Recent emphasis

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Outline

- ► Microcompression tests on multilayered pillars
- ► In-situ nanocompression tests on ZrCu TFMGs

Microcompression tests on multilayered pillar

Research motive

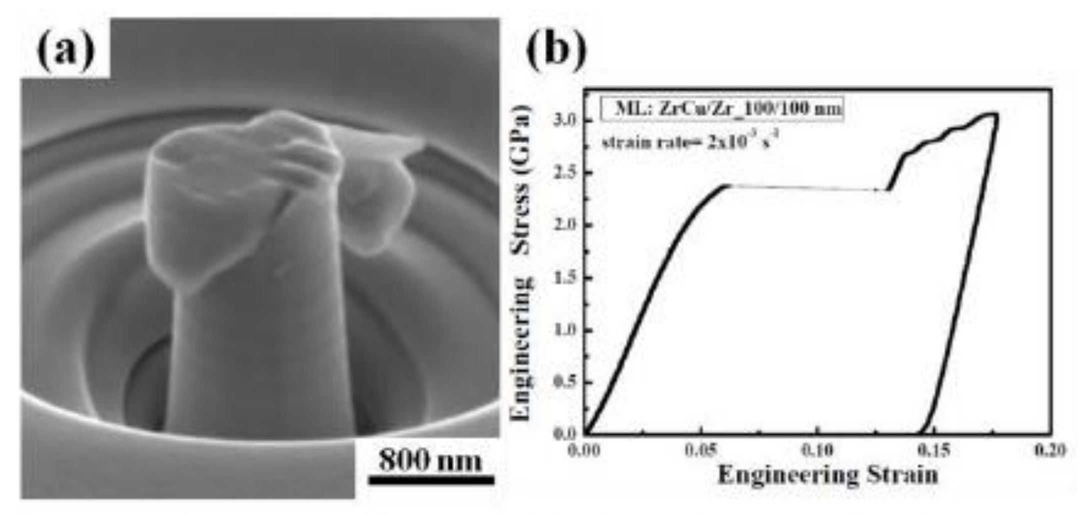
Amorphous-Crystalline nanolaminates

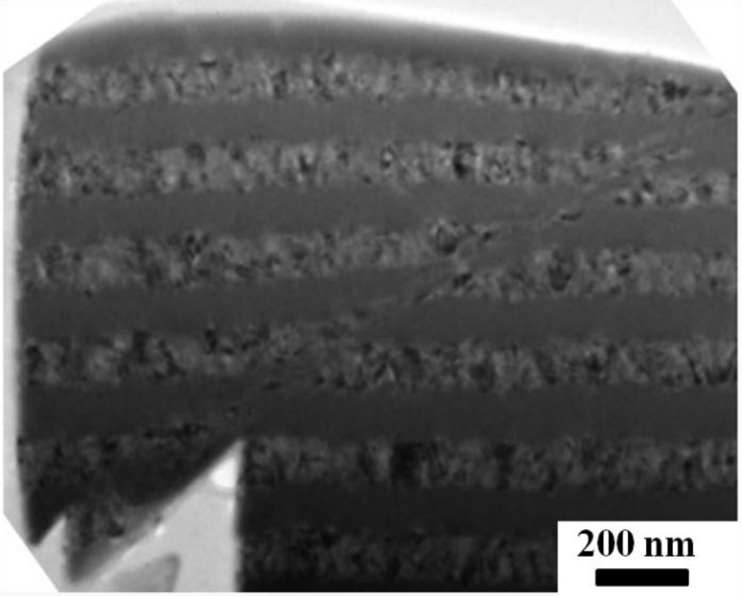
- **BGM + Nano-metals = ???**
  Nanolaminates
  ➡ **high potential for structural applications**
  ➡ **interesting model system**

- **Composite concept might be one of the ways to solve this dilemma. Analyses of mechanical properties and deformation behaviors of the multilayer micropillars are another purpose in this study.**

Results for ZrCu/Zr micropillar

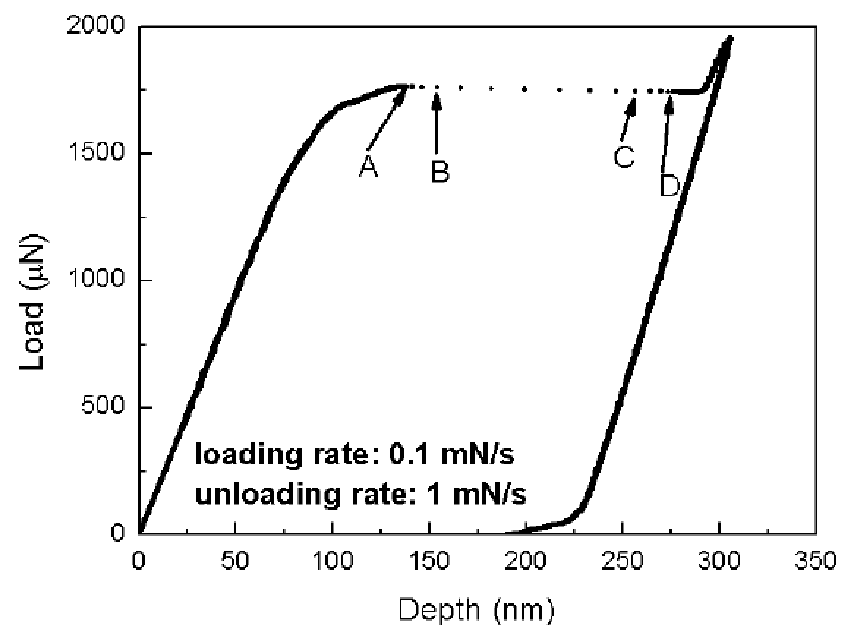
ZrCu/Zr 100/100 nm

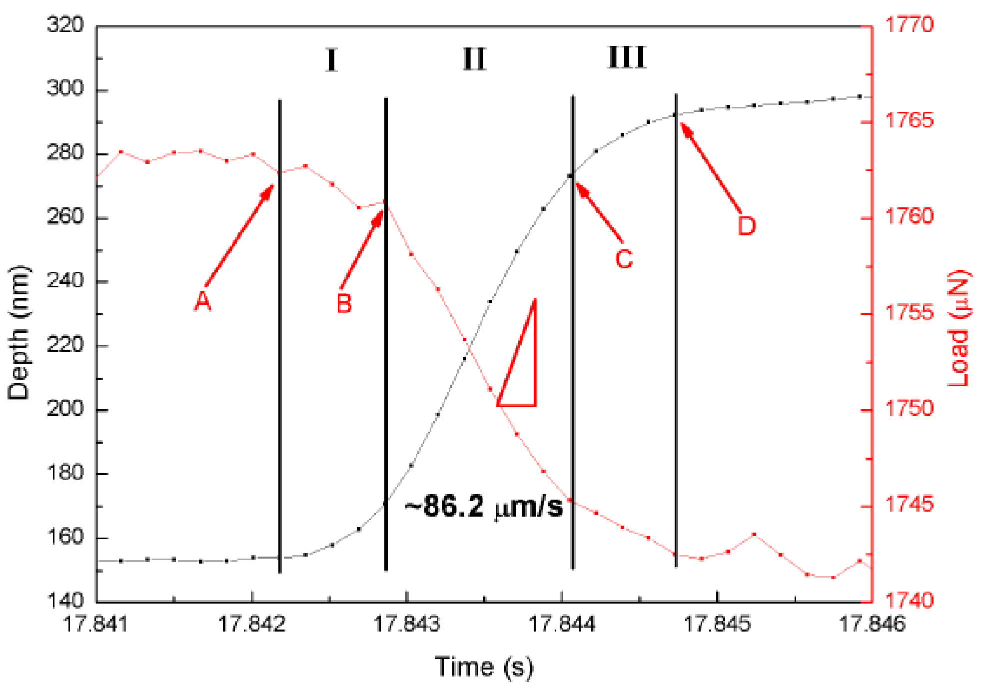




Depth-Time profile

ZrCu/Zr 100/100 multilayered sample

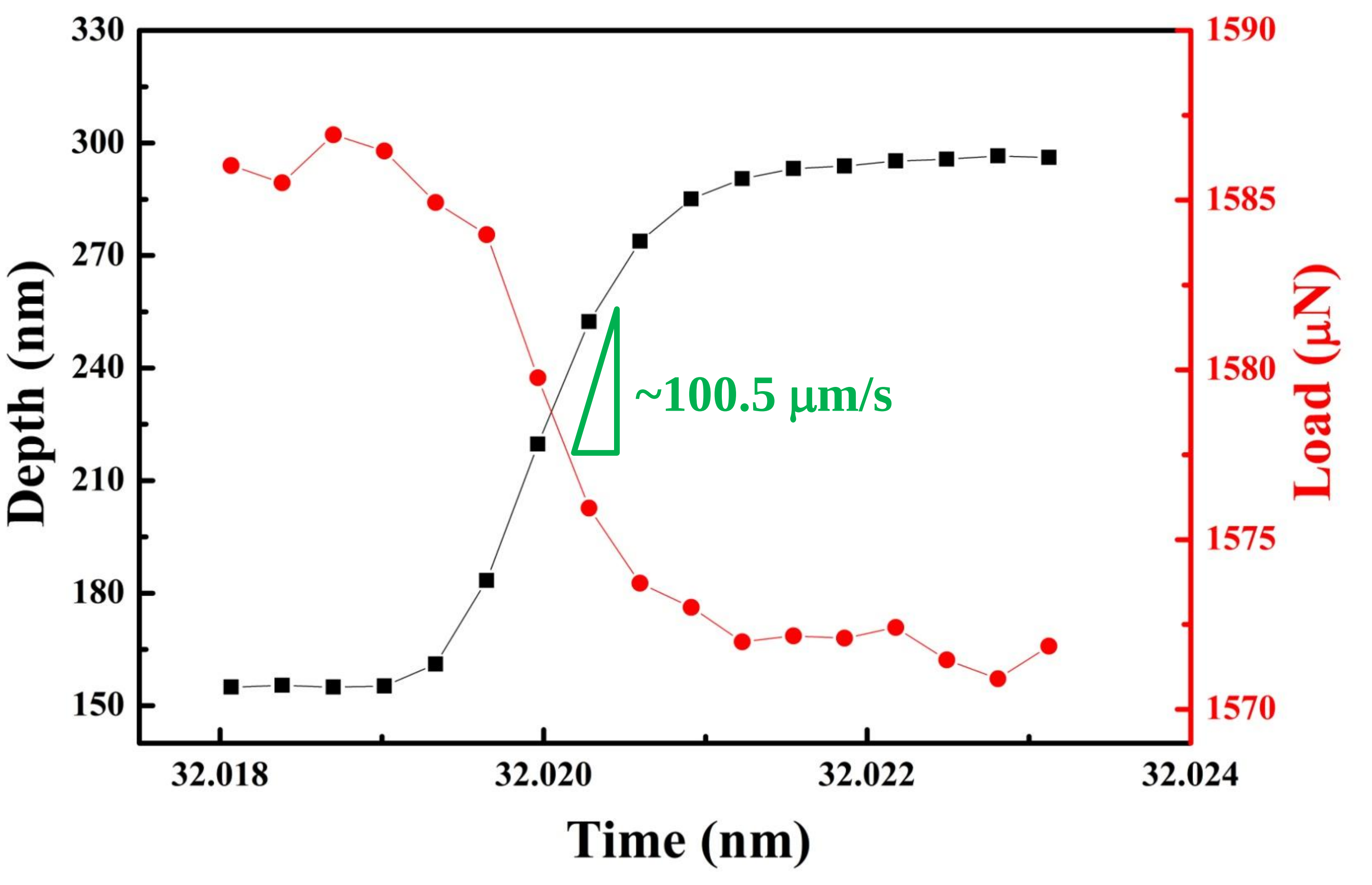




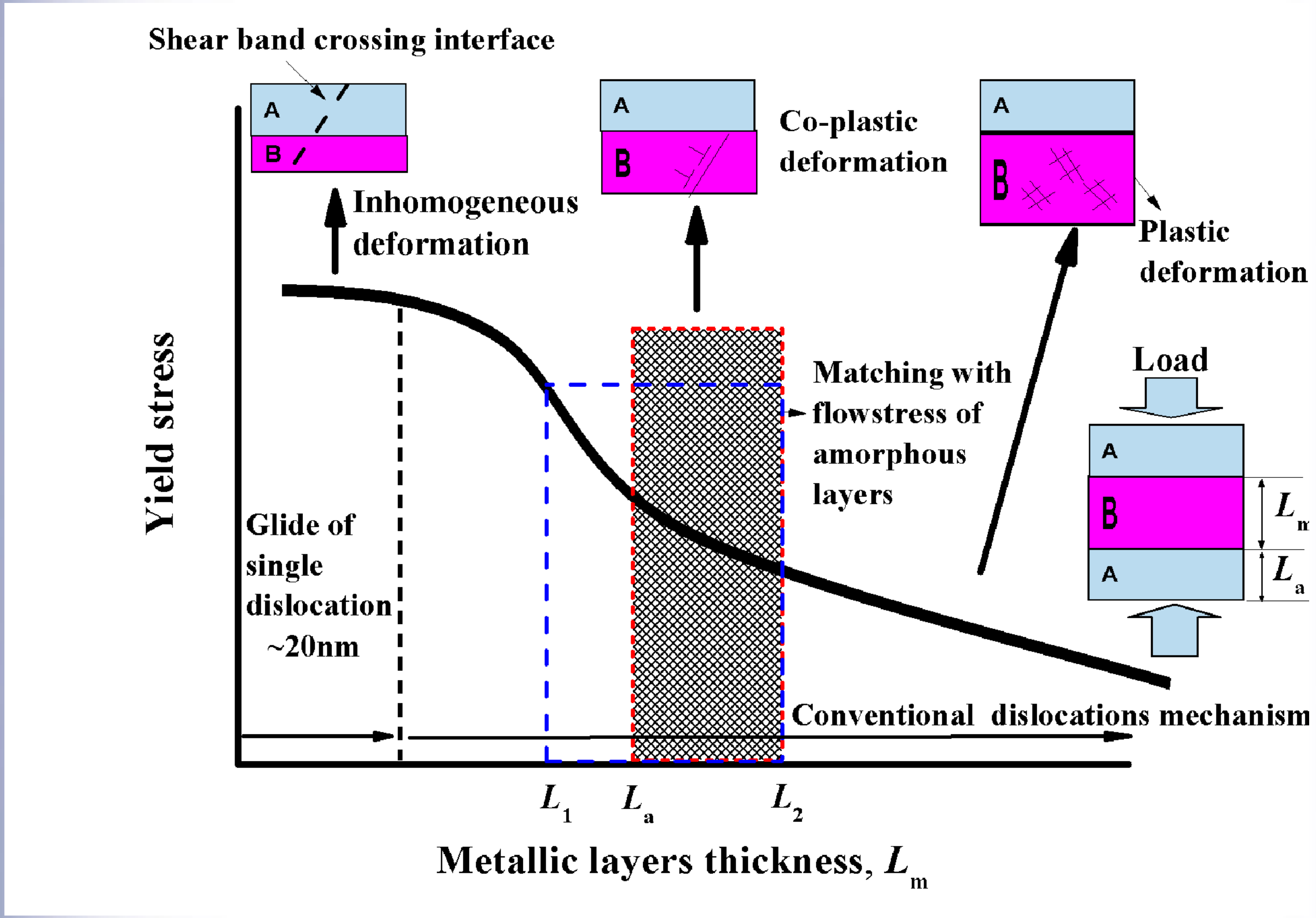
The shear-band propagation consists of three steps: acceleration (I), steady state (II), and deceleration (III).

Depth-Time profile

ZrCu sample

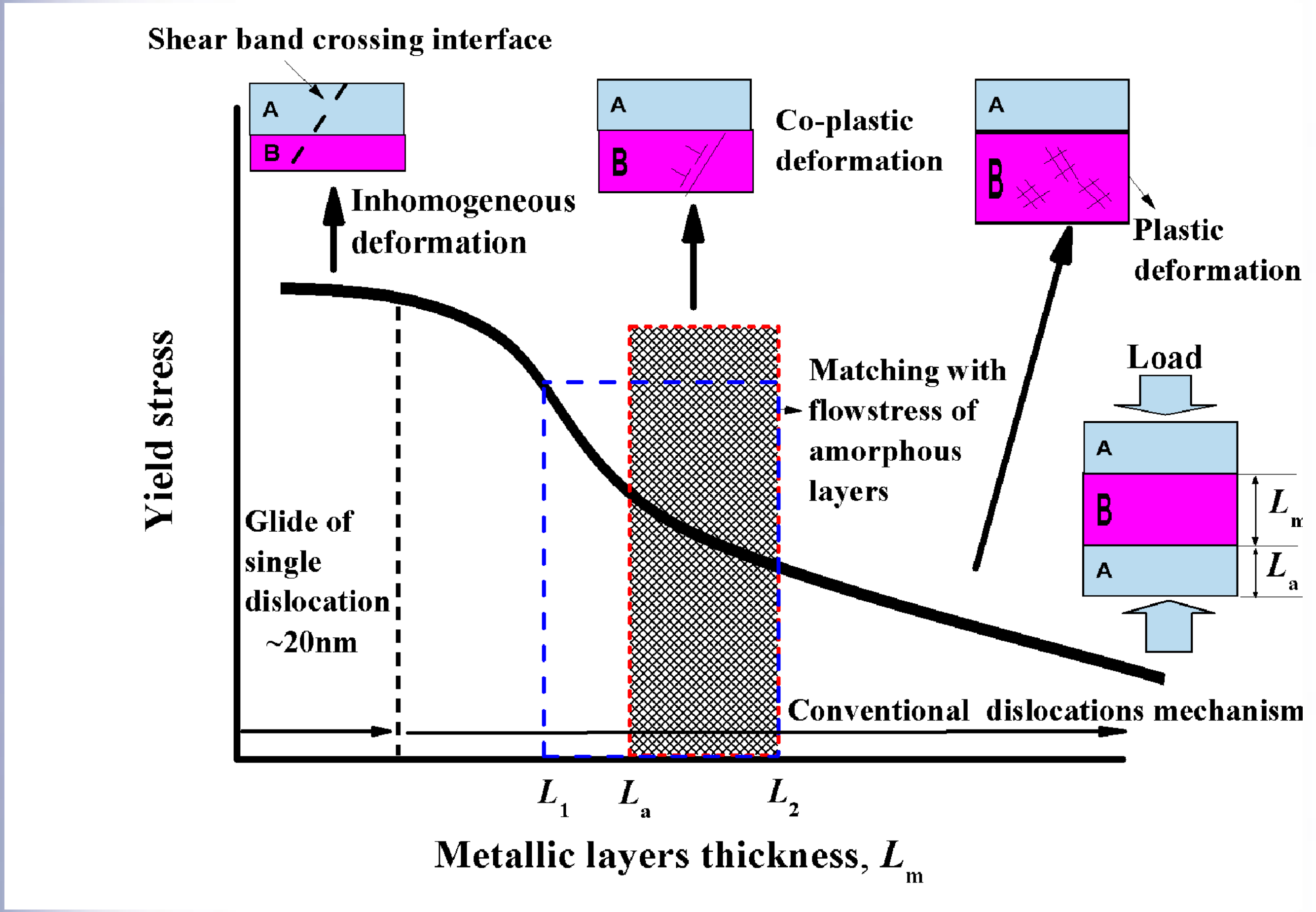


Yield stress vs. Metallic layers thickness



Schematic illustration of the deformation mechanism in the metallic amorphous/crystalline nanolayered composites as a function of metallic layers thickness.

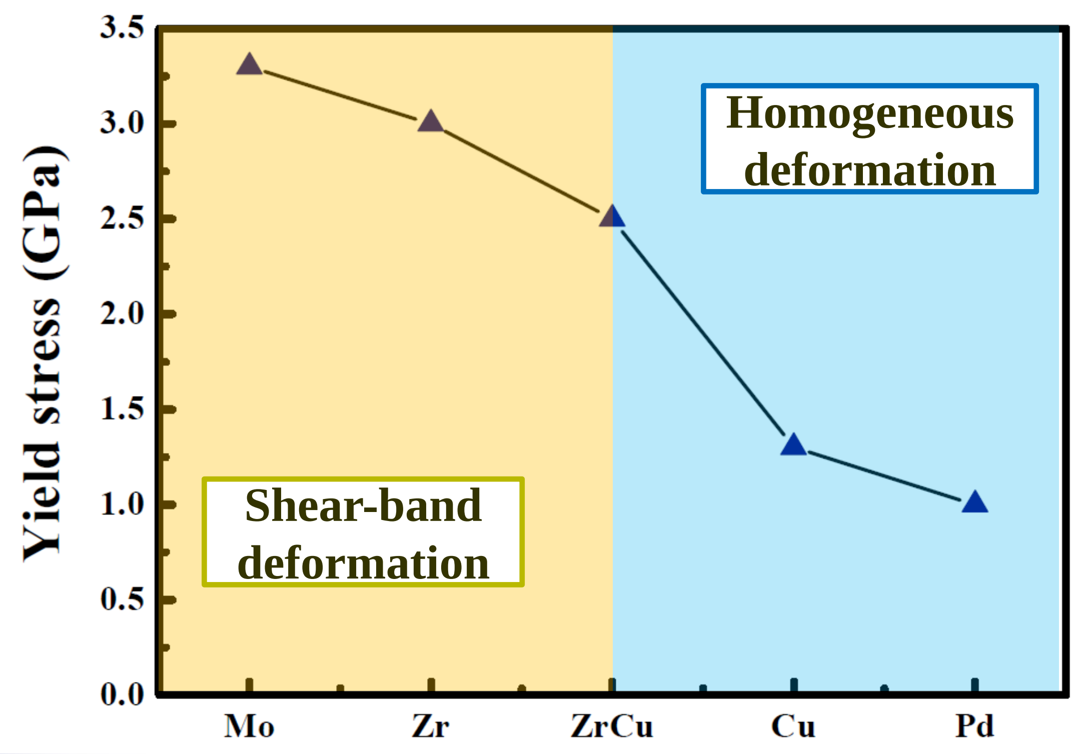
Yield stress vs. Metallic layers thickness



A: inherently ductile metallic amorphous layers (e.g. ZrCu) with L_a thickness; B: soft pure metallic layers (e.g. Cu). Pronounced semi-homogeneous and superplastic-like deformation can occur when $L_a \leqq L_m \leqq L_2$.

Microcompression tests on ZrCu/metal laminates

Materials	Mo	Zr	ZrCu	Cu	Pd
Yield stress (GPa)	~3.3	~3.0	~2.5	~1.3	~1.0



In-situ TEM nanocompression on ZrCu pillars

Research motive

- In-situ TEM compression methodology has been widespread to probe the mechanical deformation instantaneously of the crystalline or amorphous materials under nano-scale resolution.

- It is helpful for us to in-situ monitor the shear band evolution or plastic deformation behavior.

Paper review

The characteristic size of metallic glasses at which the transition from localized to homogeneous deformation occurs has also been found to vary substantially:

400 nm (Volkert et al., 2008)
250 nm (Schuster et al., 2008)
200 nm (Chen et al., 2010)
150 nm (Wu et al., 2009)
100 nm (Guo et al., 2007)

In-situ TEM sample preparation

Omni probe

A First cut

B Side cut

C Tip has been touched the sample

http://www.omniprobe.com

In-situ TEM sample preparation

Omni probe

D The sample has been lifted out.

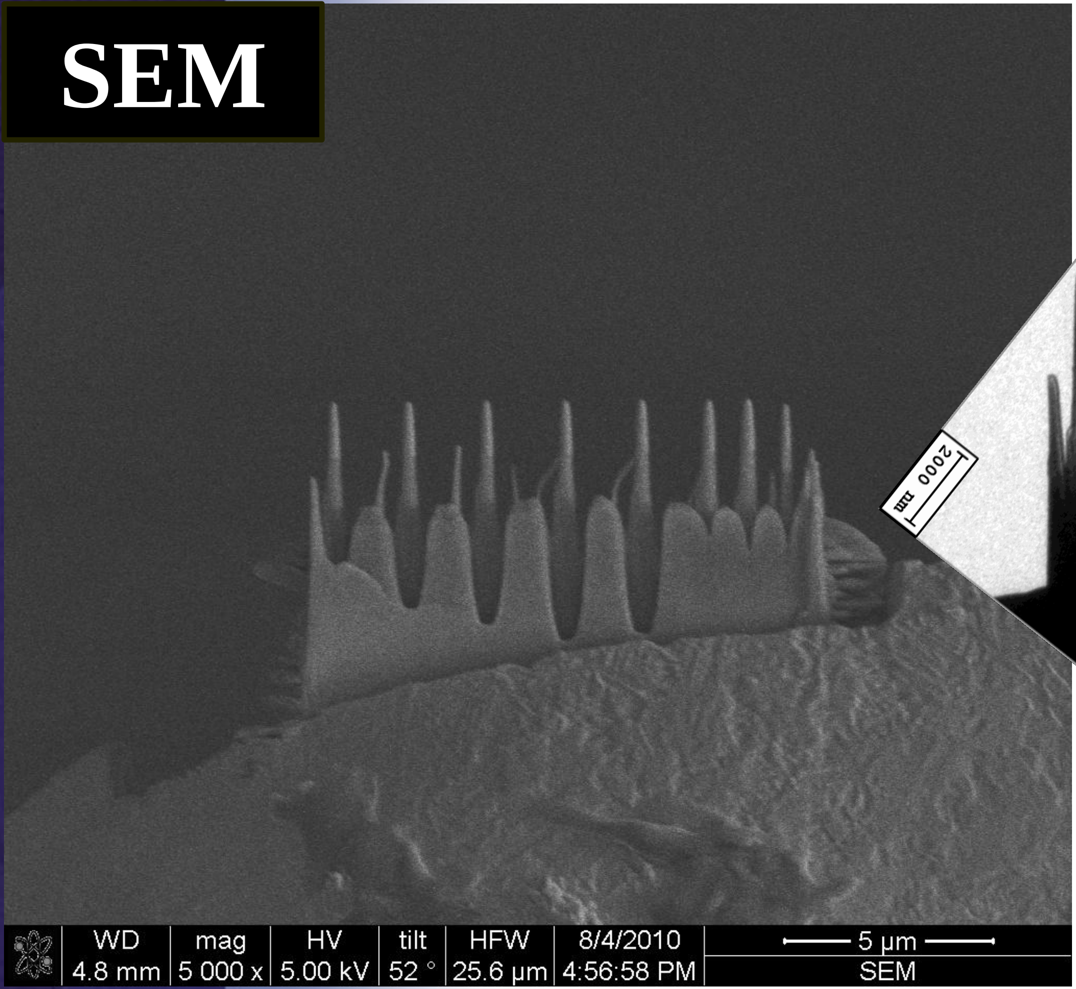
E The sample is attached to a TEM grid.

F Tip separation

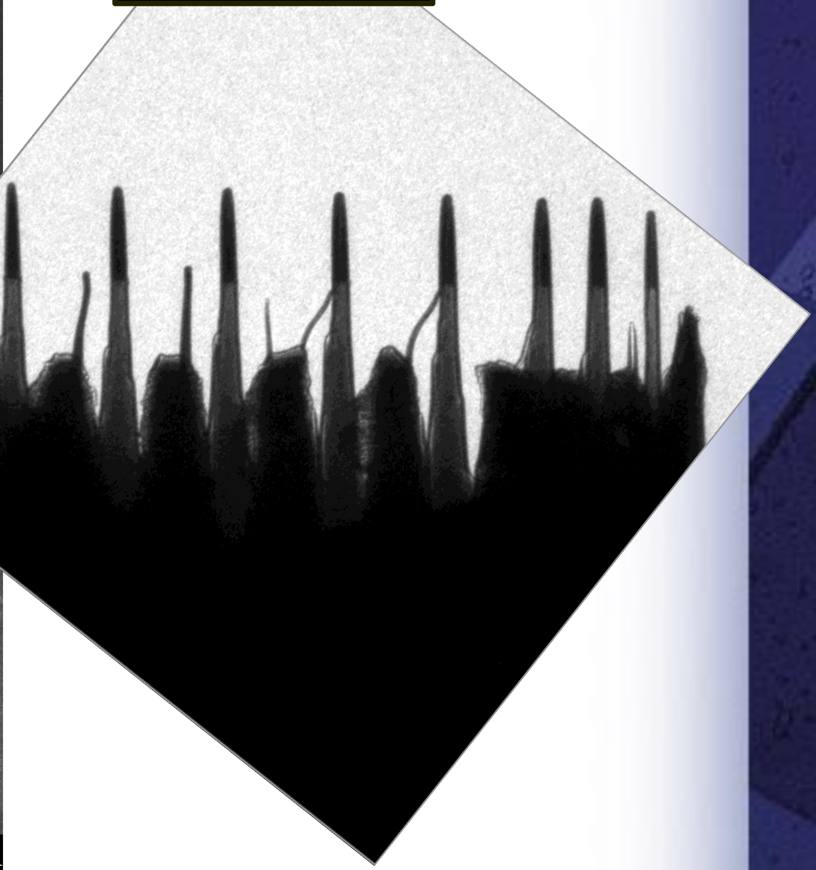
http://www.omniprobe.com

In-situ TEM sample preparation

SEM

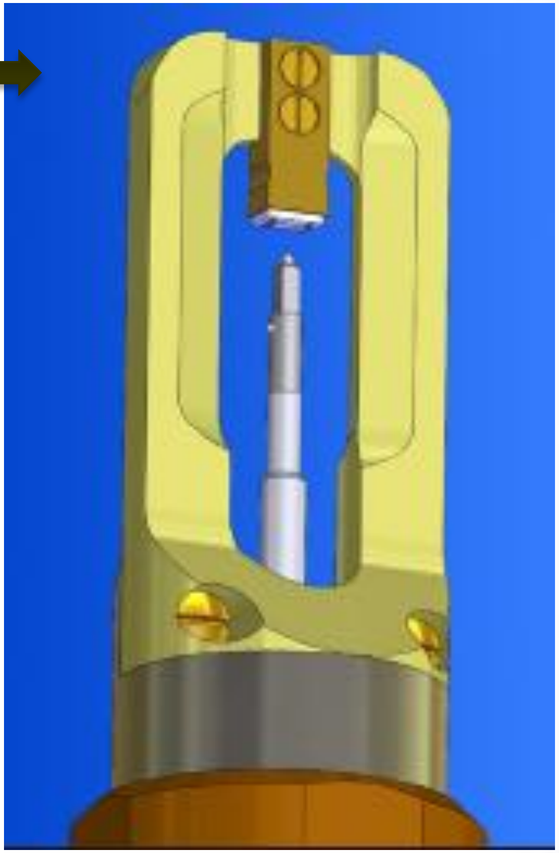


TEM



Holder specifications

TEM PicoIndenter



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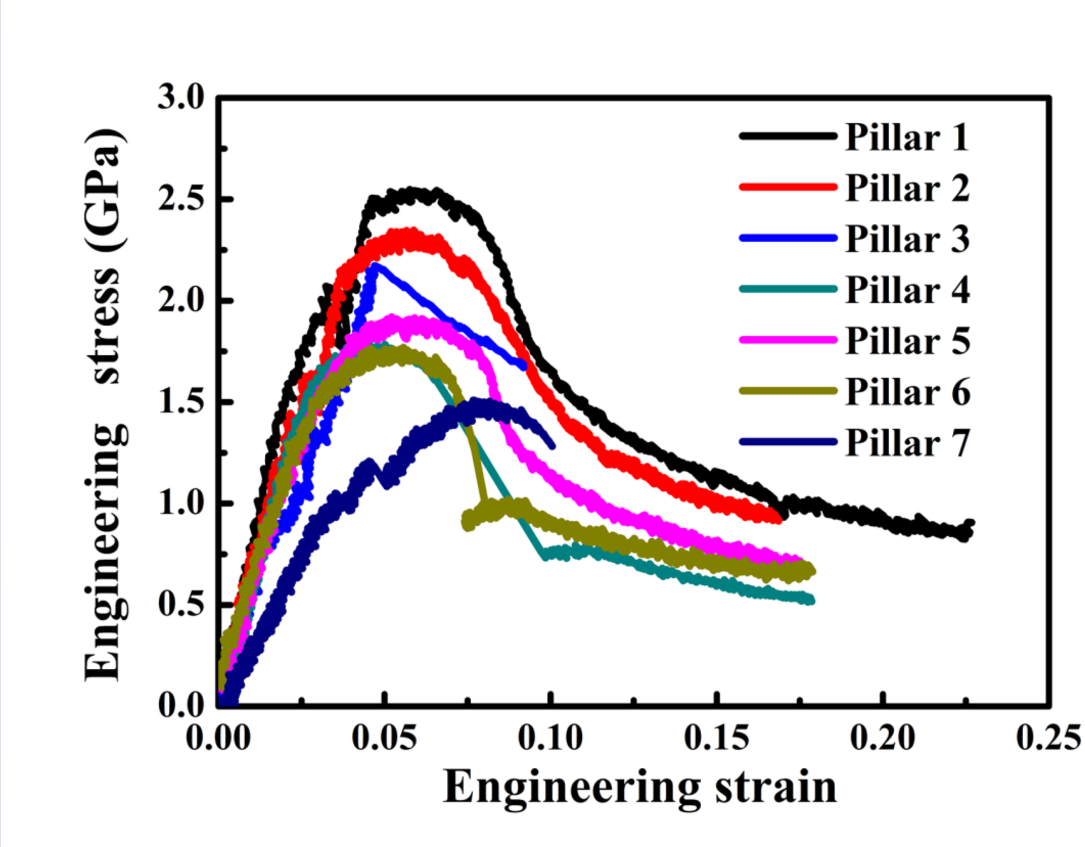
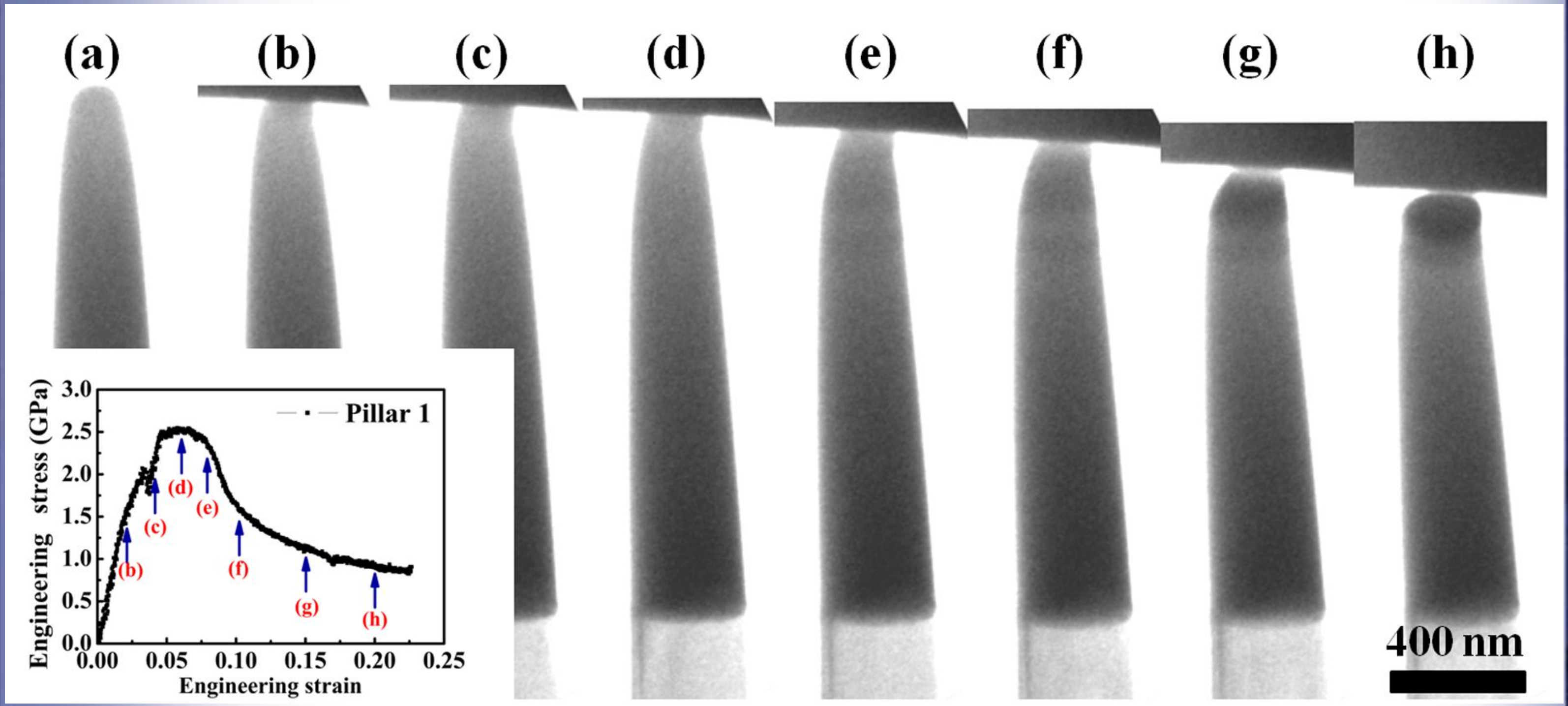
Nanocompression tests on ZrCu samples



Representative stress-strain curves for nanocompression tests on the ZrCu thin film metallic glass pillars.

Nanocompression tests on ZrCu samples



Video snaps taken from the in-situ TEM compression showing the deformation of Zr-based pillar (Pillar 1). The different stages of the nanocompression process are depicted by individual frames [(a)-(h)] at different strains: (a) undeformed. (b) ~2%. (c) ~4%. (d) ~6%. (e) ~8%. (f) ~10%. (g) ~15%. (h) ~20%.

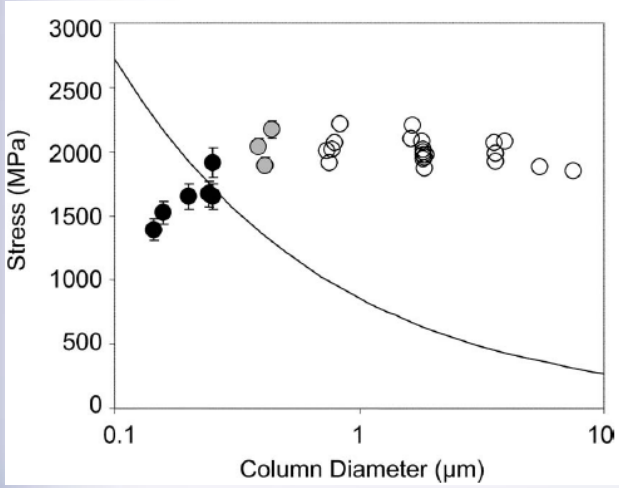
Effect of sample size

The elastic strain energy of the column is decreased by an amount $\pi\sigma\varepsilon r^2 h/2$.
(where σ, ε, r, and h is stress, strain, pillar diameter, and shear band thickness)

The shear band energy is increased by an amount $(2^{1/2}\pi r^2\Gamma)^{1/2}$.
(where Γ is the energy per unit area of shear band.)

Estimation of the critical stress required for shear band formation

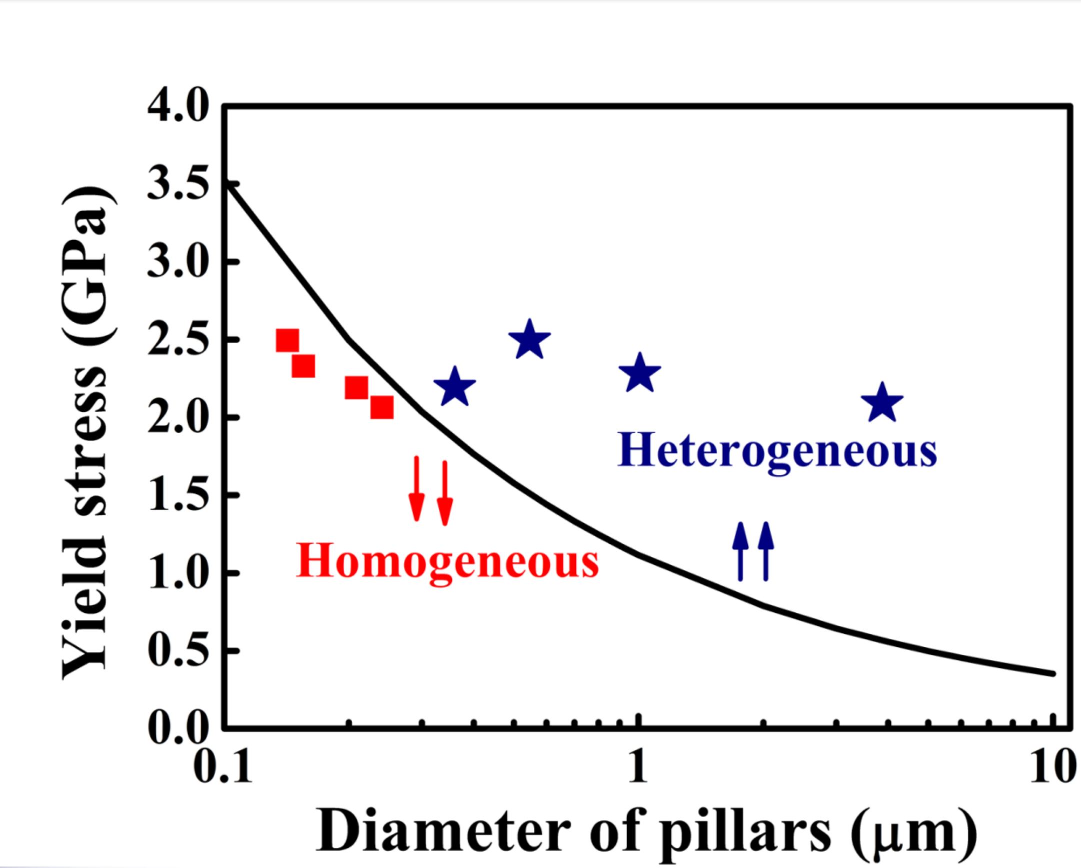
$$\sigma = (2^{3/2}\Gamma E/h)^{1/2}$$



$Pd_{77}Si_{23}$

C. A. Volkert et al. J. Appl. Phys. 103 (2008) 083539.

Effect of sample size



The calculated solid line showing the estimate of the minimum stress required to raise the strain energy high enough to allow for shear band formation. (Upper right region: shear band heterogeneous deformation; lower left region: homogeneous deformation.)