

# Dislocation Confinement and Ultimate Strength in Nanoscale Metallic Multilayers

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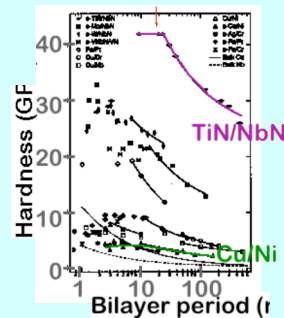
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## Motivation and Background

- Unlimited freedom in choosing layering constituents
- Atomic scale periodicity in structure and composition
- High yield and fracture strength: GPa
- Wide usage: hard coating, MEMS, magnetic media

Special phenomenon in nanoscale multilayers:



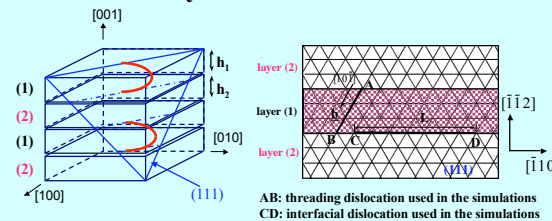
Strength increases with decrease of layer thickness  $h$  and reaches a plateau or softens at very small  $h$ .

Experiment Data on strength plateau or softening in nanoscale multilayer systems (Clemens, Barnett, and Kung, MRS Bulletin, Feb. 1999)

## Methodology

Discrete Dislocation Model is employed. Different layers are assumed to have lattice mismatch and no elastic modulus mismatch. The effects from lattice mismatch and interfacial misfit dislocation substructure are included in the model.

FCC multilayer considered:



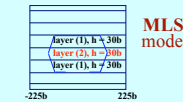
Implementation:

- (111) planes: discretized into triangular cells ( $\sim 20b$ )
- 3 possible line directions and Burgers vectors
- Cells may slip if  $\sigma E = \sigma E(\text{elastic}) - \sigma W(\text{stress}) < 0$
- $\sigma E$  computed using elasticity of Volterra dislocation
- Biaxial stress is ramped on the multilayer thin film

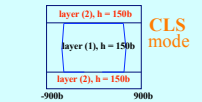
## Results

With  $h_1 = h_2$ ,  $\sigma_1 = \sigma_2$ ,  $a_2^0/a_1^0 = 1.002$ :

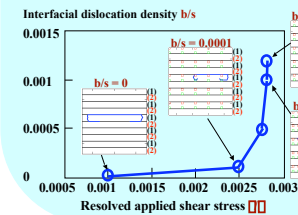
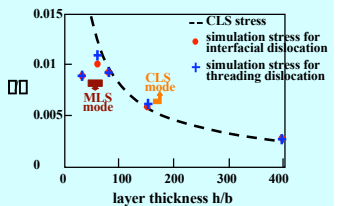
Multiple layer slip for  $h_1 = h_2 = 30b$



Confined layer slip for  $h_1 = h_2 = 150b$



Multilayer strength vs. layer thickness from simulations



Interfacial misfit dislocation evolution during loading for  $h_1 = h_2 = 400b$

## Objective

Unveil the possible mechanisms behind this strength plateau or softening phenomenon in nanoscale multilayers

## Conclusions

For large layer thickness (such as  $400b$ ):

- Coherent interface is unstable
- CLS occurs initially,  $b/s \uparrow$ , interfacial disl. strengthening
- Later, transition from CLS to codeformation

For small layer thickness (such as  $30b$ ):

- Coherent interface is stable
- No CLS, and no interfacial disl. strengthening
- MLS: strength plateau