



Texture Inheritance in Al(Cu) Interconnect Materials

Conal Murray

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Outline

Offset Texture

- definition and description
- texture inheritance

Experimental

- Al(Cu)/Ti on **interlevel dielectric (ILD)** layers
- Characterization: XRD, TEM, SEM, AFM

Surface Offset Distribution (SOD)

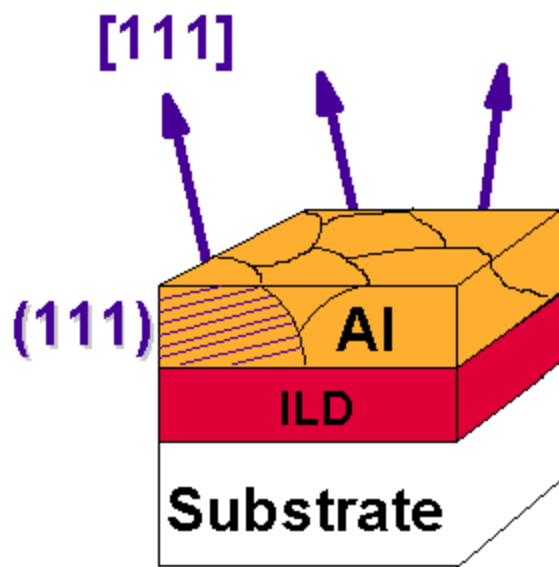
- calculation using AFM data

Link between SOD and Offset Texture

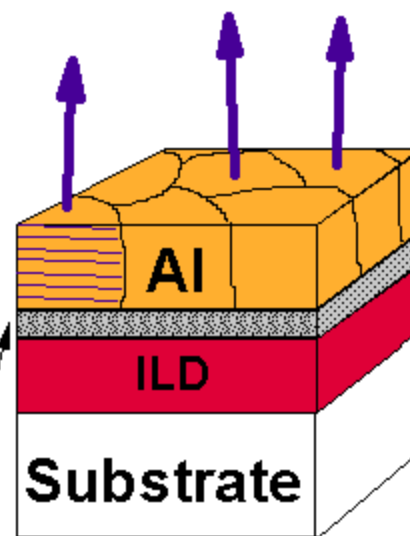
- praises and pitfalls



Texture Inheritance



- **Al on Interlevel Dielectrics (ILD)**
 - offset in maximum $\{111\}$ texture from substrate normal

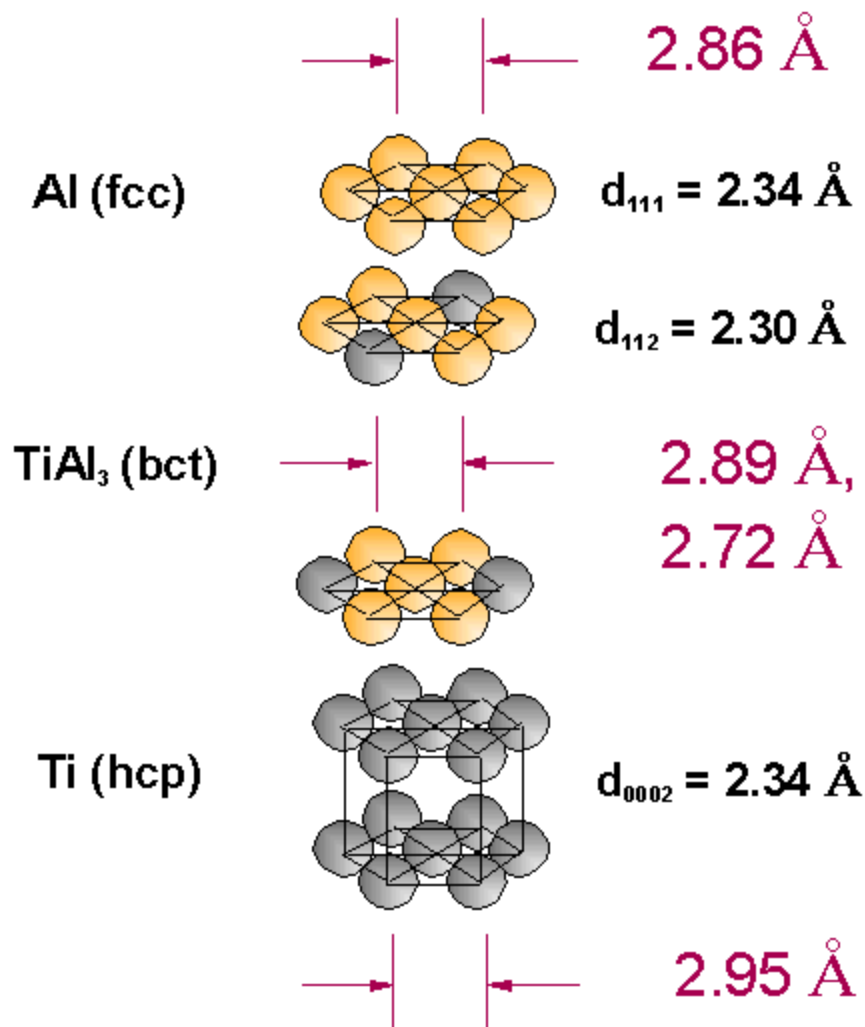


- **Ti underlayer on ILD**
 - sharpens Al $\{111\}$ texture
 - grain boundary orientation



Proposed Effects of Ti

- Surface energy modification
- Epitaxial relation
- Reaction layer





Motivation

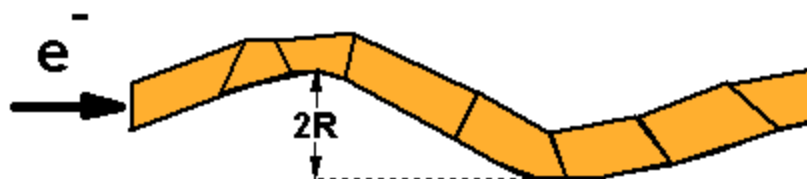
Deposition Surface Morphology

- Effects of roughness on microstructure



Ti Underlayer

- Effects of epitaxy
- surface energy



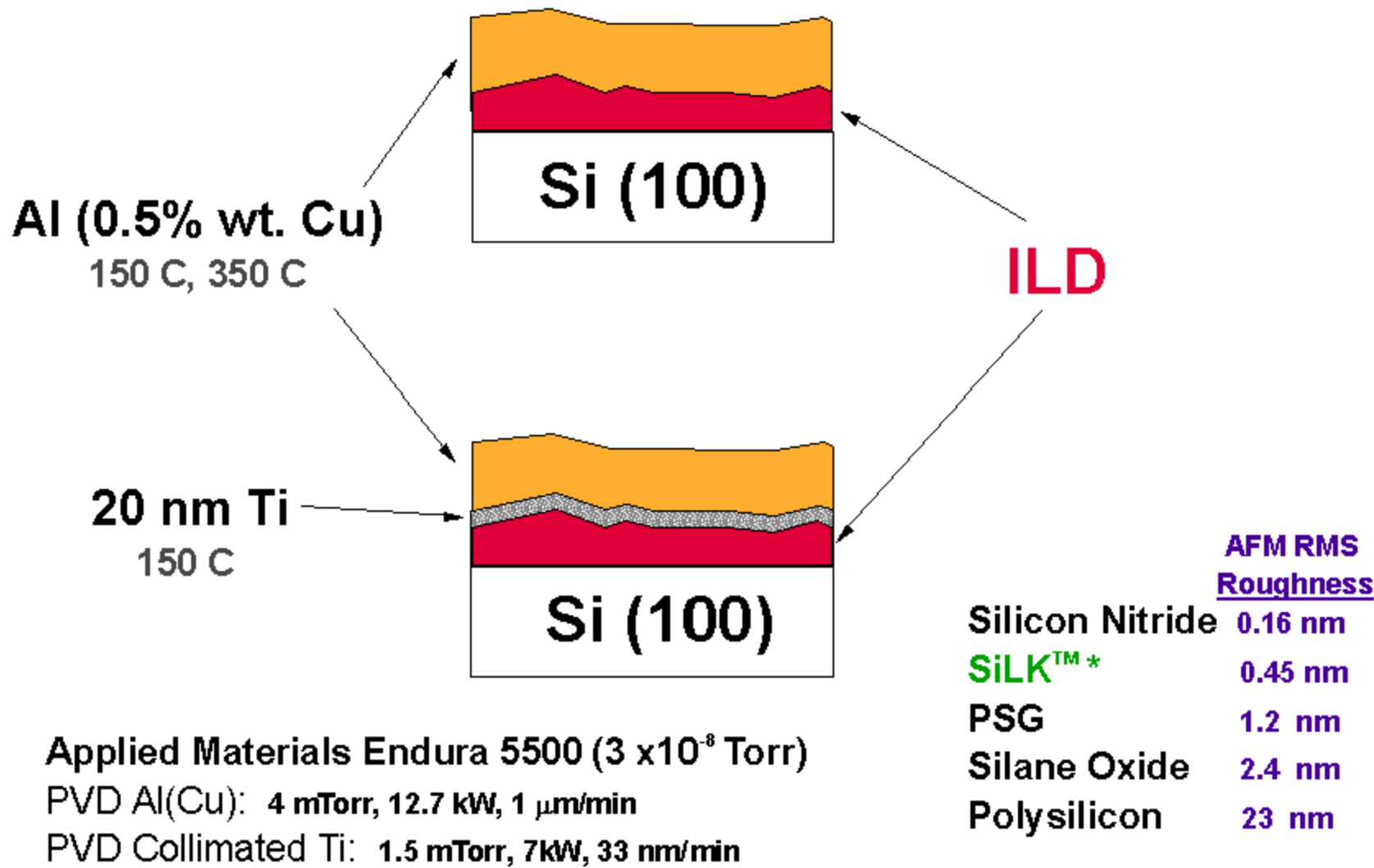
As $t \downarrow (< R)$, roughness effects \uparrow



Experimental



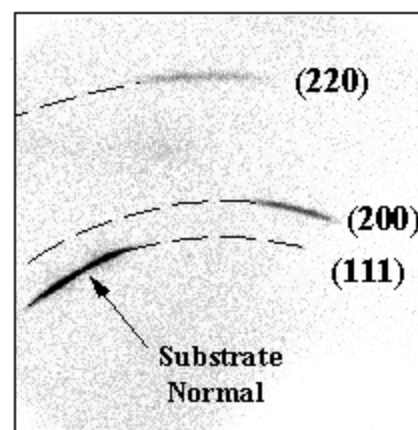
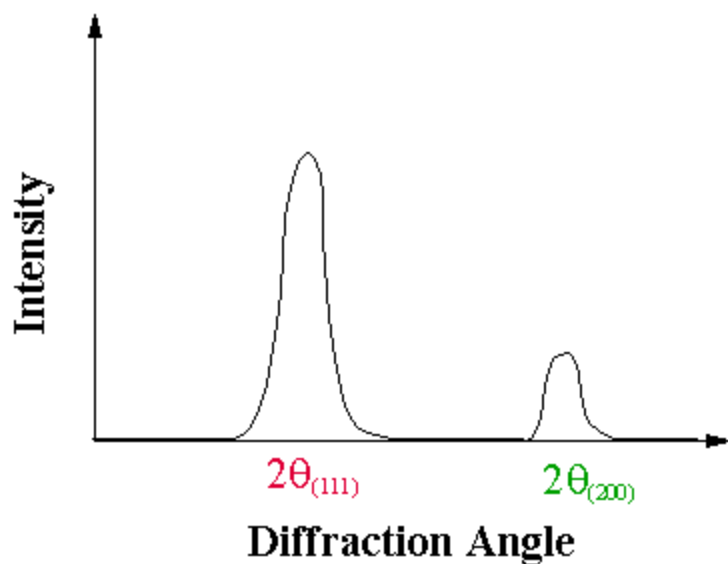
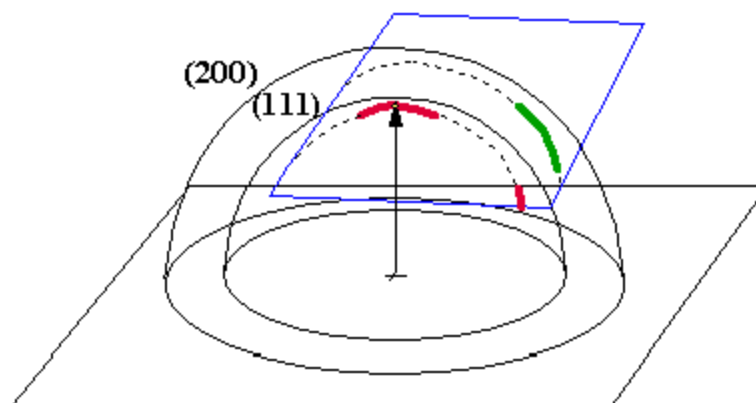
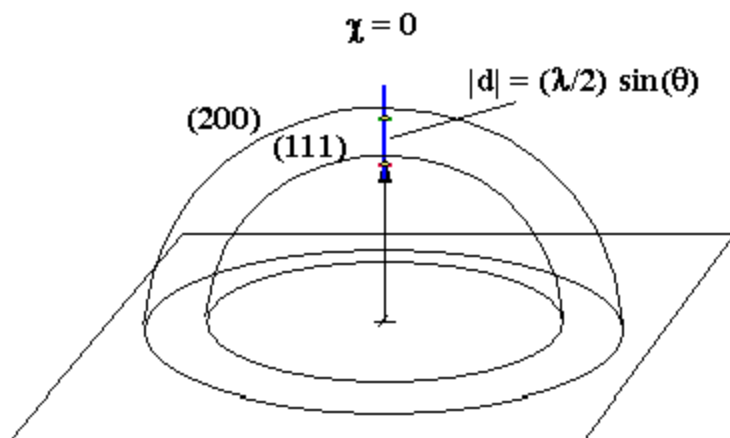
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* The Dow Chemical Company
Midland, MI

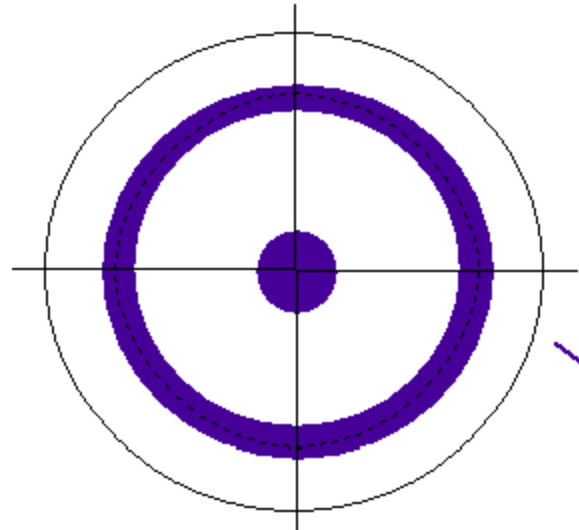


θ - 2θ vs. Texture Measurements

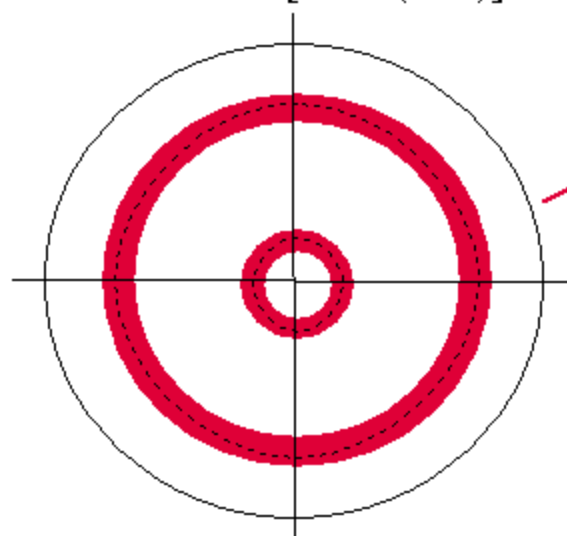


▼ (111) Fiber Texture Scenarios

Conventional

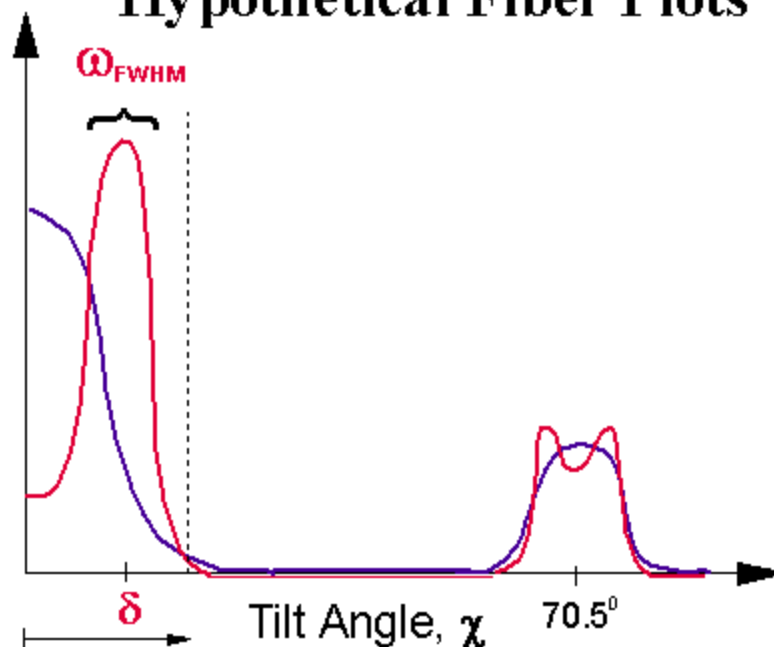


Offset [near-(111)]



Normalized Intensity

Hypothetical Fiber Plots



ω_{95} (95% of peak area)

ω_{95} is not unique

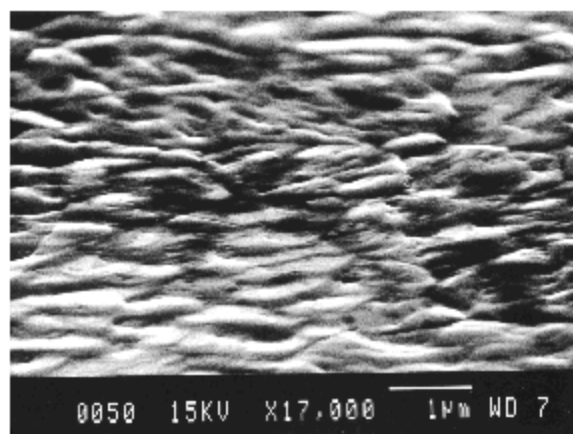
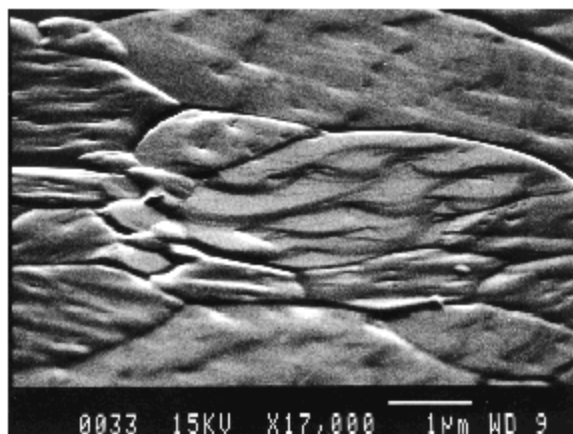
$$\omega_{95} \sim \delta + \omega_{FWHM}$$



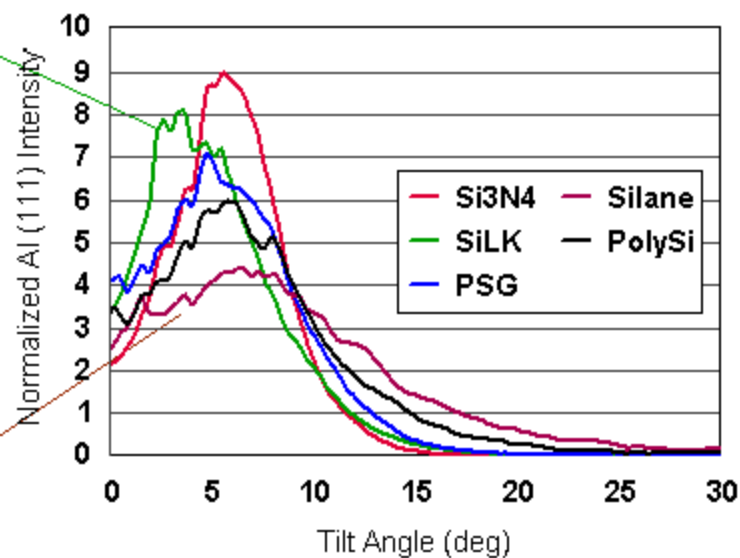
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Results - Offset Texture



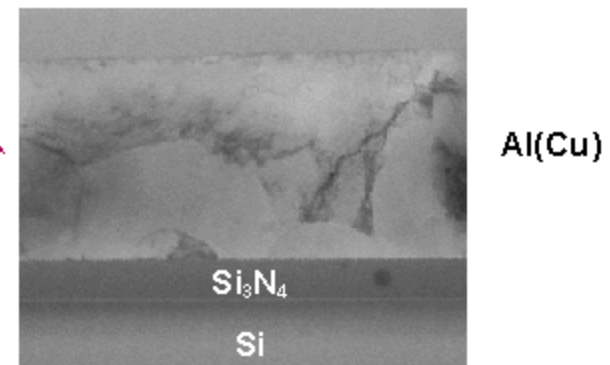
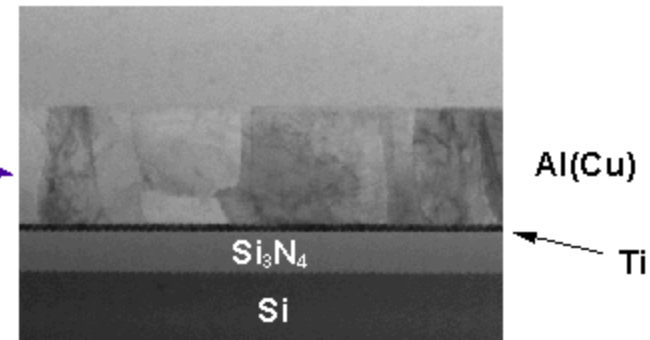
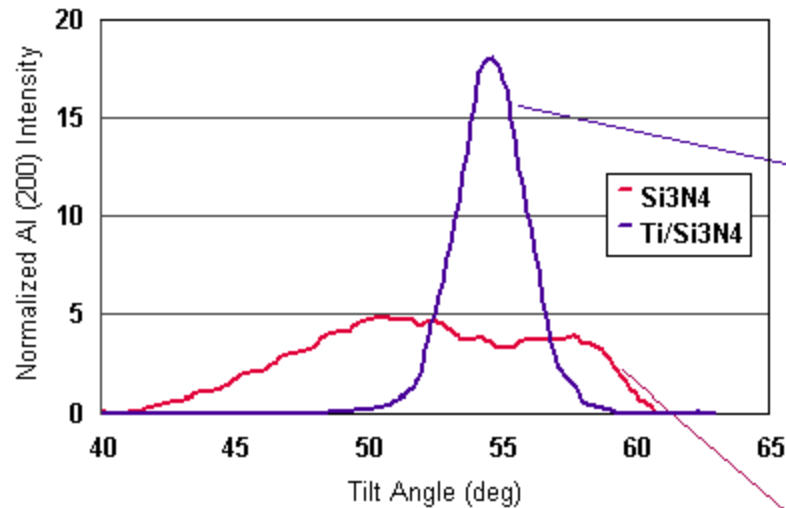
500 nm Al(Cu) Fiber Plots (350 C)





Results - Effects of Ti

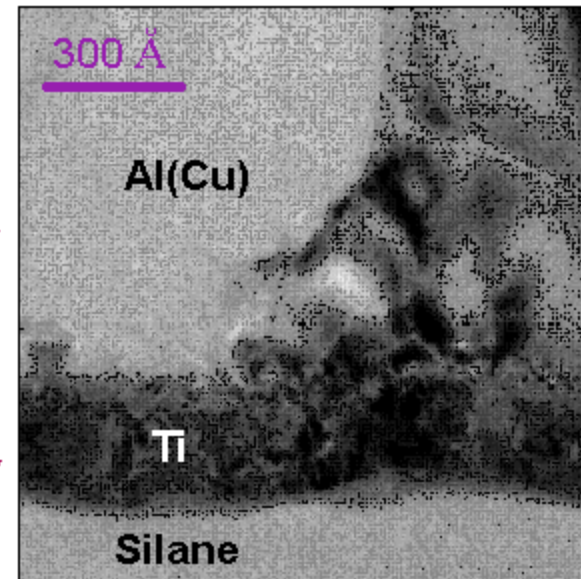
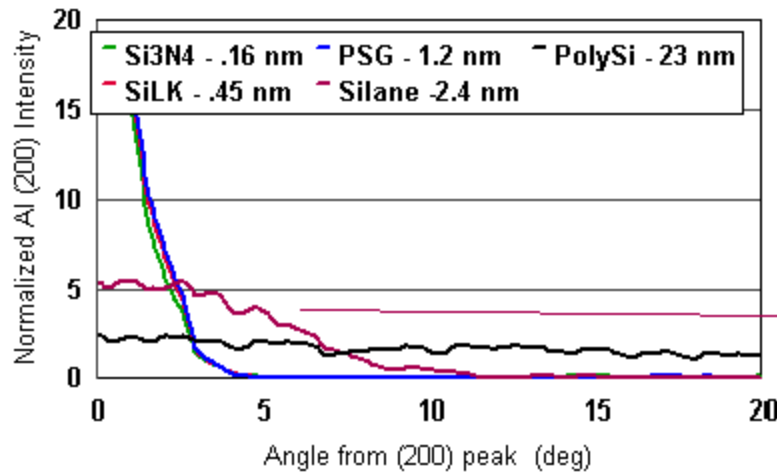
500 nm Al(Cu)/Ti (200) Fiber Plots



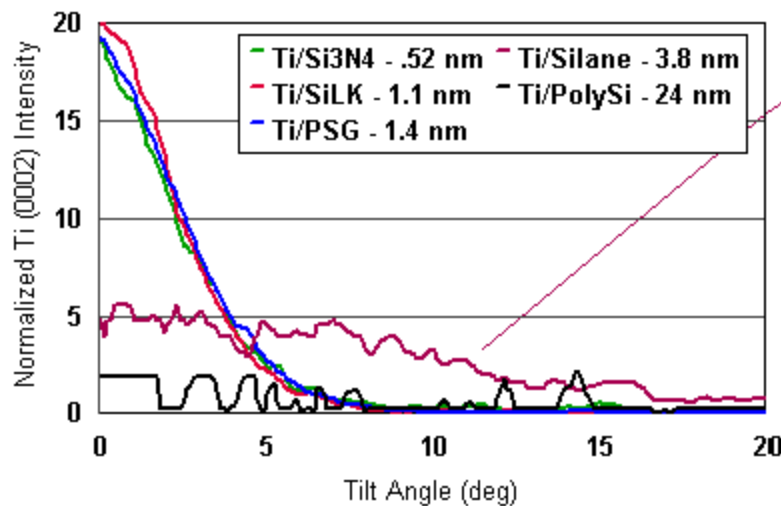
- removes Al(Cu) offset texture
- epitaxial template

Texture Inheritance (150 °C)

500 nm Al(Cu)/Ti (200) Fiber Plot



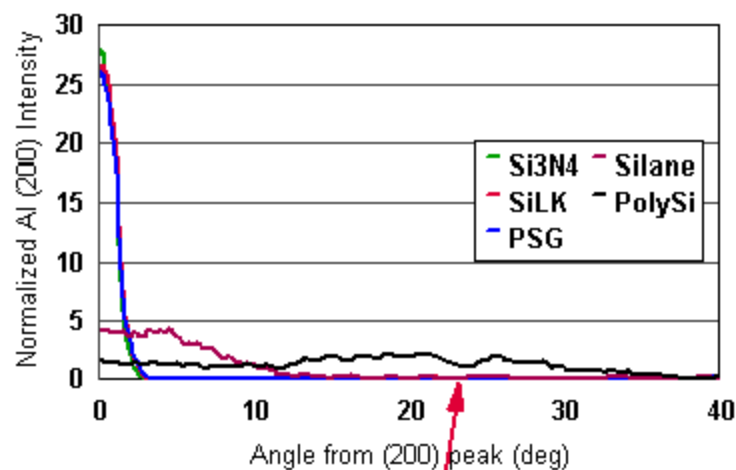
20 nm Ti (0002) Fiber Plot





Texture Inheritance (350 °C)

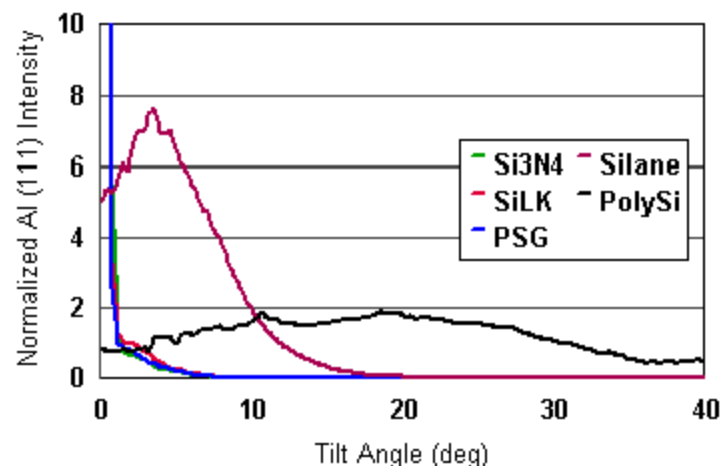
500 nm Al(Cu)/Ti (200) Fiber Plot



✗ spurious 'dips' in texture intensity

✓ offset in (111)-oriented grains

500 nm Al(Cu)/Ti (111) Fiber Plot



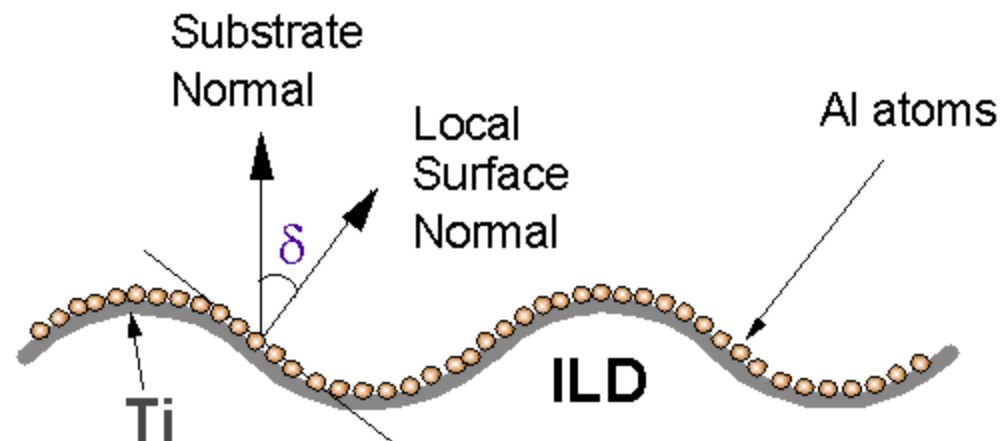
✗ contribution from Ti (0002)

✓ better resolution of offset

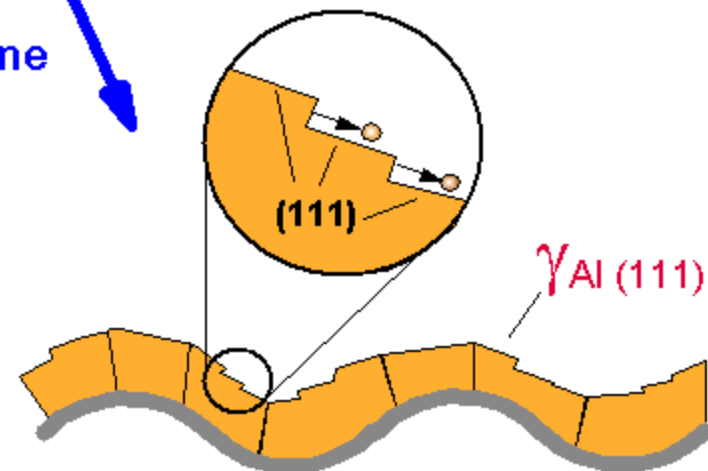
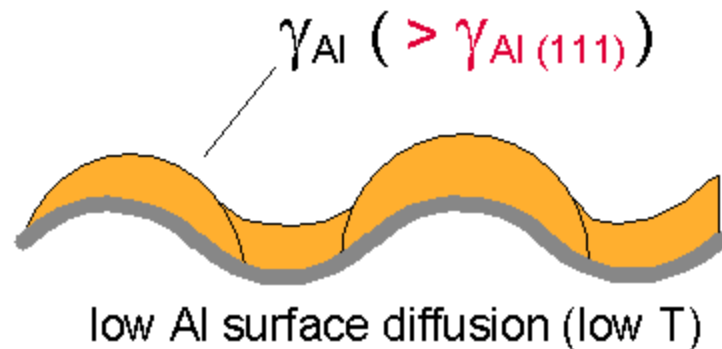


Linking Surface and Offset Texture

Early in Deposition

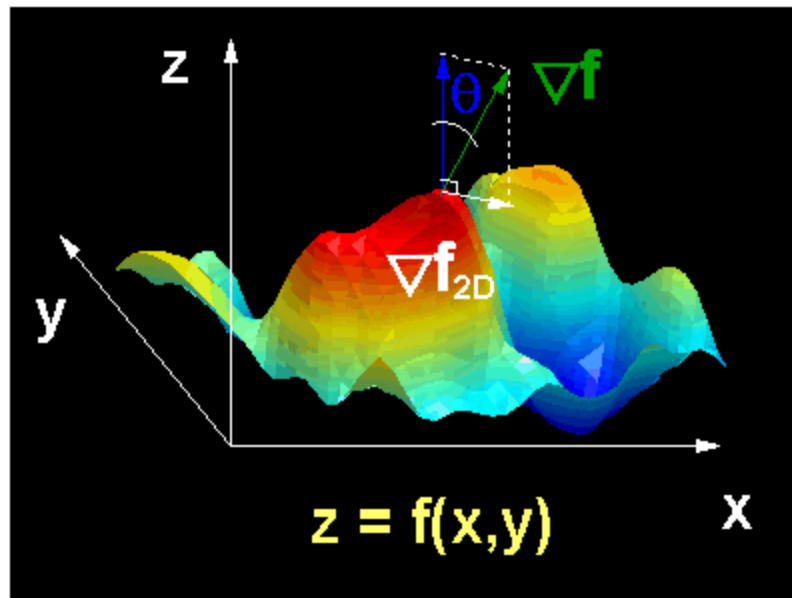


Increasing Deposition Time



higher Al surface diffusion
- faceting of Al grain surfaces
- reduction of surface energy γ

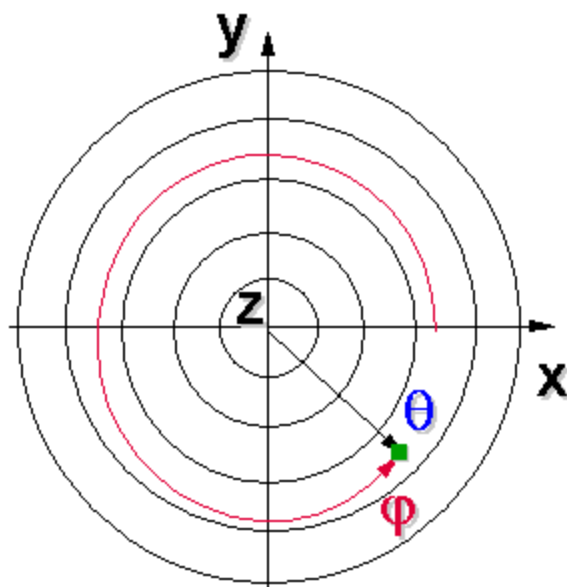
Surface Offset Calculation



At each point on surface:

$$\theta = \tan^{-1} (|\nabla f_{2D}|)$$

$$\varphi = \tan^{-1} \left(\frac{df}{dy} / \frac{df}{dx} \right)$$

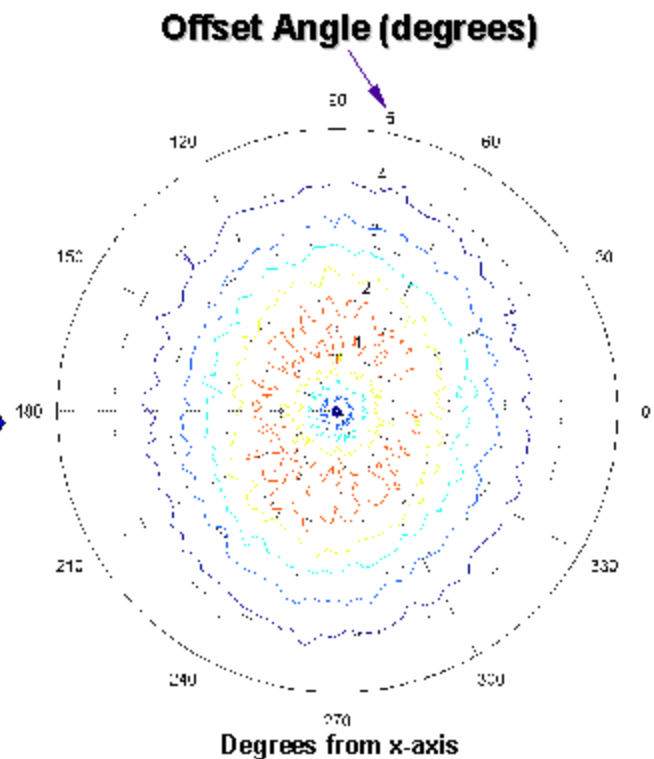
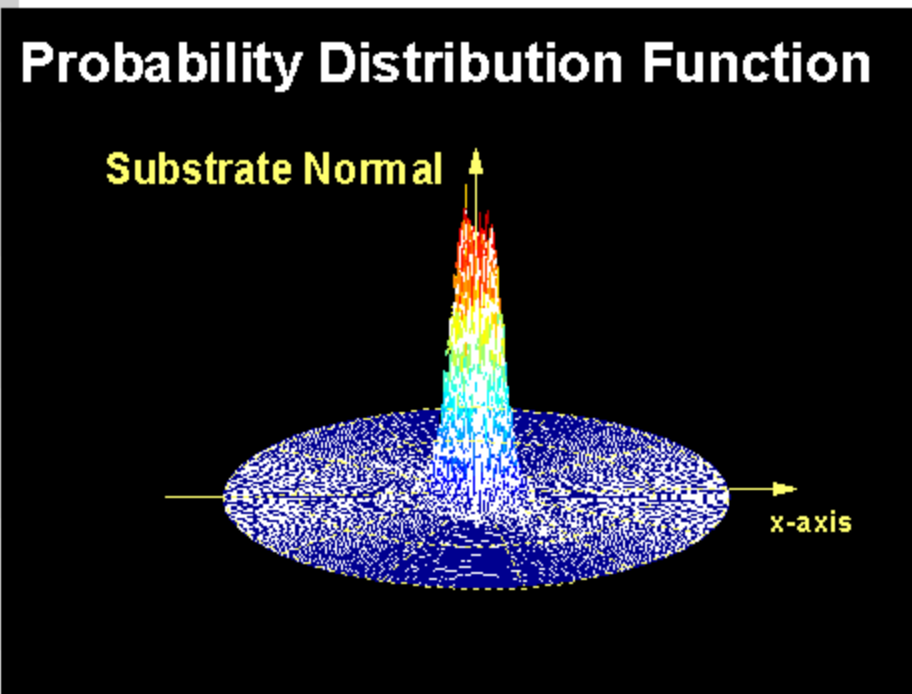


Calculate distribution of local offset angles from AFM surface heights



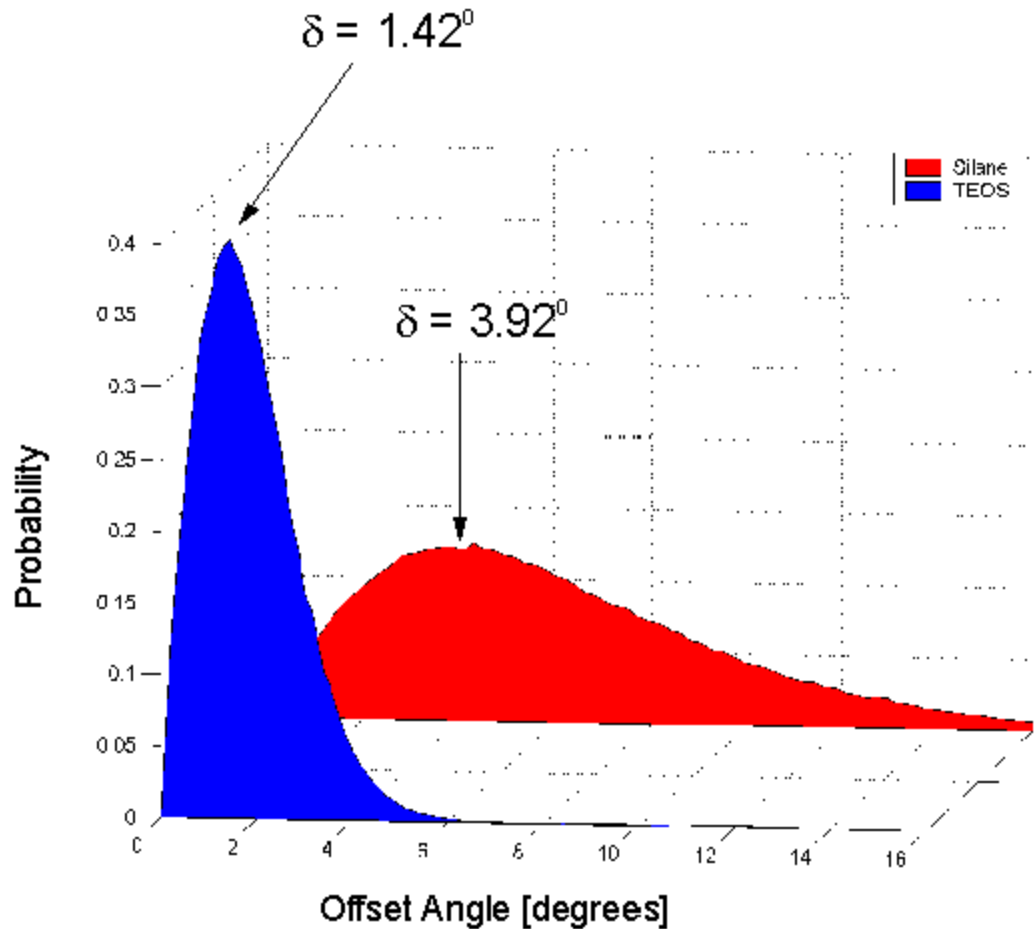
Surface Offset Distribution

PE-TEOS / Si (100) wafer



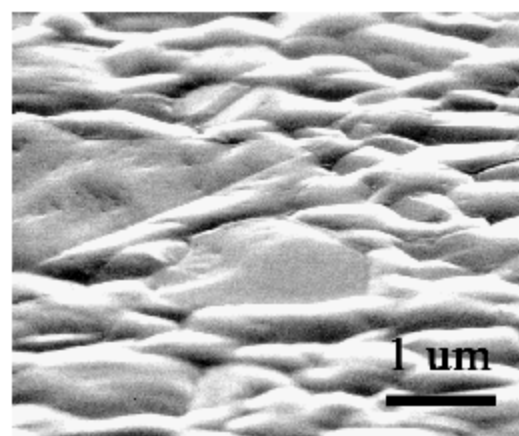
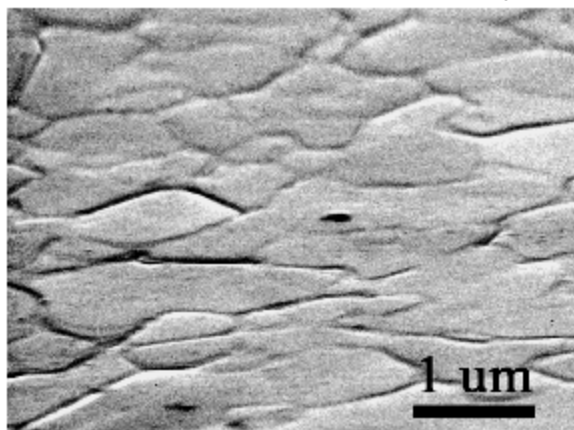
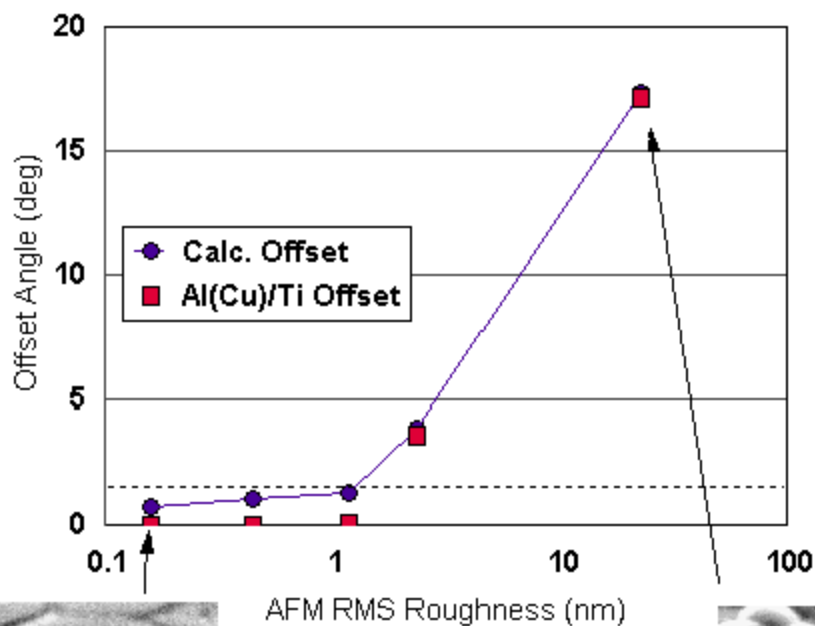


SOD Fiber Plot





Results - Al (111) Offset on Ti/ILD



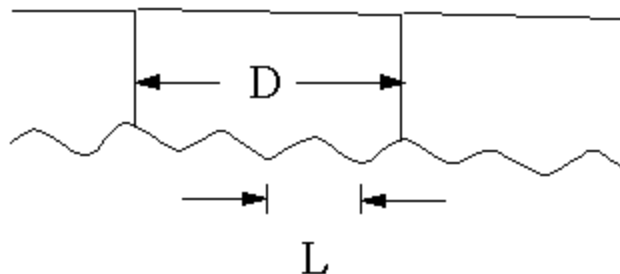


Limitations

What affects threshold roughness ?

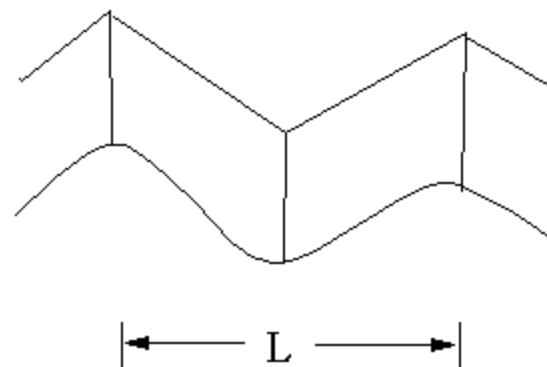
Physical

- lateral extent of roughness, L
vs. grain size, D



Experimental

- ability to resolve offset
- AFM tip convolution





Summary & Future Work

Offset Texture

- Grain surface faceting

Al(Cu)/Ti on ILD

- Epitaxial template

Surface Offset Distribution (SOD)

- Al(Cu)/Ti offset texture \leftrightarrow ILD roughness

In-situ Growth

- Development of terraces, coalescence

Implications for Cu



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