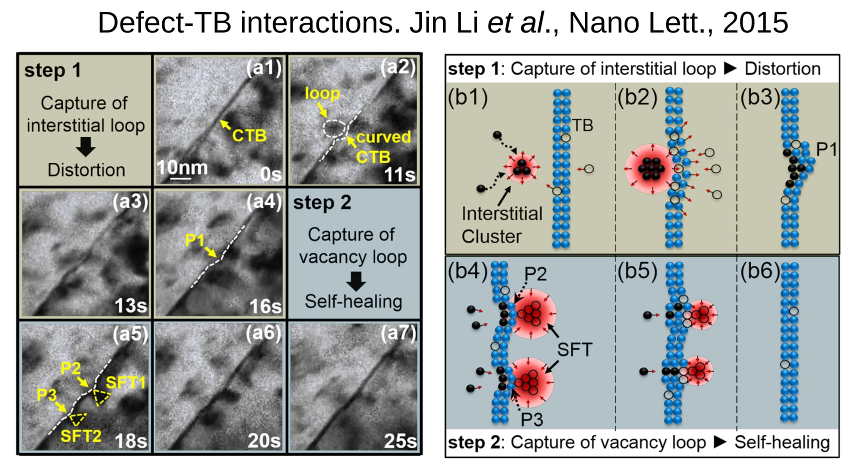
In situ study showing detwinning, C. Fan et al, Metall Trans. A, 2017



In situ study of nanovoid-nanotwinned Cu C. Fan et al, J. Nuclear Mater., 2017

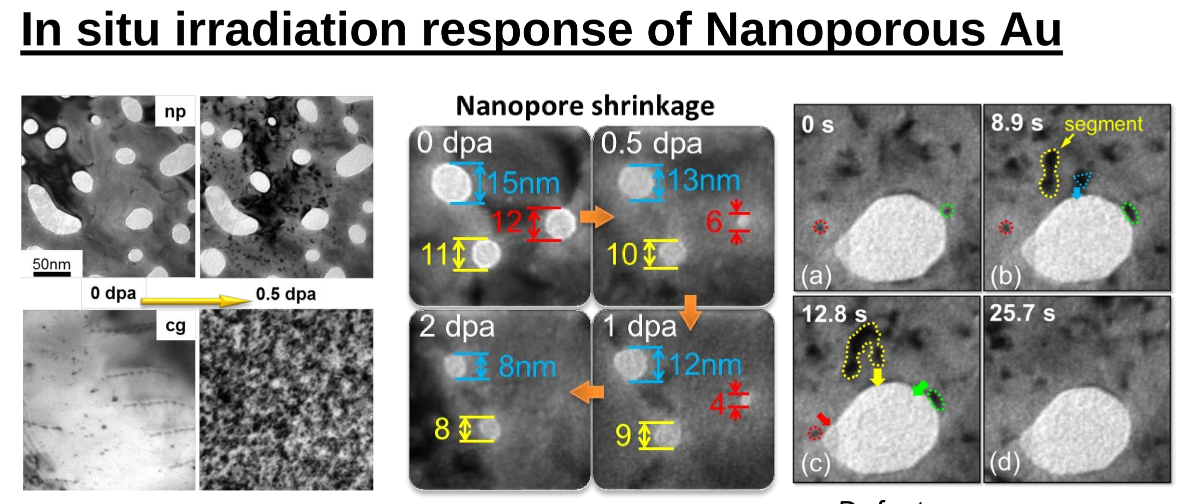


Defect-TB interactions. Jin Li *et al*., Nano Lett., 2015



Distortion and self-healing of coherent twin boundaries (CTBs) (left) and the schematics illustrate the capturing of defect clusters by a CTB and its self-healing mechanism (right).

In situ irradiation response of Nanoporous Au



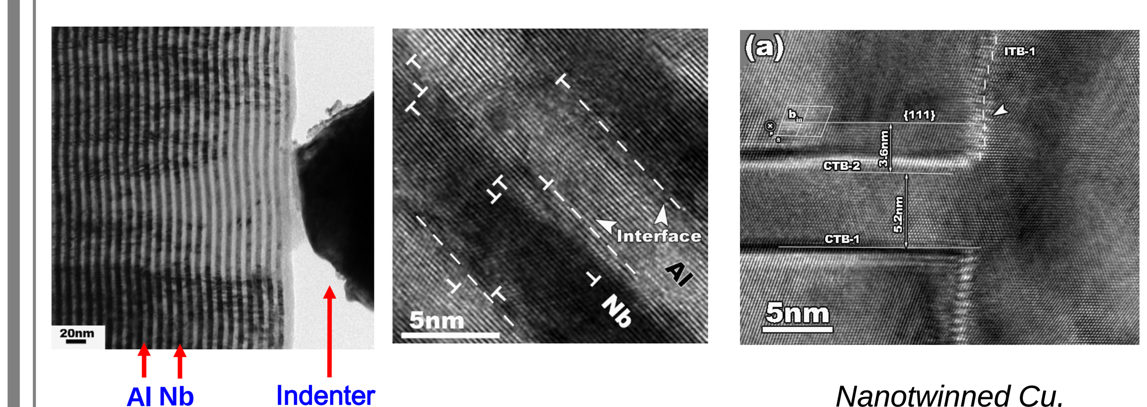
Nanoporous (NP) Au has much less defects than coarse-grained (CG) Au. | *Irradiation-induced nanopore shrinkage* | *Defect-nanopore interaction (absorption)*

Jin Li *et al*., Sci. Rep., 2017; Acta Mater., 2017.

In situ nanomechanical testing

We apply in situ mechanical testing to understand the relation between the microstructure evolution and mechanical response. The goal is to identify the deformation mechanisms of materials.

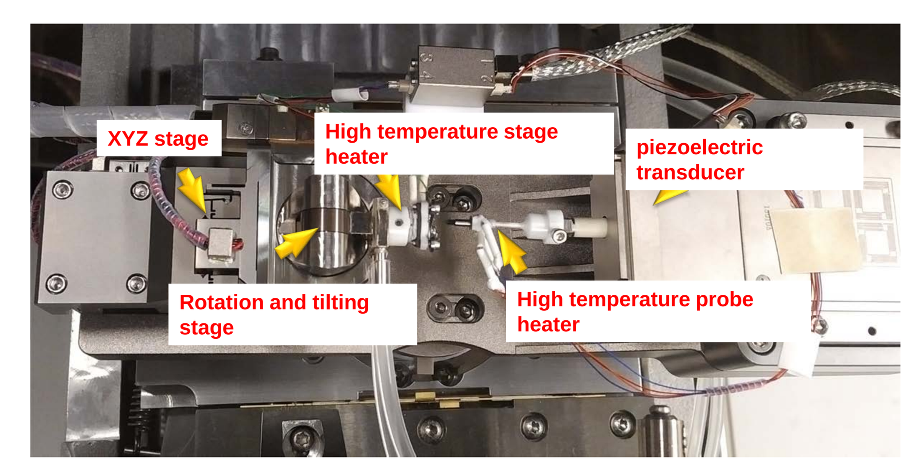
In situ nanoindentation in TEM

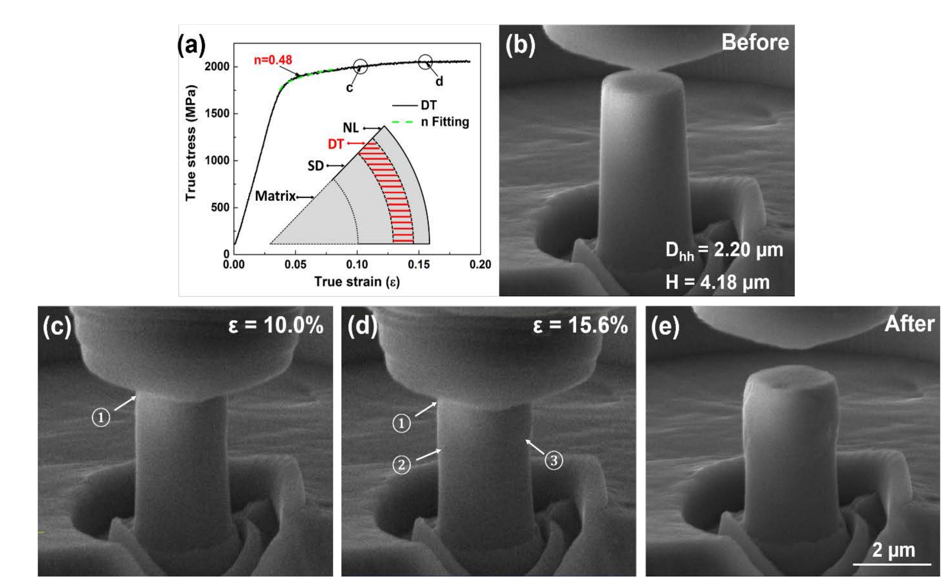


Al/Nb nanolayers Nan Li et al, Scripta Mater, 2010 | *Nanotwinned Cu, Nan Li et al, Scripta Mater, 2011*

In situ compression in SEM

Hysitron PI 87×R In-Situ SEM PicoIndenter: high temperature in-situ experiments up to 800 °C

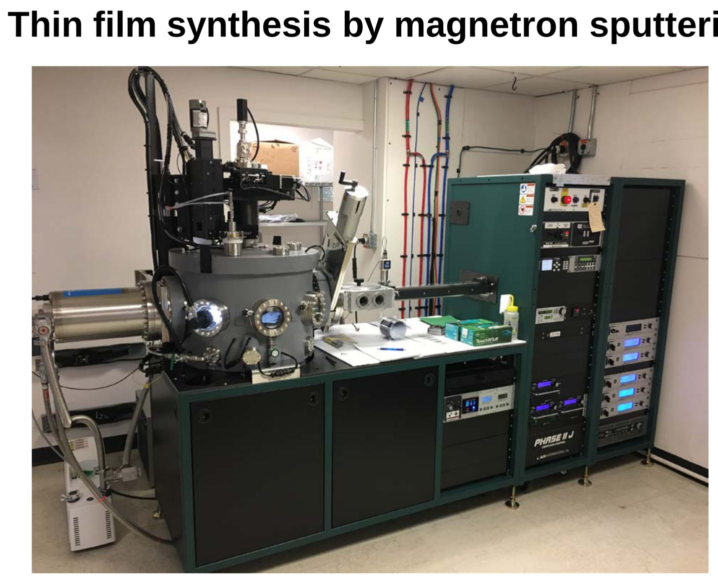




In situ compression of Ni alloy pillars
Jie Ding et al, submitted.

Nanofabrication capability

Thin film synthesis by magnetron sputtering (AJA)



8 sputtering guns
DC, RF sputtering
Heated substrate
UHV system

Bulk nanostructured materials by spark plasma sintering (SPS)

Up to 2000^{o}C

Acknowledgements

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