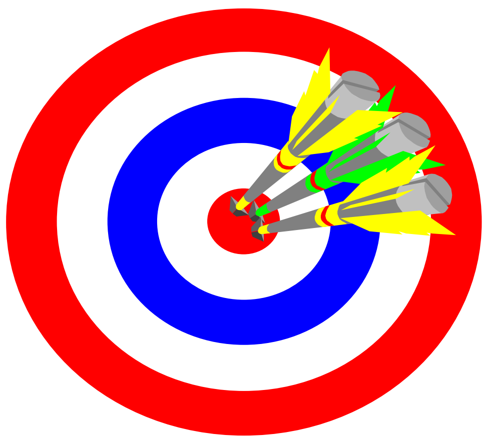
# Crystallographic Texture in Plated Cu Thin Films



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# Outline

- Why measure film texture?
- Measuring Techniques
  - Four-Circle Goniometer
  - Area Detector
  - EBSP
- Texture in Aluminum Films
- Texture in Copper Films
- Conclusions

# Time Dependent Failure Mechanisms

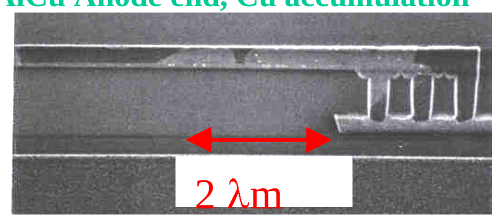
**Gradients** → **Fluxes**

Electric Field, E → Current

Temperature, T → Heat Flow

Concentration ($\lambda$), c → Diffusion

AlCu Anode end, Cu accumulation



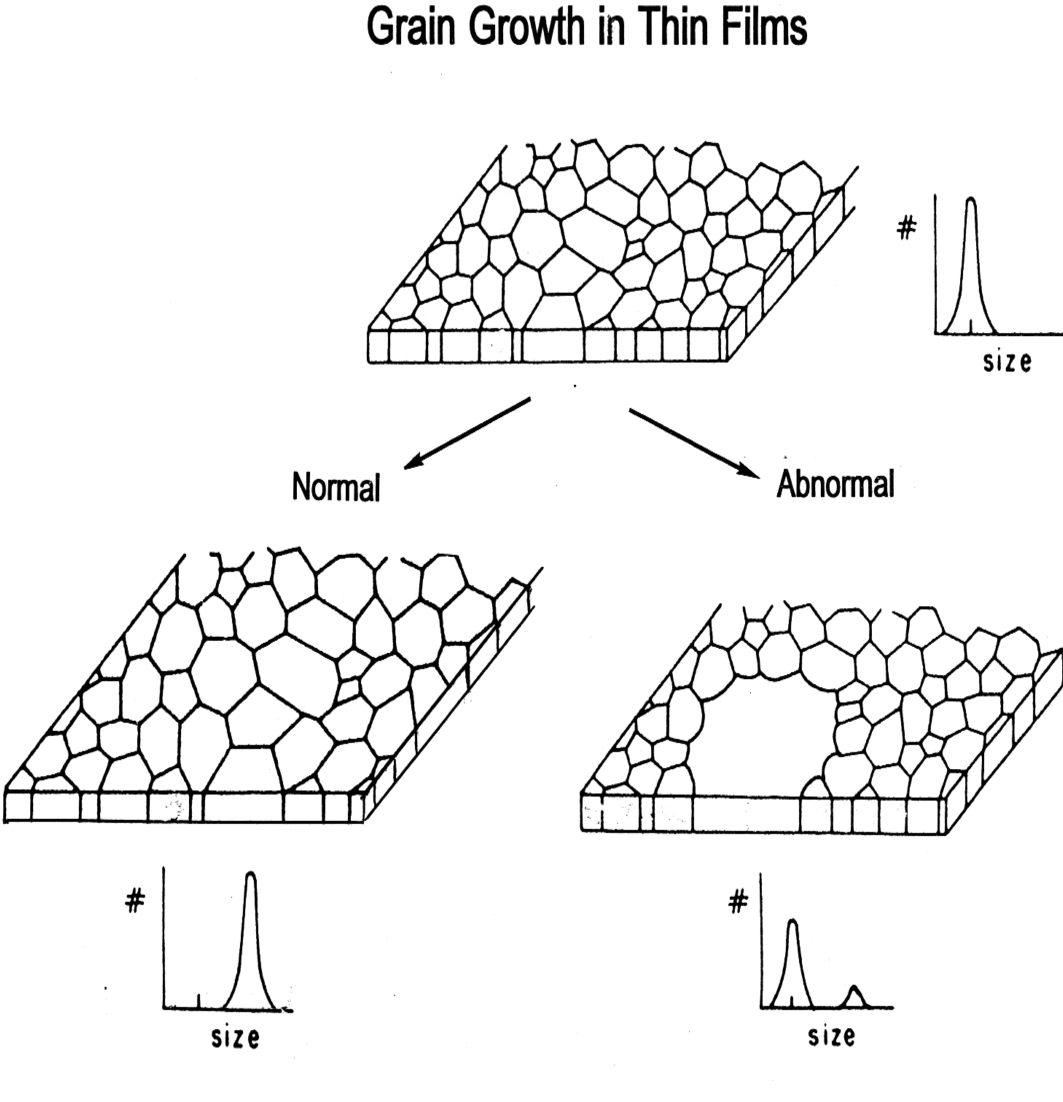

Diffusion - Kinetic Model

$$J_{atoms} = -J_{vacancies}$$

$$J_{atoms} = L_1\, dc/dx + L_2\, E + L_3\, dT/dx + L_4\, d\rho/dx$$

**“Microstructure” sets the boundary conditions and sets the sinks and sources of vacancies**

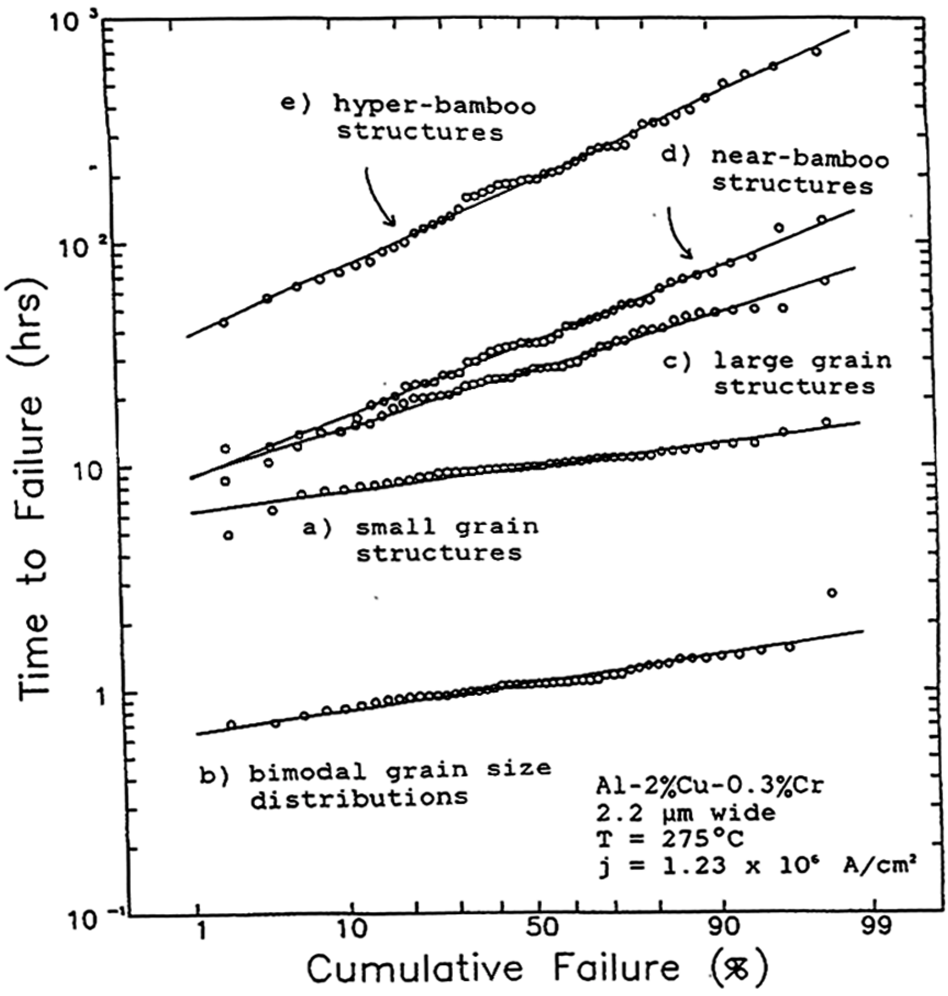
# Texture & Grain Growth



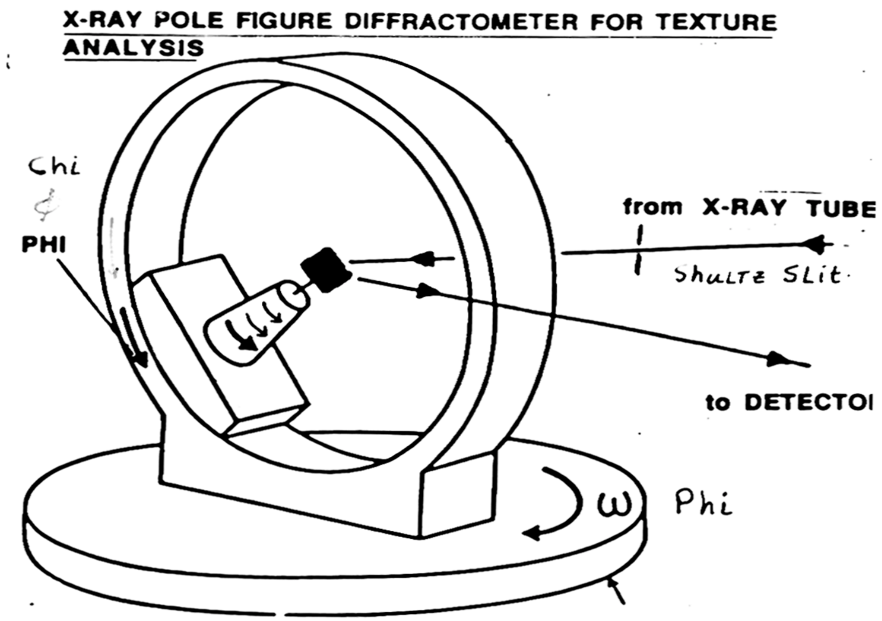

NIST Texture in Electronic Applications Workshop 10/10/00

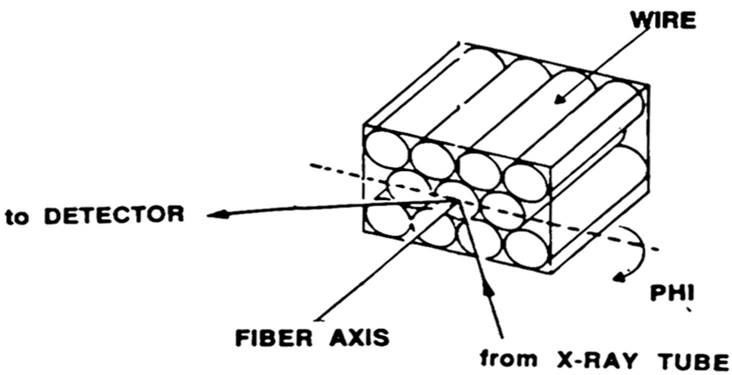
# Grain Size & EM

J. Cho and C.V. Thompson, APL **54** 25 (1989)

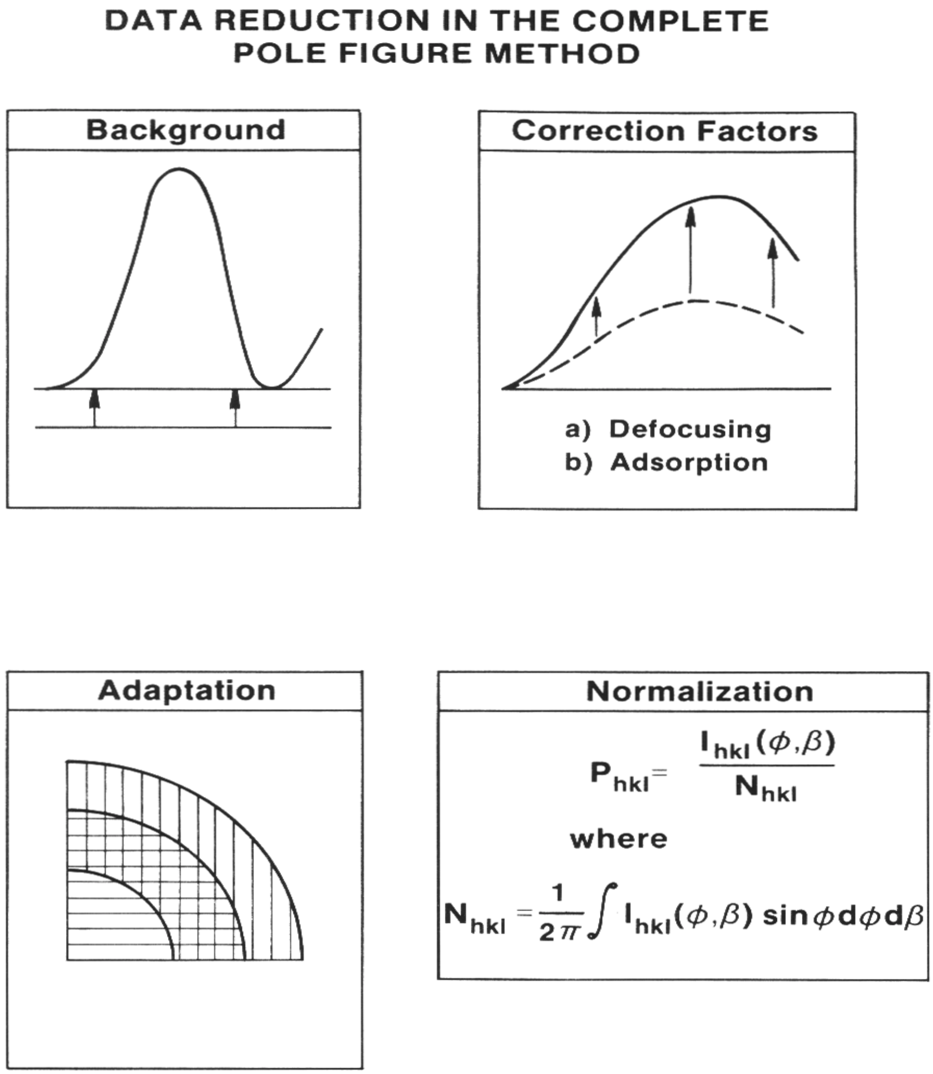


# Four - Circle Diffractometer

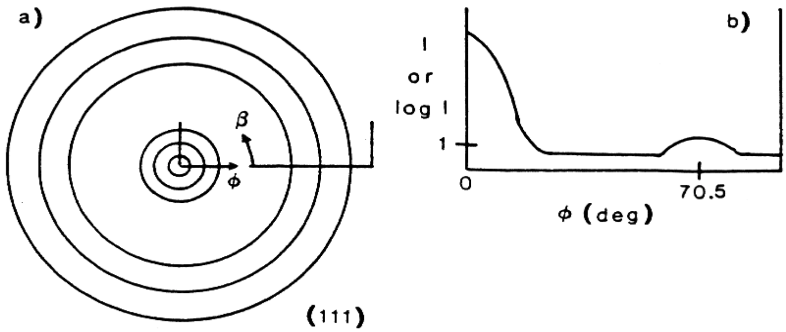


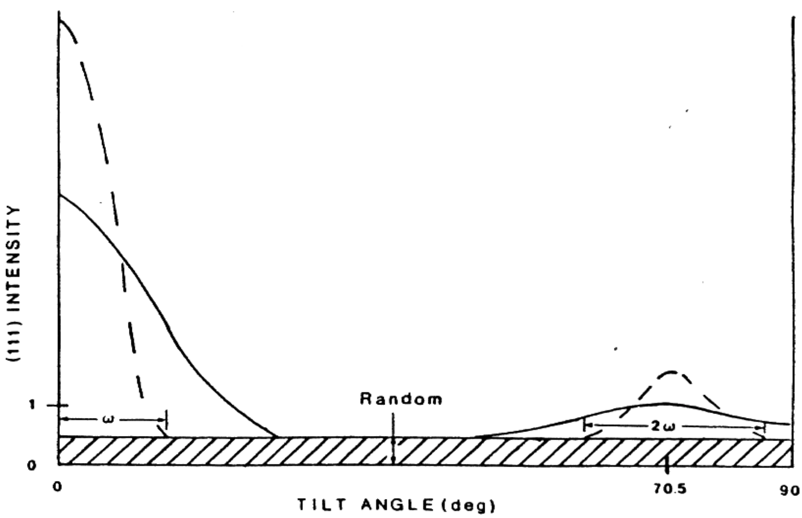



# Discrete PF Data Reduction



# Fiber Texture



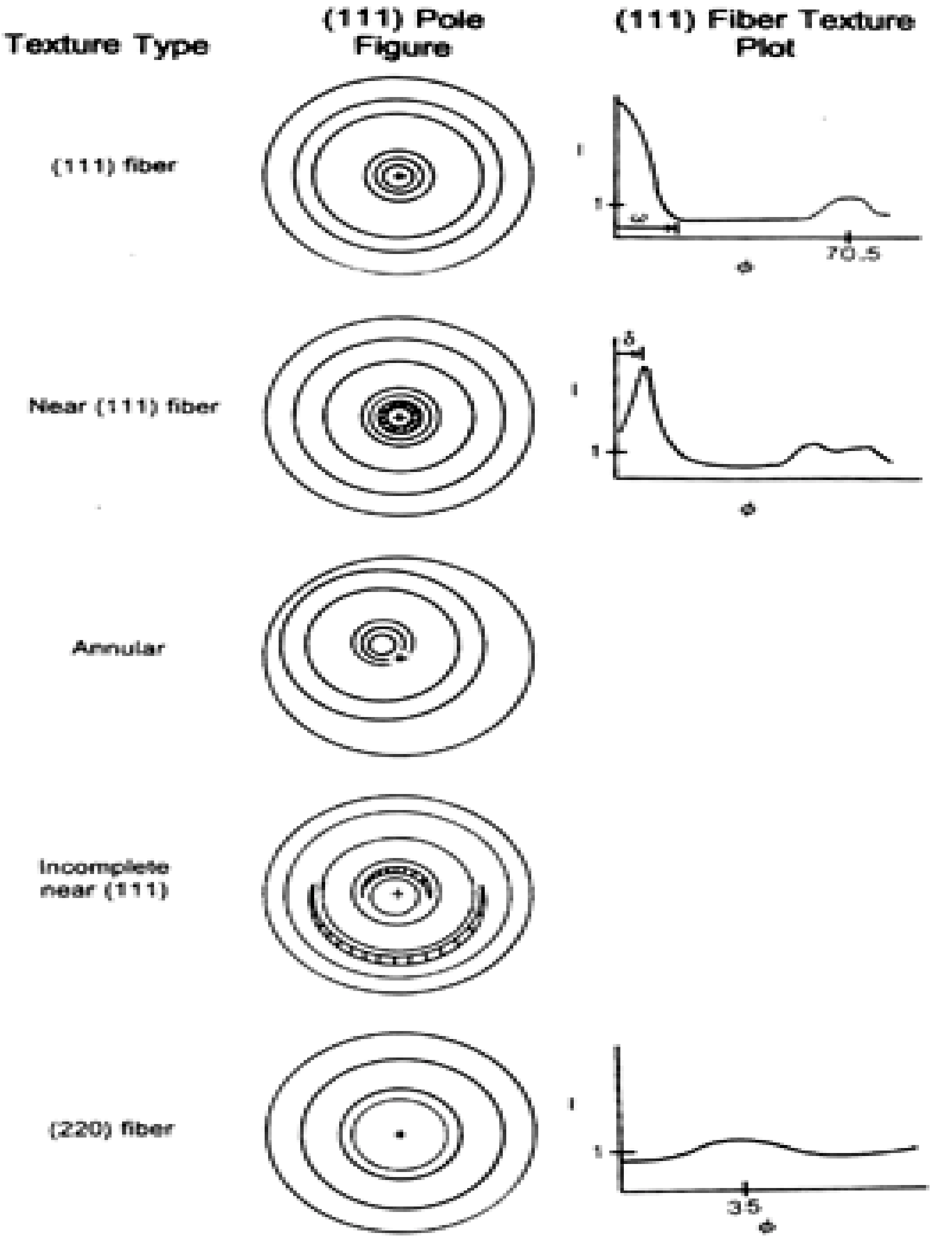



# $\theta$ / 2$\theta$ Scans, Rocking Curves and PoleFigures

| | $\theta$ / 2$\theta$ | | Rocking Curve | Pole Figure | |
|---|---|---|---|---|---|
| Film | $I_{(111)}$ | $I_{(111)}/I_{(200)}$ | FWHM | Rand. Frac. | $\theta(^o)$ |
| 1 | 897 | 667 | 9.07 | 0.08 | 20 near (111) |
| 2 | 20727 | 10000 | 3.04 | 0.05 | 9 |
| 3 | 29550 | infinite | 1.03 | 0.04 | 4 |
| 4 | 2307 | 1000 | 10.2 | 0.08 | 14 near (111) |

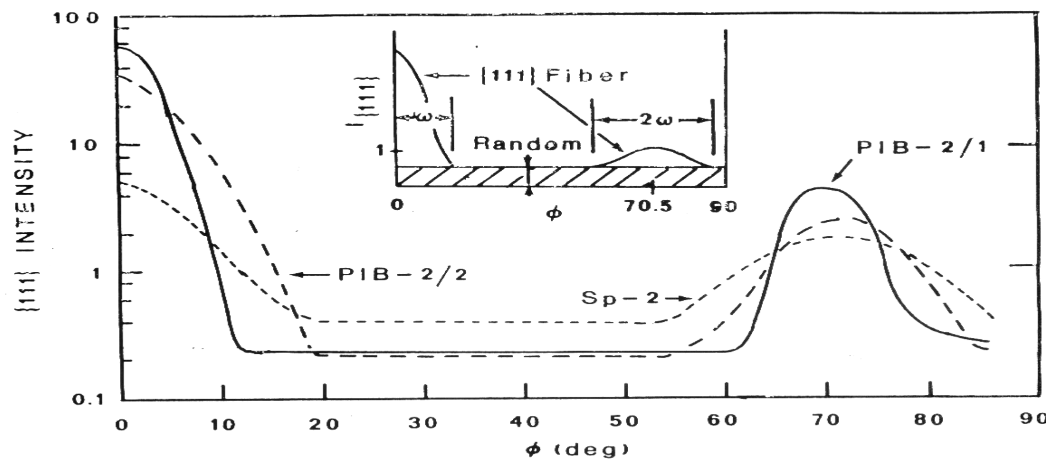
K.P. Rodbell, Mat. Res. Soc. Symp. **403** 617 (1996)

# Fiber Texture Variants



# Al Crystallographic Texture and EM

D.B. Knorr, et al, APL **59** 3241 (1991)




APL, **59**, 3241 (1991).

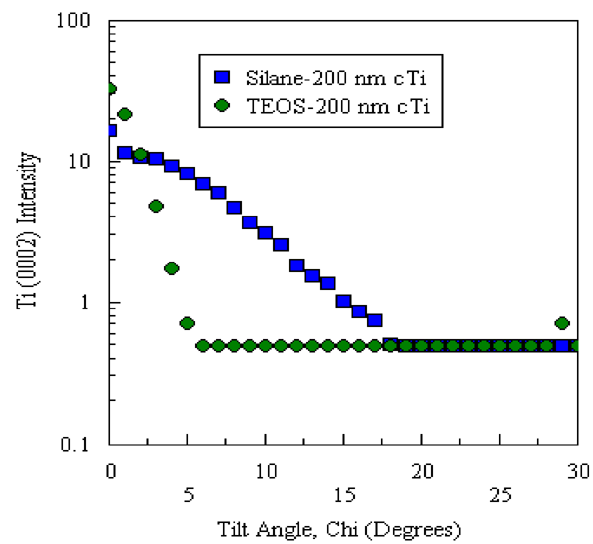
# Ti - Oxide Surface Roughness & Crystallographic Texture

- X-ray Reflectivity Measurements
  - Ti film thickness
  - Interface surface roughness
    - Ti roughness = oxide roughness
    - Oxide / Si interface smooth (0.1 nm)
  - Agrees with AFM data

| | Ti thickness (nm) | Ti / Oxide Surface Roughness, rms (nm) | Oxide / Si Roughness, rms (nm) |
|---|---|---|---|
| Silane / cTi | 23.1 | 2.6 | 0.1 |
| TEOS / cTi | 18.7 | 0.6 | 0.1 |

K.P. Rodbell et al., Mat. Res. Soc. Symp. Proc. **428** 261 (1996)

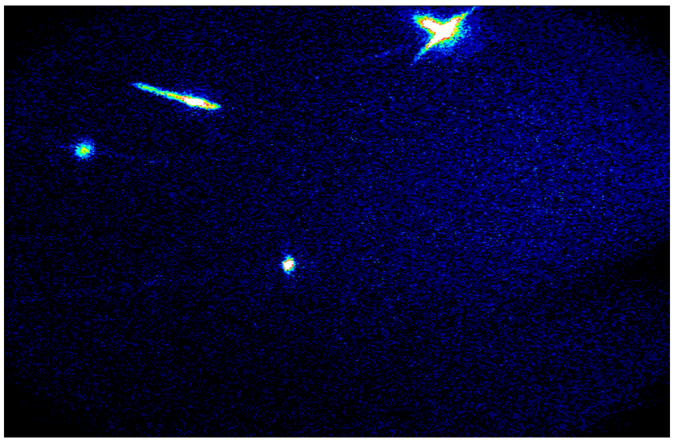
- Ti Texture; 20 nm & 200 nm cTi (150C)
  - Silane / cTi; **weak (0002)**
  - TEOS / cTi; **sharper (0002) fiber**



# X-RAY DATA FOR ELECTRONIC THIN FILMS

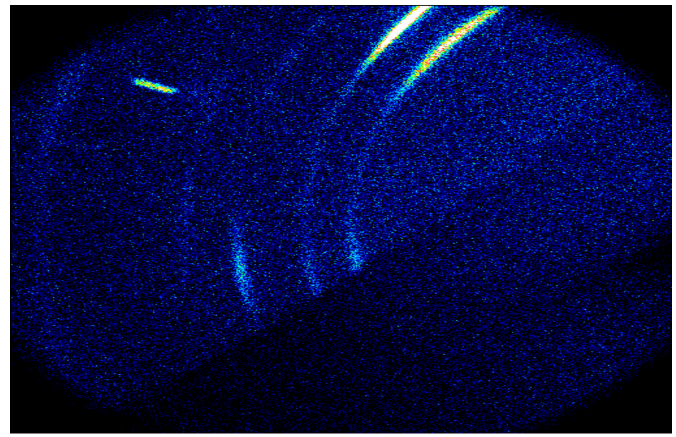
| Material | Lattice Param. (Å) | | μ for $CuK_\alpha$ ($cm^{-1}$) | (111) | | (200) | | (220) | | (311) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RI | 2θ | RI | 2θ | RI | 2θ | RI | 2θ |
| Al | 4.0494 | | 135.6 | 100 | 38.47 | 47 | 44.74 | 22 | 65.13 | 24 | 78.22 |
| Cu | 3.6150 | | 460.3 | 100 | 43.29 | 46 | 50.43 | 20 | 74.13 | 17 | 89.93 |
| Au | 4.0786 | | 4006 | 100 | 38.18 | 52 | 44.39 | 32 | 64.57 | 36 | 77.54 |
| Ag | 4.0864 | | 2990 | 100 | 38.12 | 40 | 44.28 | 25 | 64.42 | 26 | 77.47 |
| TiN | 4.24173 | | 852.5 | 72 | 36.66 | 100 | 42.59 | 45 | 61.81 | 19 | 74.07 |
| Co | 3.5447 | | 2980 | 100 | 44.21 | 40 | 51.52 | 25 | 75.85 | 30 | 92.22 |
| | | | | (111) | | (220) | | (311) | | (400) | |
| | | | | RI | 2θ | RI | 2θ | RI | 2θ | RI | 2θ |
| Si | 5.43088 | | 152.2 | 100 | 28.44 | 55 | 47.30 | 30 | 56.12 | 6 | 69.13 |
| | | | | (1010) | | (0002) | | (1011) | | (1120) | |
| | c (Å) | a (Å) | | RI | 2θ | RI | 2θ | RI | 2θ | RI | 2θ |
| Ti | 4.686 | 2.950 | 912.8 | 30 | 35.06 | 26 | 38.40 | 100 | 40.15 | 17 | 62.96 |
| Co | 4.060 | 2.505 | 2980 | 20 | 41.68 | 60 | 44.76 | 100 | 47.57 | 80 | 75.94 |
| | | | | (110) | | (200) | | (211) | | (220) | |
| | | | | RI | 2θ | RI | 2θ | RI | 2θ | RI | 2θ |
| W | 3.1648 | | 3282 | 100 | 40.26 | 15 | 58.27 | 23 | 73.19 | 8 | 87.02 |
| Cr | 2.8839 | | 1814 | 100 | 44.39 | 16 | 64.58 | 30 | 81.72 | 18 | 98.14 |

# Area Detector; Multiple Debye Rings



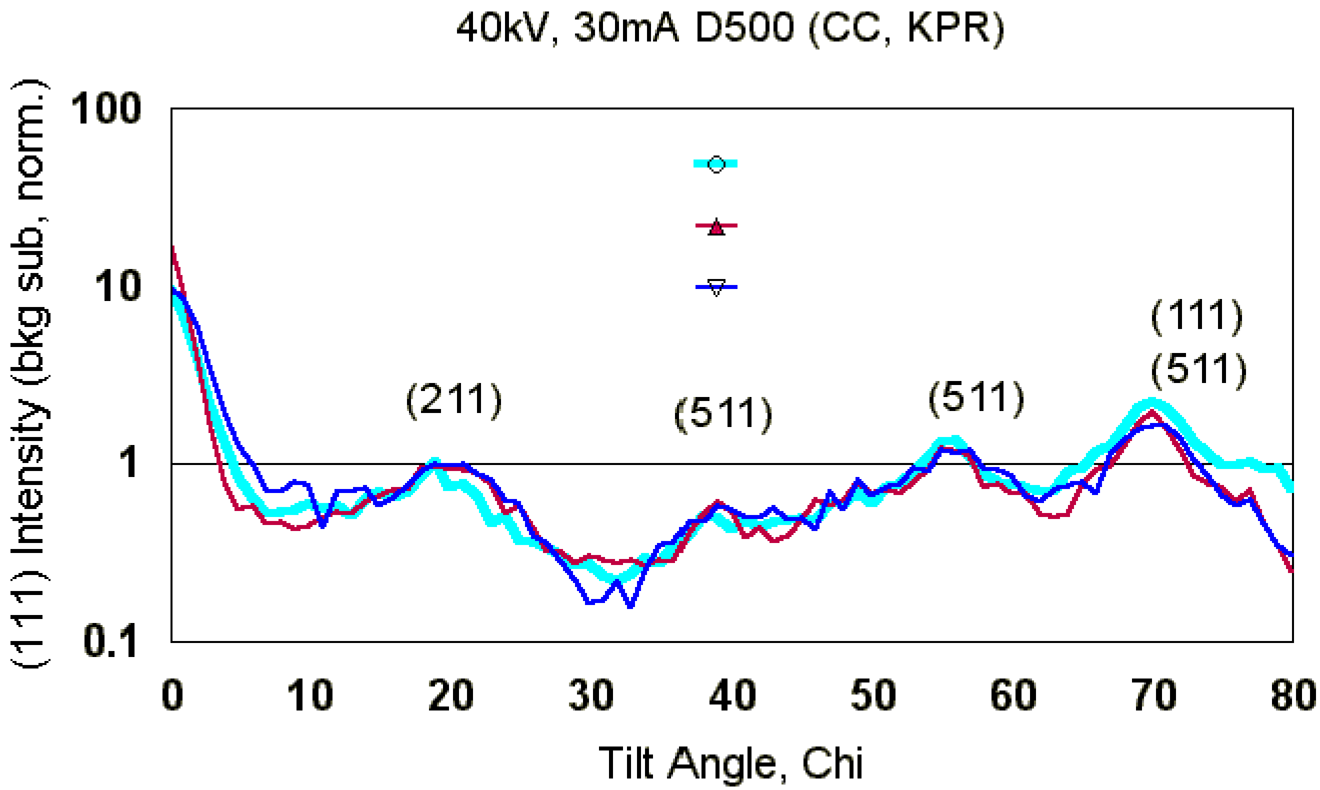
Al (111) + Si spots

$2\eta = 40^{o}$
$\eta = 28.5^{o}$
40 kV, 100 mA Cu radiation
10 s / frame



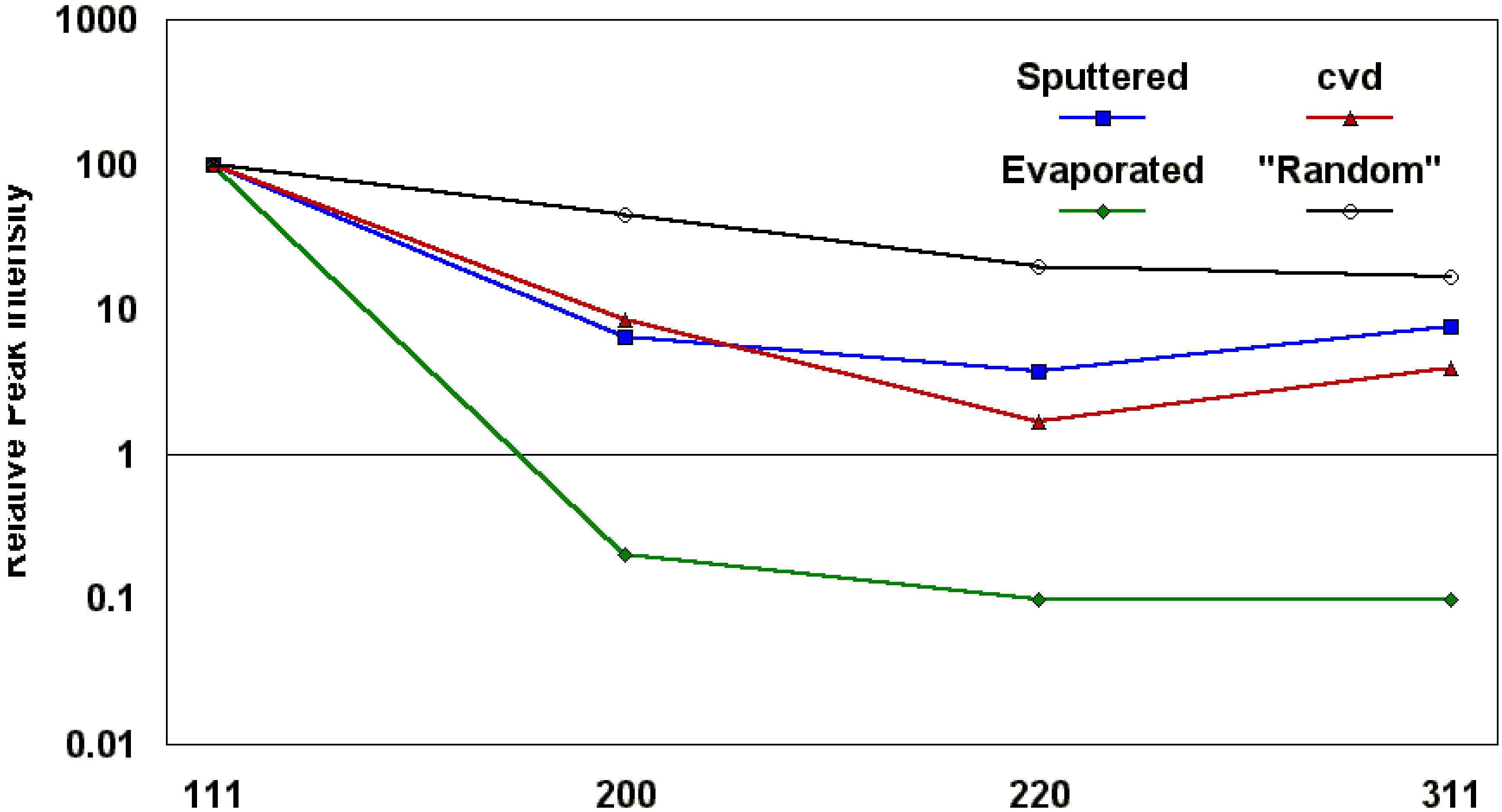
Cu (111), (200), (220), (311)

# Plated Cu (111) Fiber Texture



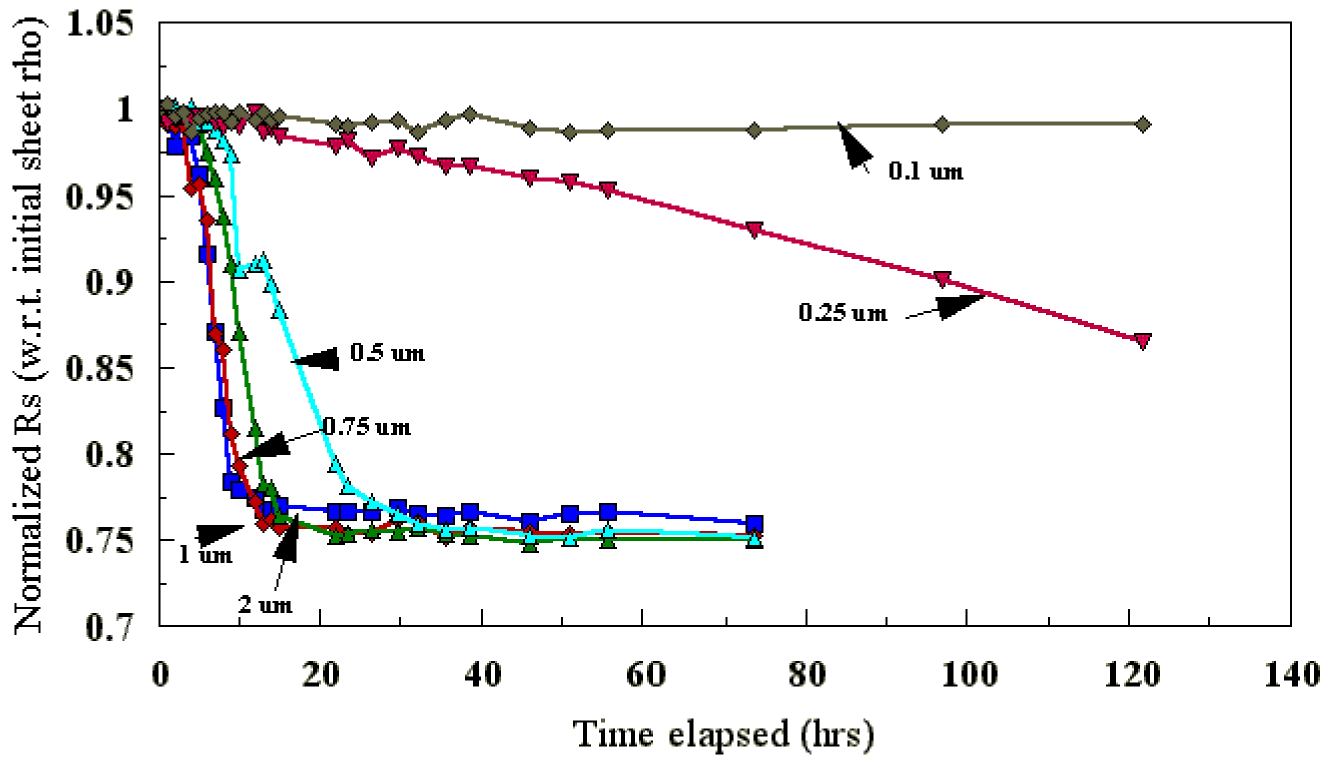

12/98

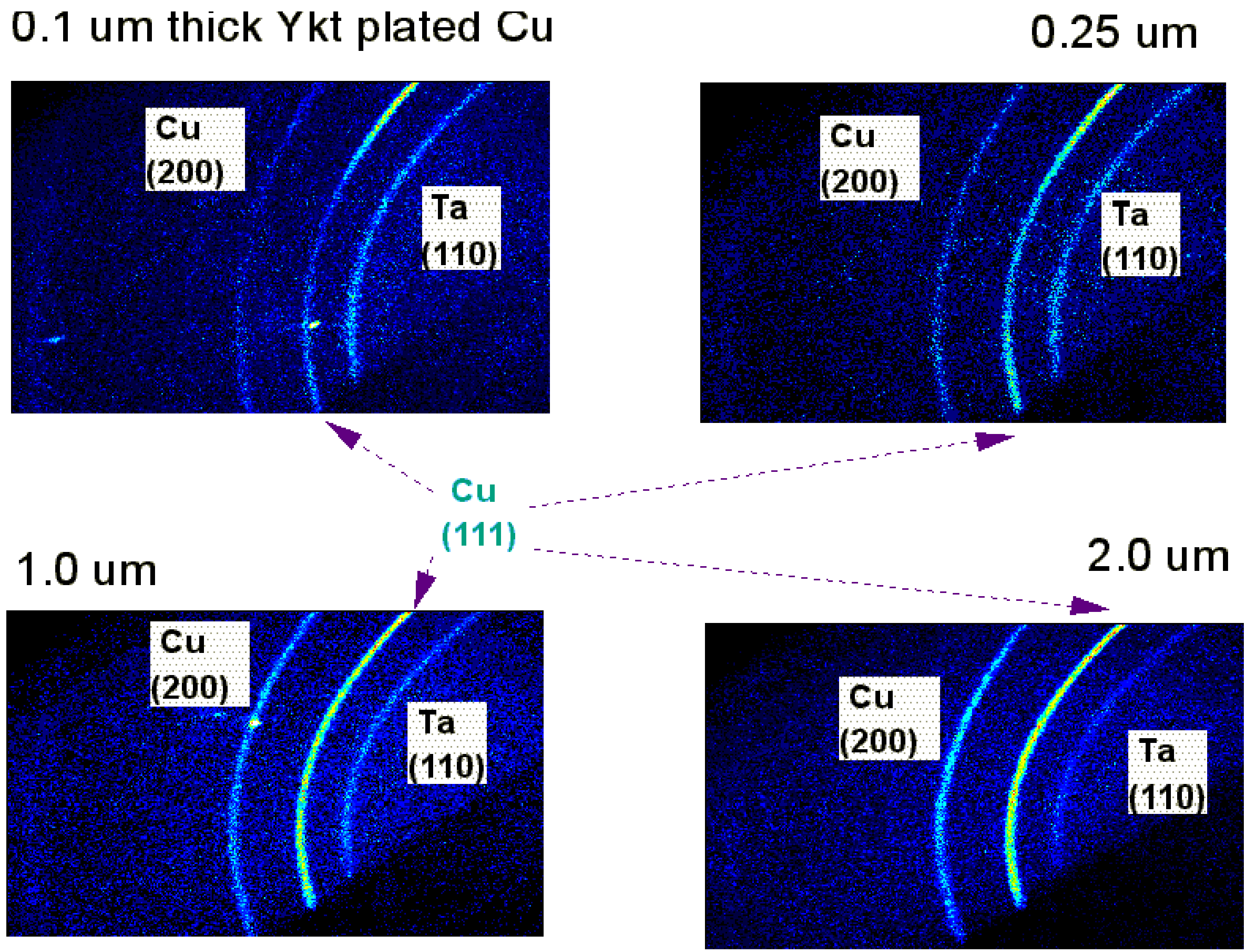
# Effect of Cu Seed, Plated Cu



# Excess Resistivity Transients (at RT) as a Function of Film Thickness

samples frozen at -43 deg C for ca. 72 hrs prior to Rs Measurement

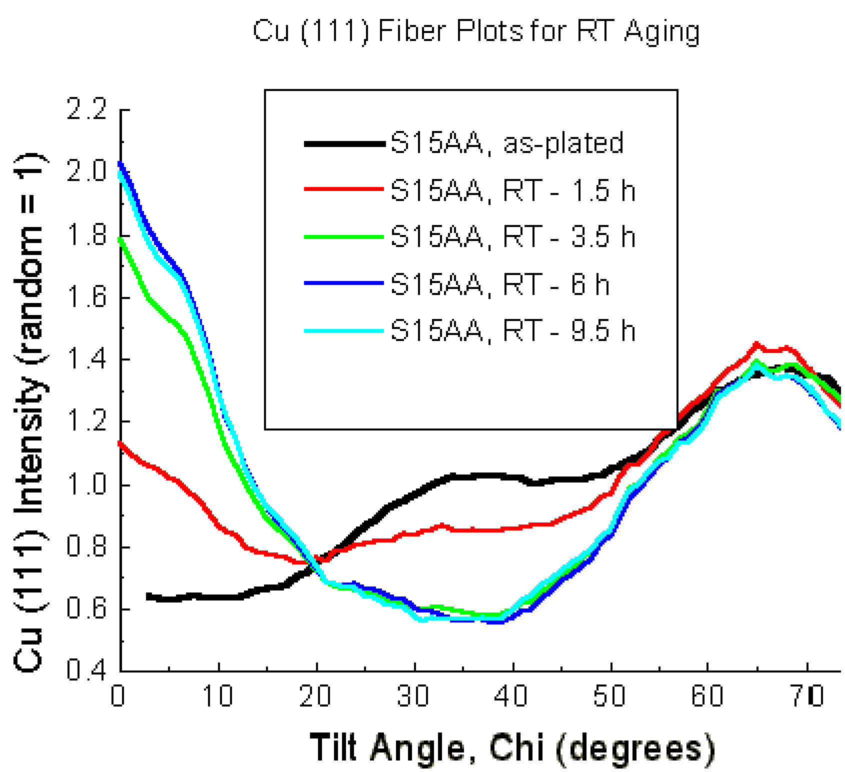


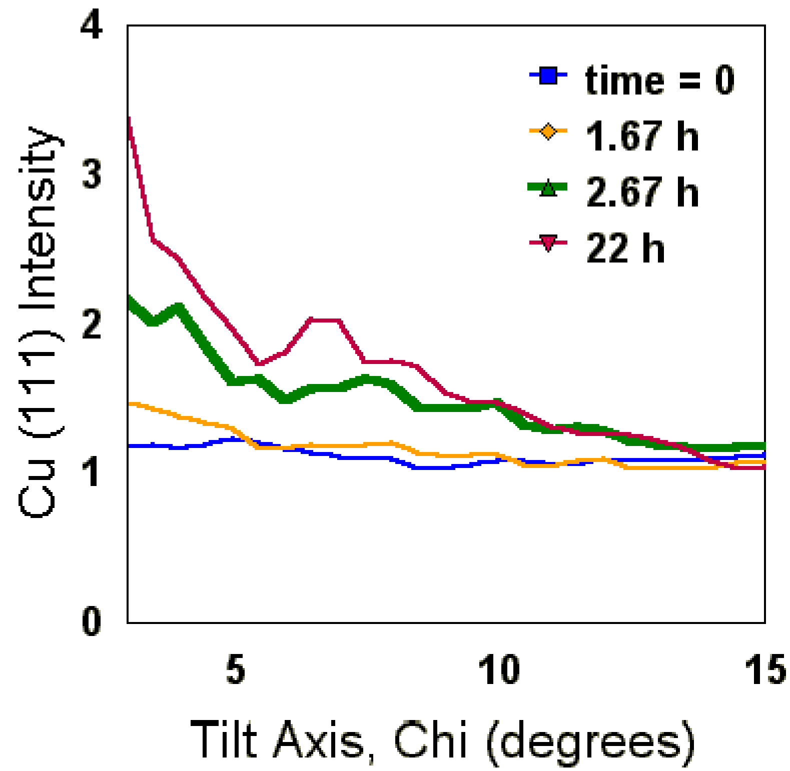


0.1 um thick Ykt plated Cu
0.25 um
1.0 um
2.0 um
Cu (111)
Cu (200)
Ta (110)
Cu (200)
Ta (110)
Cu (200)
Ta (110)
Cu (200)
Ta (110)

# Plated Cu

## Siemens D500 vs. Area Detector
## (970nm Plated Cu)



# EBSP

THE DETERMINATION OF LOCAL TEXTURE

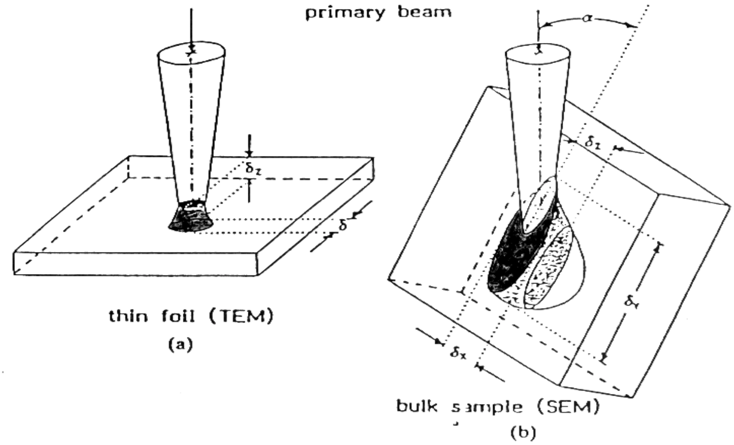
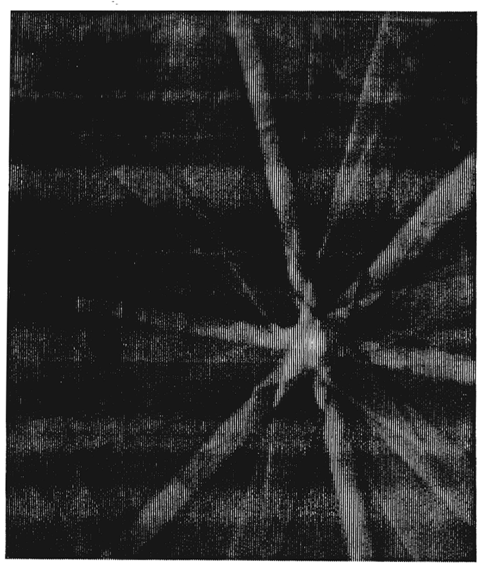


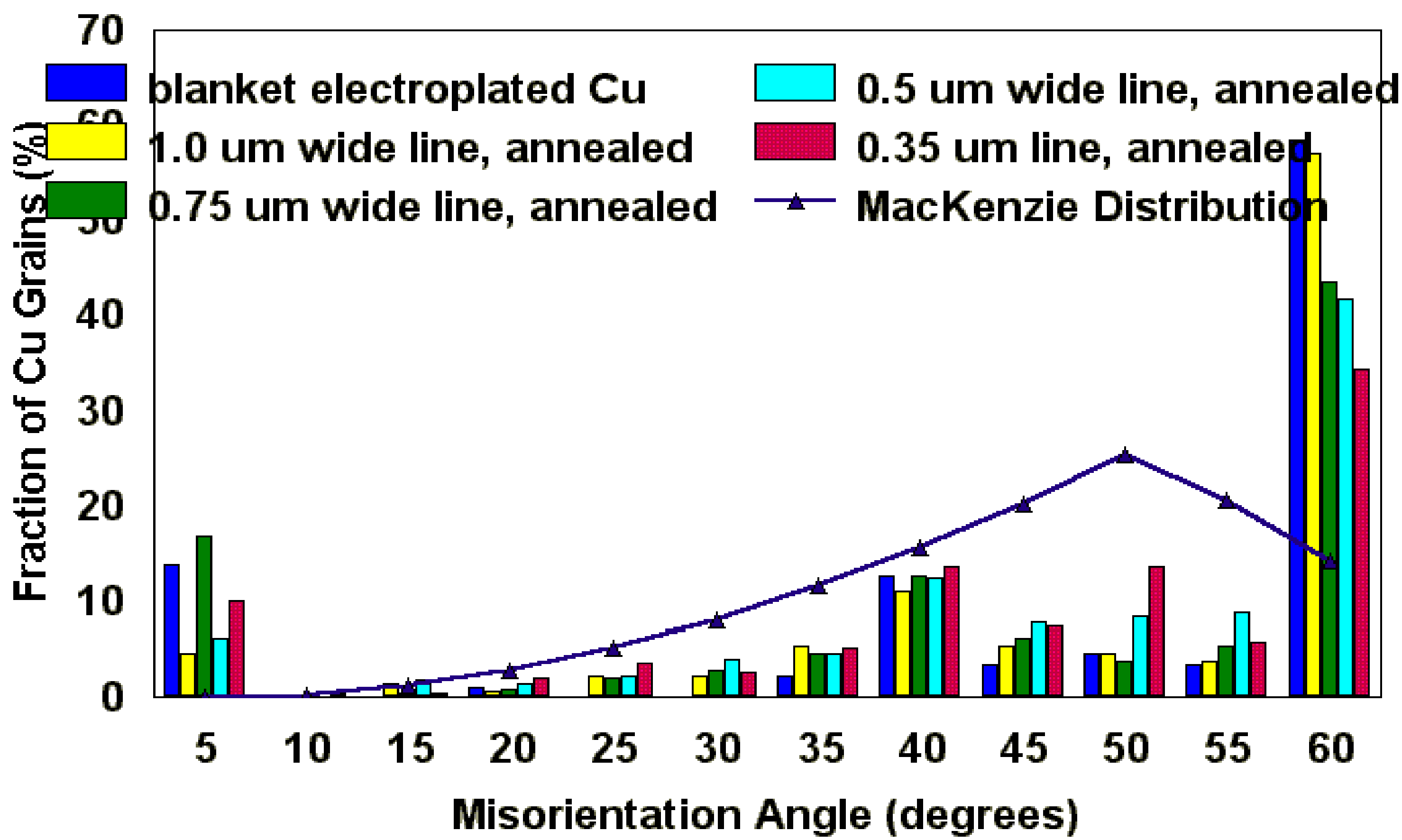

**Figure 1** Diffra .ion volume and spatial resolution, δ, with transmission (a) and backscatter (b) Kikuchi patterns.

Index pattern



# Plated Cu Grain to Grain Misorientations

Large number of "Sigma 3" CSL and low angle grain boundaries



# XRD vs. EBSP (Inverse PF)

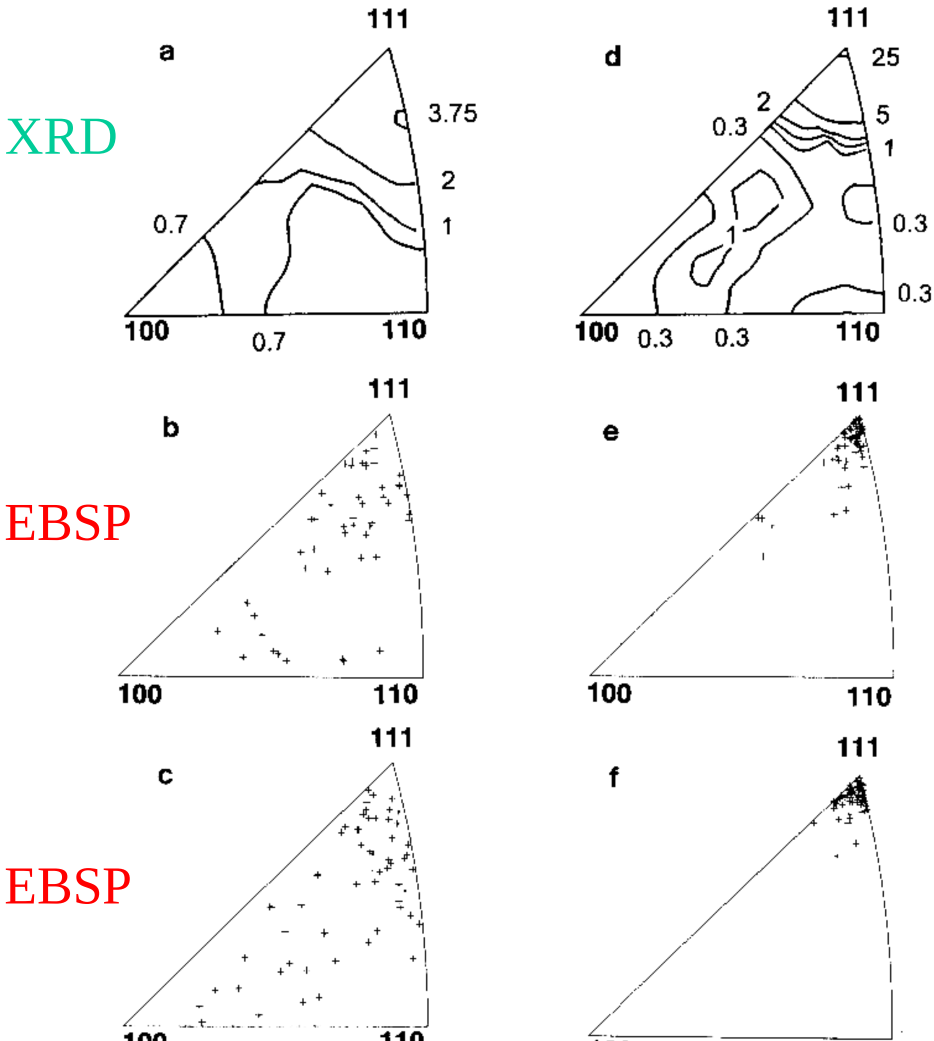
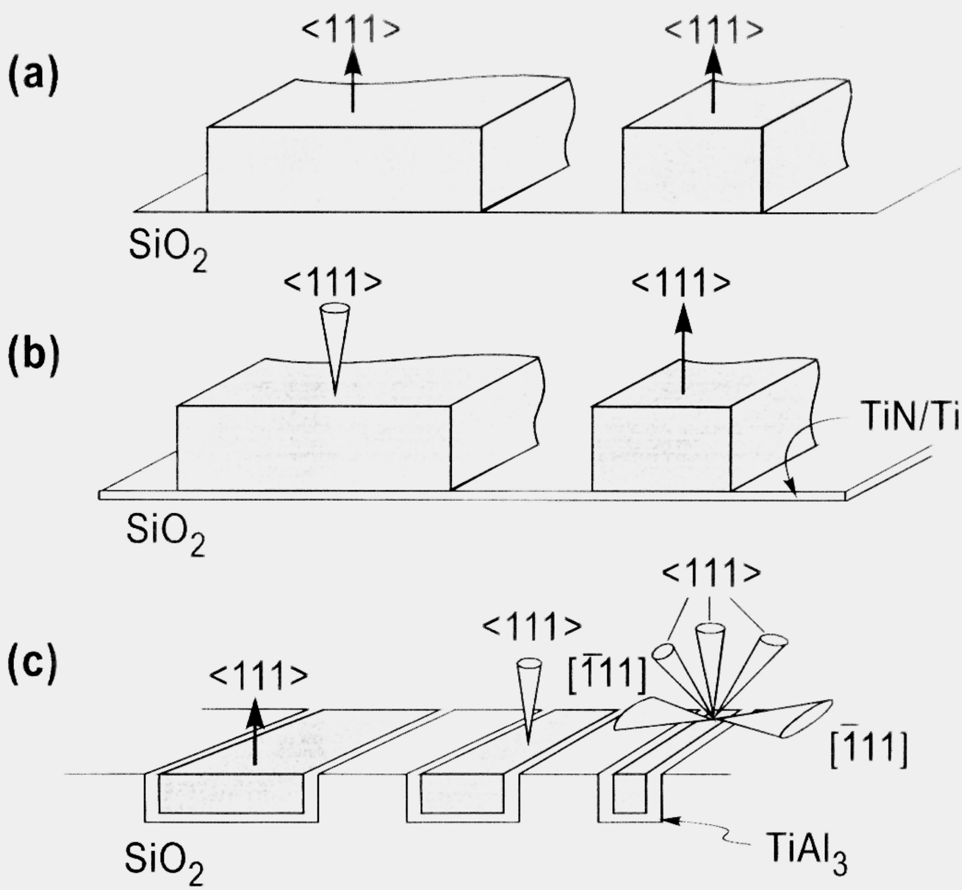



Figure 1. SP-2 inverse pole figures: (a) from a blanket film (XRD), (b) for 50 grains from a 100 x 100 $\mu m^2$ pad region on a chip (BKD) and (c) for 60 grains from a 0.6 µm wide line (BKD). PIB2/1 inverse pole figures: (d) from a blanket film (XRD), (e) for 56 grains from a 100 x 100 $\mu m^2$ pad region on a chip (BKD) and (f) for 60 grains from a a 0.5 µm wide line (BKD).

J.L. Hurd, et al. Mat. Res. Soc. Symp. Proc. **343** 653 (1994)

# Texture in Narrow Lines

**J.L. Hurd, et al.,** APL 72 **326** (1998)




**Schematic diagram depicting <111> plane normals to those (111) planes influenced by various interfaces for (a) a planar film etched into lines, (b) a planar film with a TiN/Ti under-layer and (c) three damascene line widths, containing appreciable $TiAl_3$, which results in a tri-modal (111) orientation distribution as the lines narrow.**

# Summary

In general, increased (111) Cu texture ==> longer Rs

Decreased Plated Cu thickness (blanket) shows an increased (111) Cu texture, smaller grain size and a longer Rs

The Plated Cu microstructure is dependent upon the plating bath additives and plating parameters