SAND2012-3231C
SAND2012-3231 C

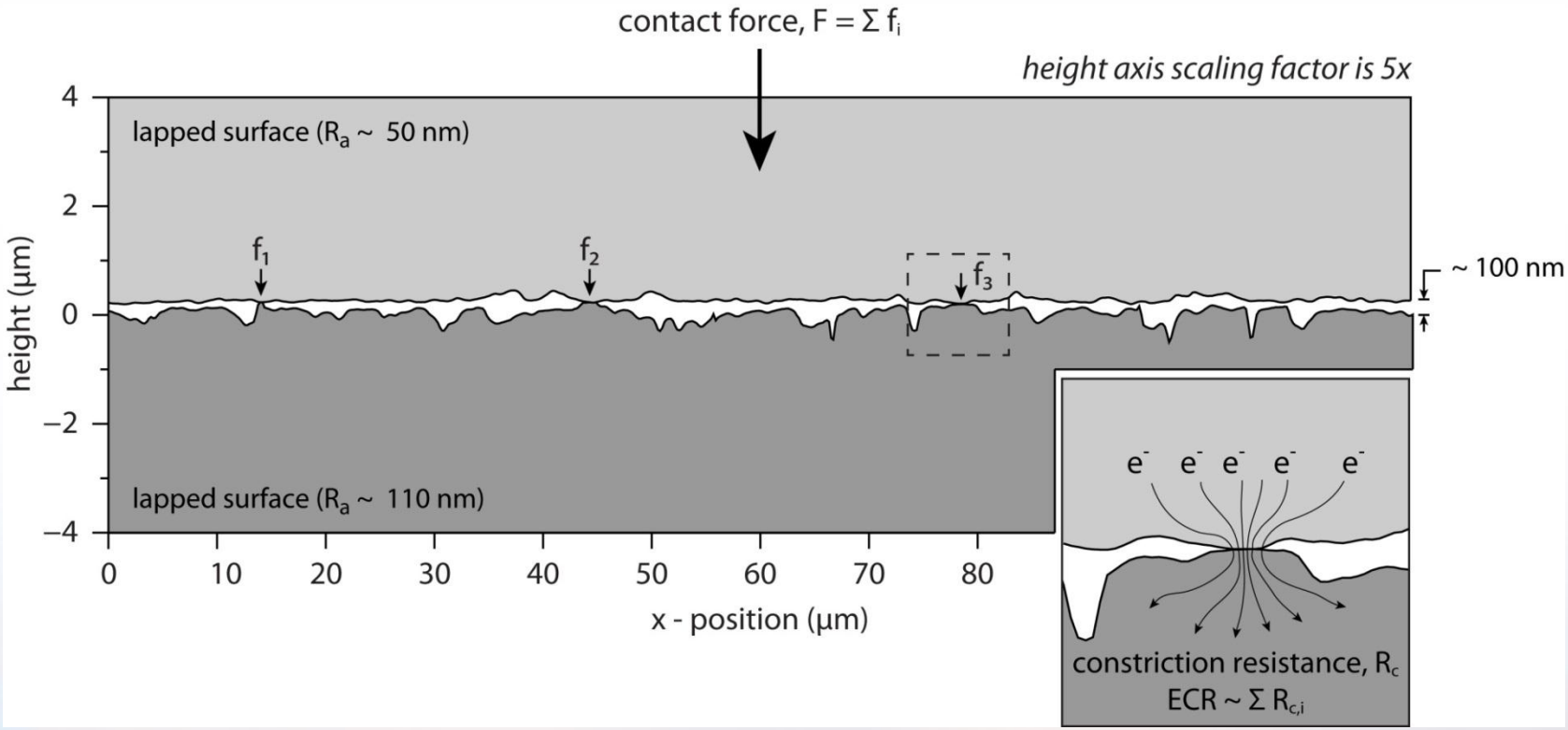
Electrical Contact Resistance (ECR)-Friction Relationships in Au Nanocomposites

Somuri Prasad, Ron Goeke, Nicolas Argibay, Paul Kotula

Materials Science & Engineering Center
Sandia National Laboratories
Albuquerque, NM 87185-0889, USA
svprasa@sandia.gov

International Conference on Metallurgical Coatings & Thin Films
San Diego, CA, April 23-27, 2012

Fundamentals of Contact



ECR ⇨ Maximize Junction Growth

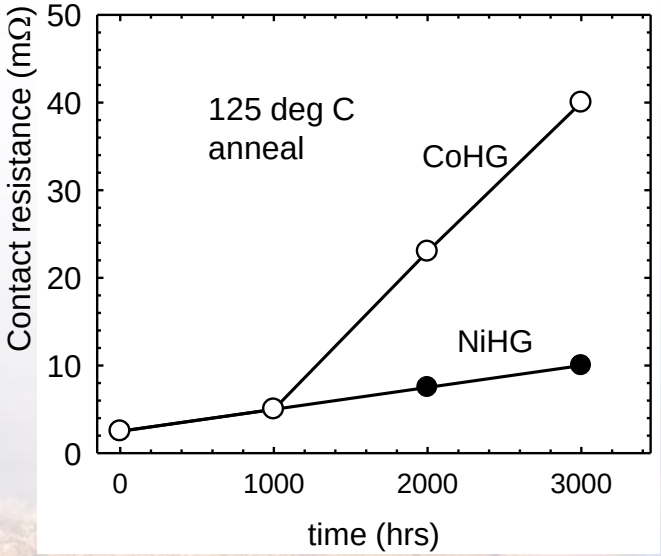
Friction ⇨ Minimize Metal-to-Metal Contact

Hard Au Platings

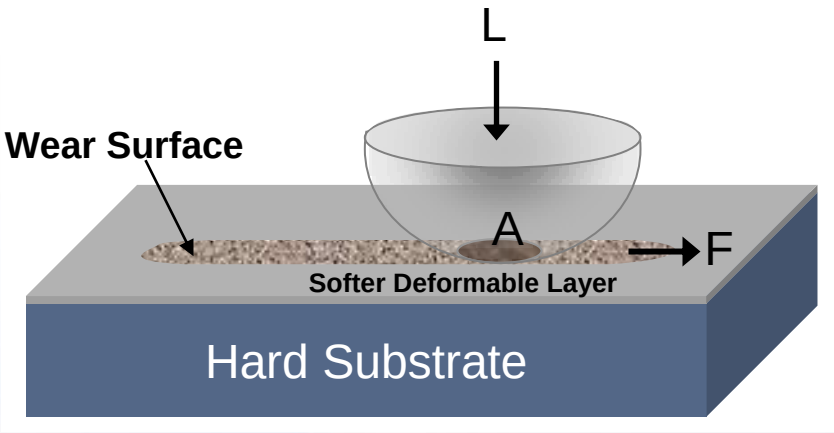
- Friction and ECR are two fundamentally opposing phenomena
- Typical industry practice is to apply a thin deformable layer on an alloy surface
- Electroplated Au hardened with minute alloying elements (e.g. Ni, Co) is the material of choice

Issues and Challenges

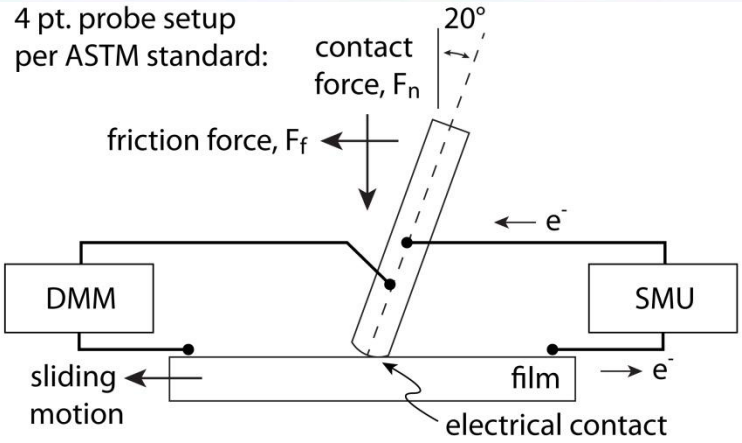
- Long term materials aging
- Limit on the choice of hardeners
- Quality control issues with electroplating (non-technical)

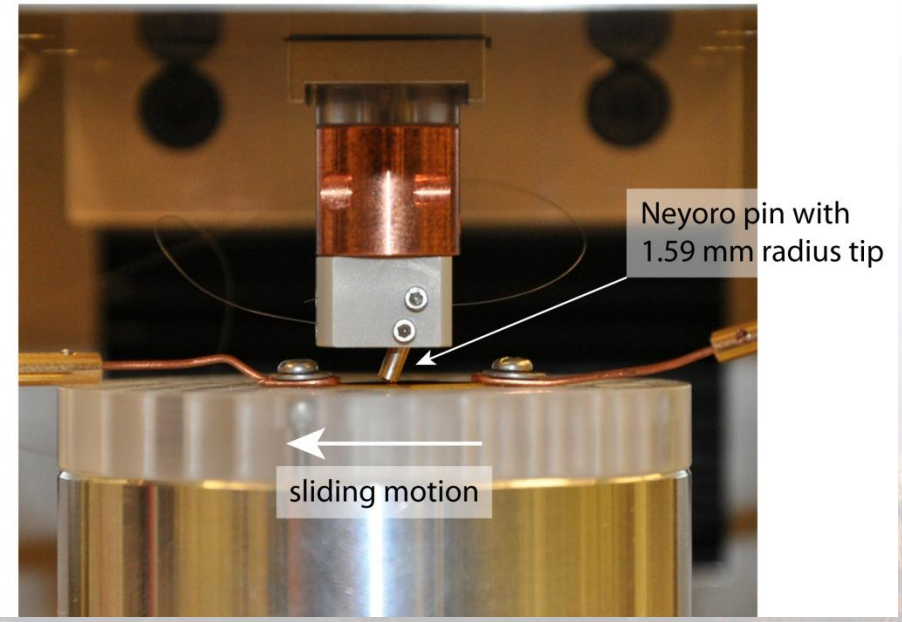


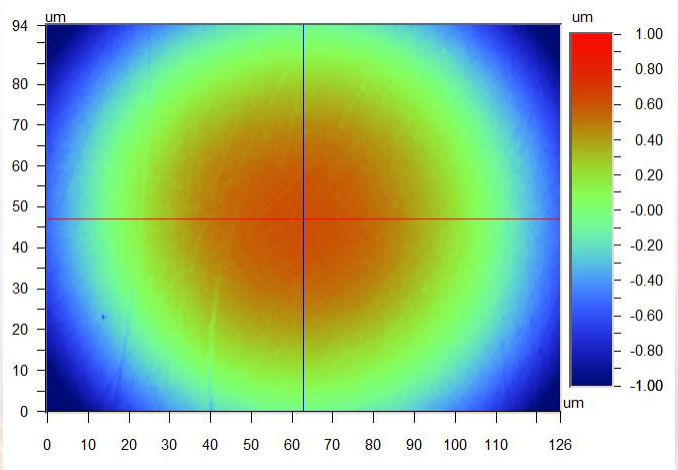
Both ECR and Friction are systems properties



Four-Point Probe ECR-Friction Testing: Pin-on-Disk



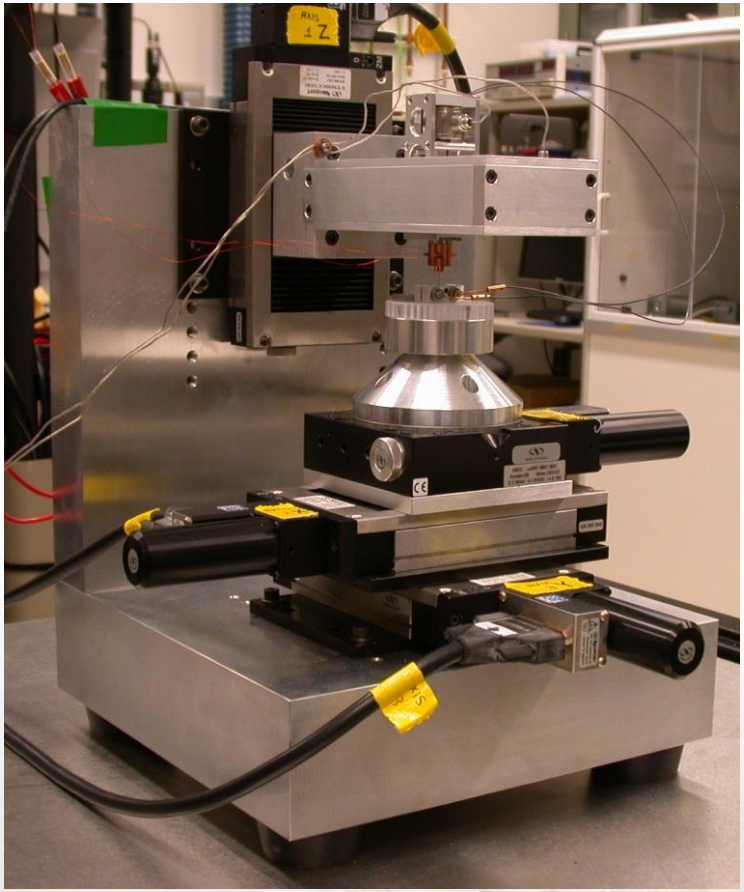




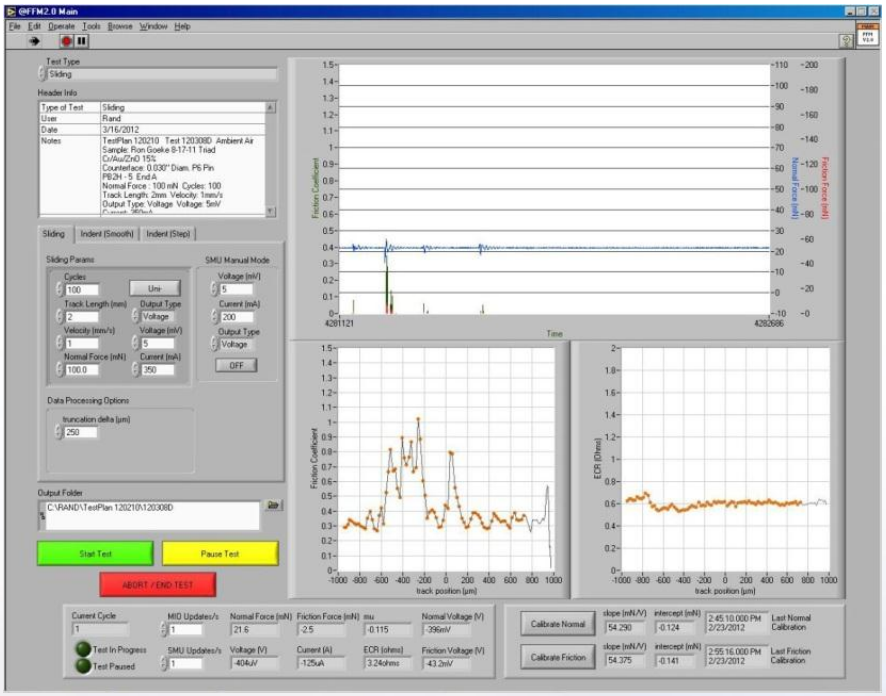
Pin Head

Sandia National Laboratories

ECR Tester

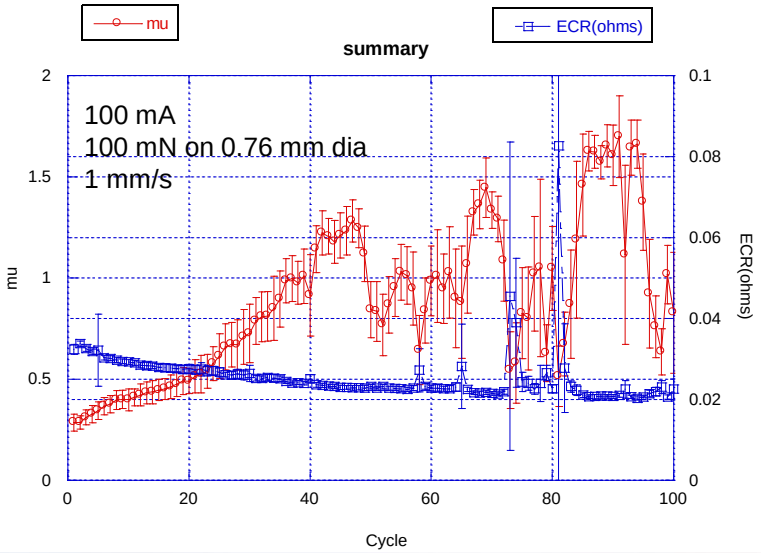


Up to 2000 mA
1 mN to 1.5 N

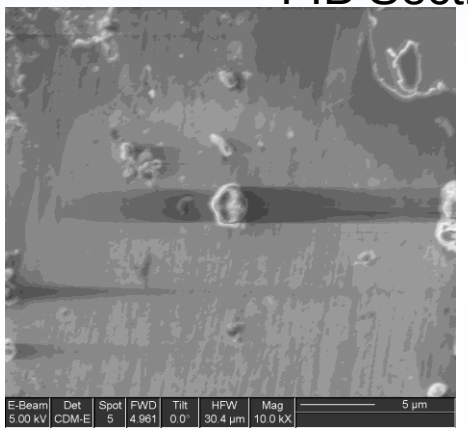


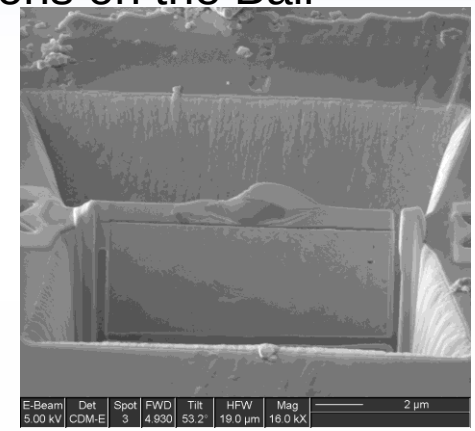
Data Acquisition

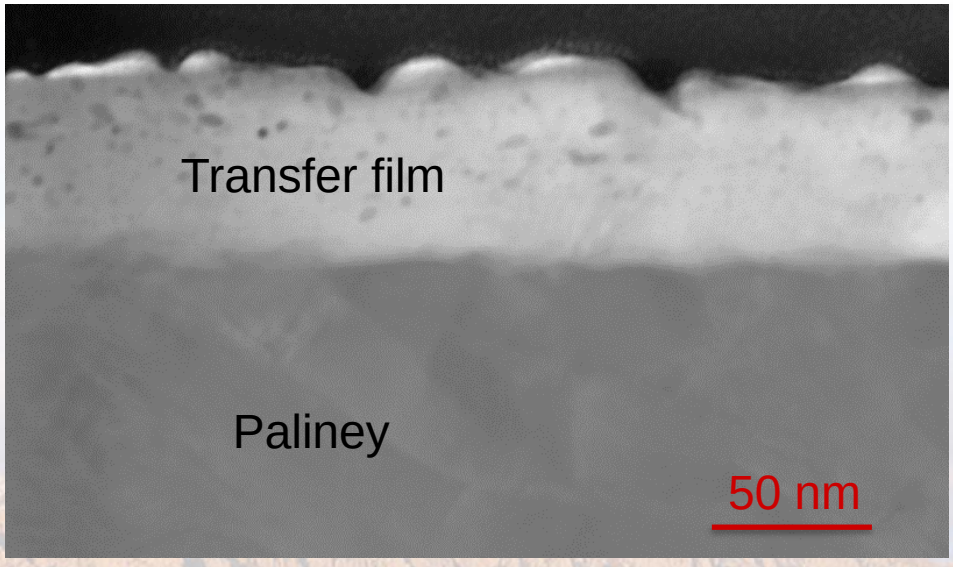
Ag-Pd-Cu Alloy Pin on Hard Au



FIB Sections on the Ball



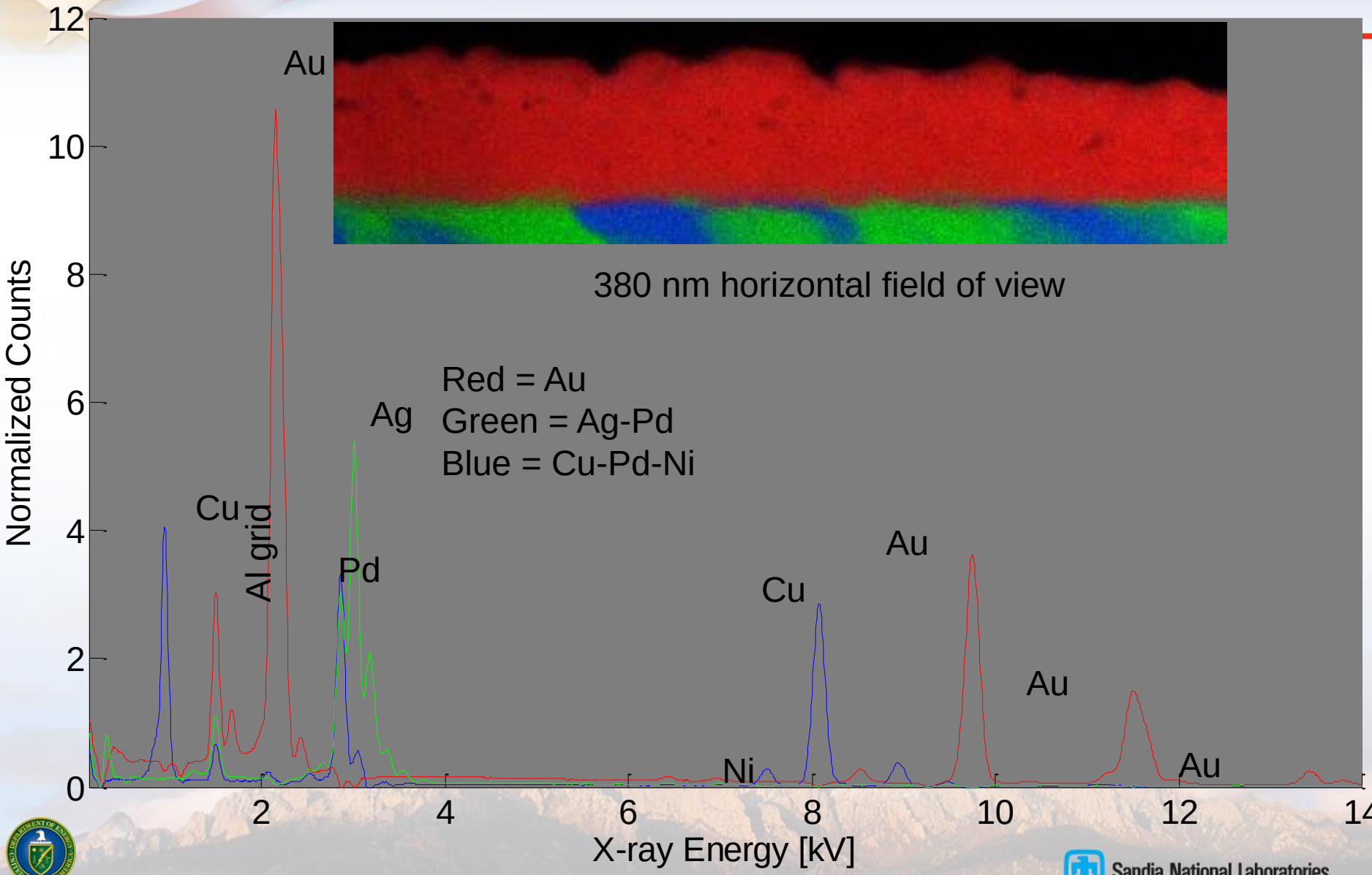




TEM

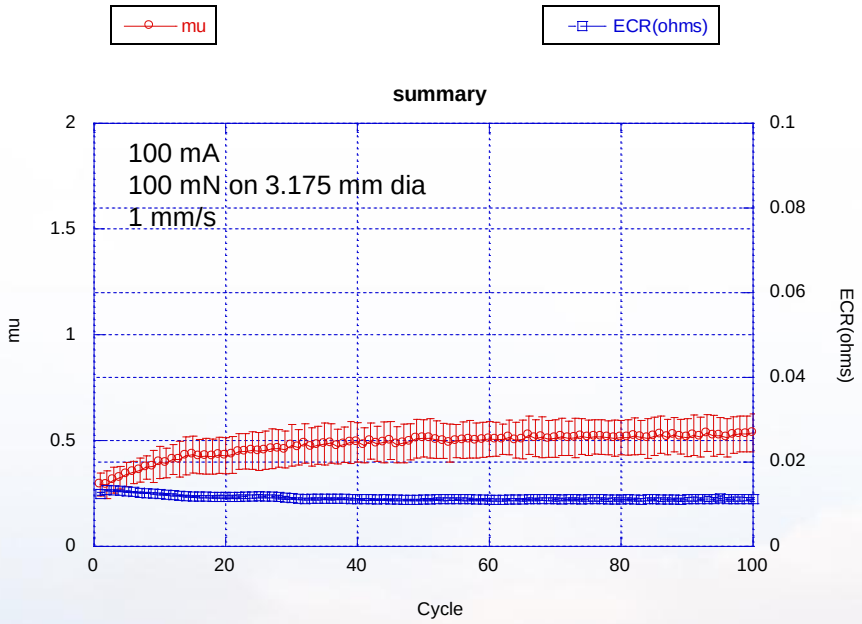
Sandia National Laboratories

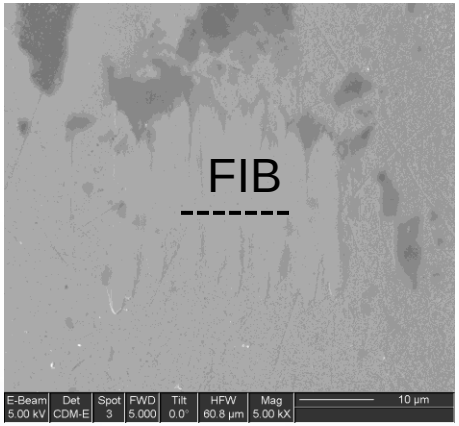
Ag-Pd-Cu Alloy on Hard Au: Spectral Image

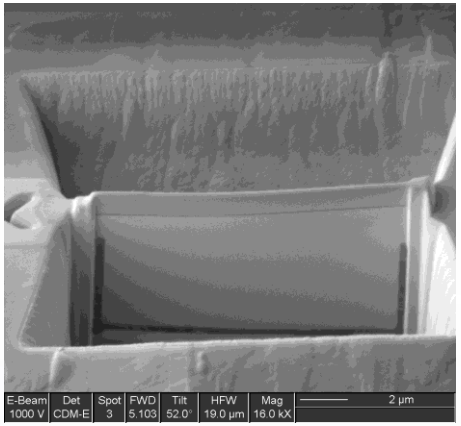


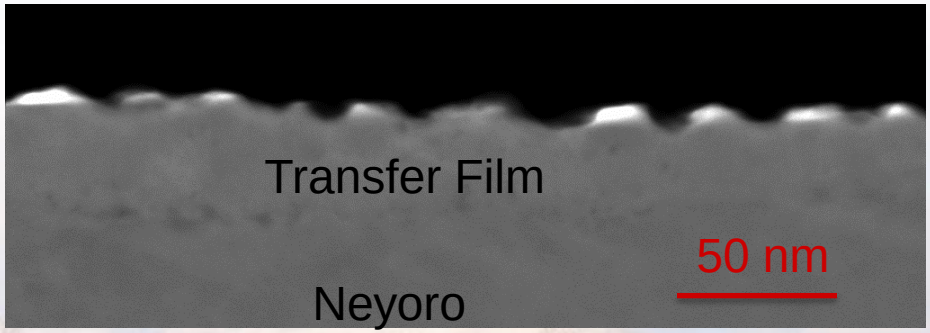
Sandia National Laboratories

Au-Cu-Ag Alloy Pin on Hard Au



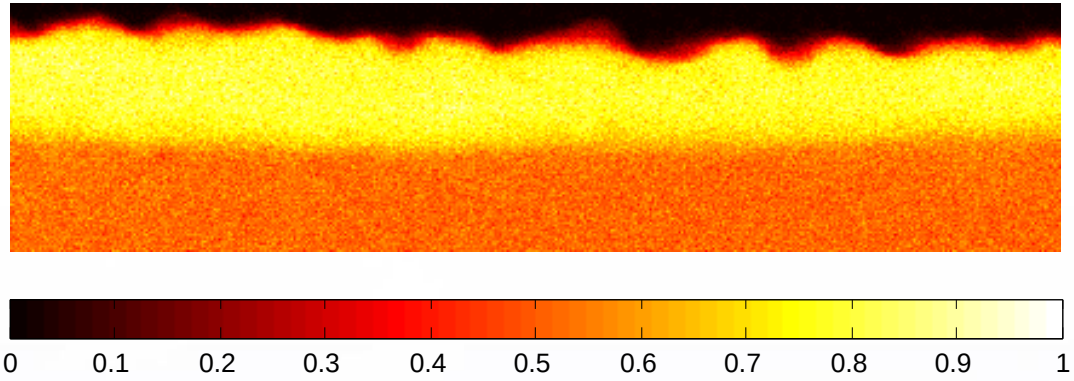




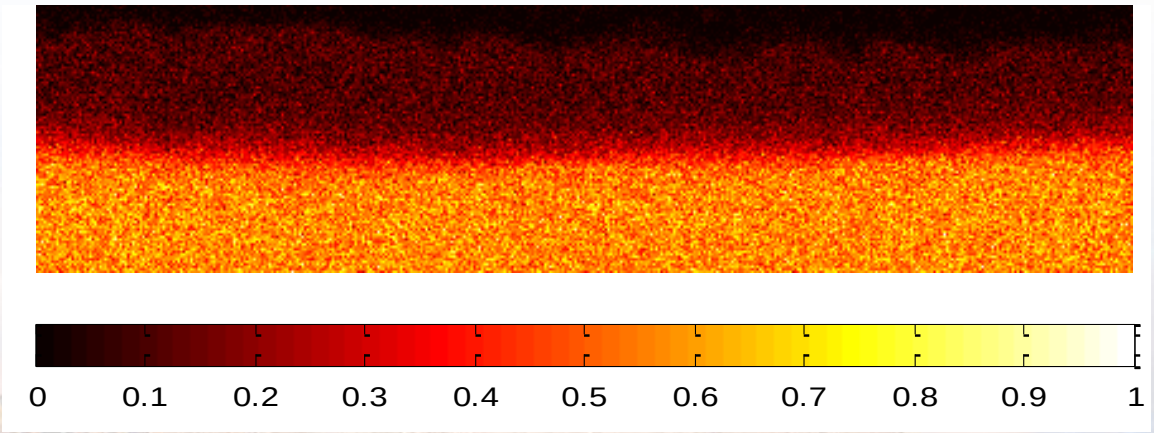


Spectral Images of Transfer Film: Au-Cu-Ag Alloy on Au

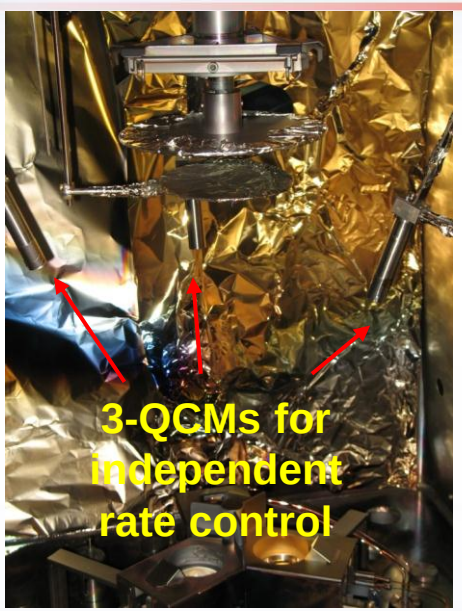
Au distribution

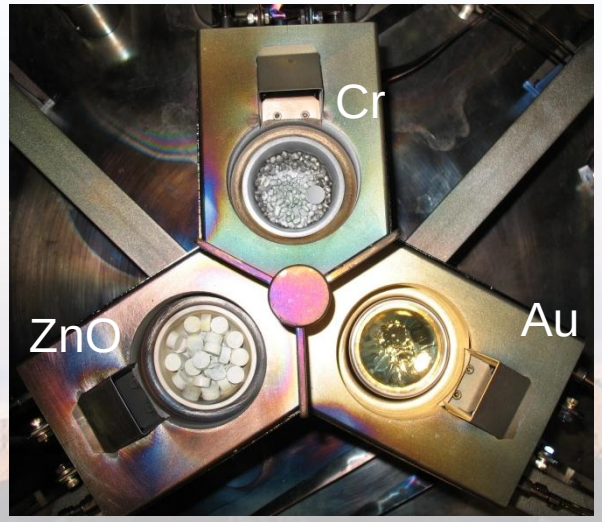


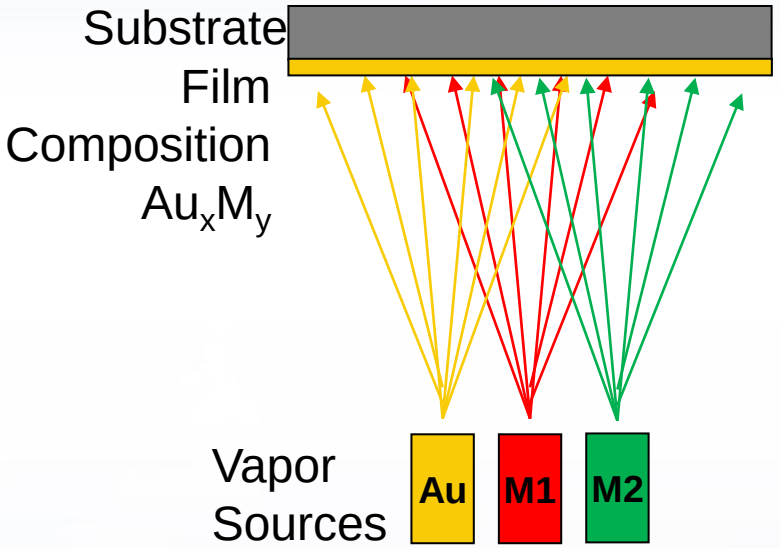
Cu-Ag distribution



Triad E-Beam Deposition





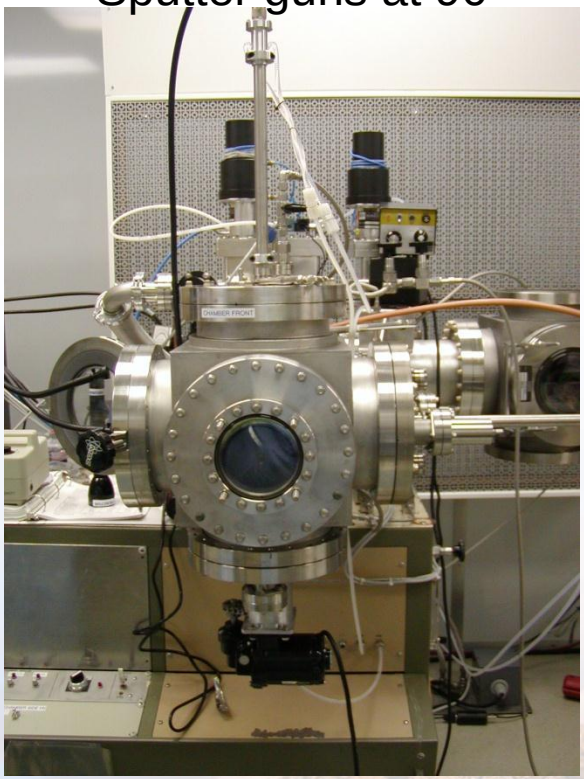


- Triad electron gun for E-beam evaporation
- Co-deposition of ternary alloy thin films
- Shutter in front of substrate for consistent composition
- Substrate rotation for improved uniformity
- Line of sight shields on QCMs eliminate cross-talk

Sputter Deposition

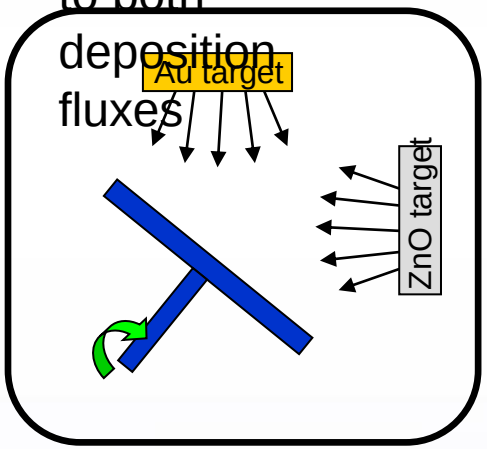
Sputter Co-Deposition System

Sputter guns at 90°



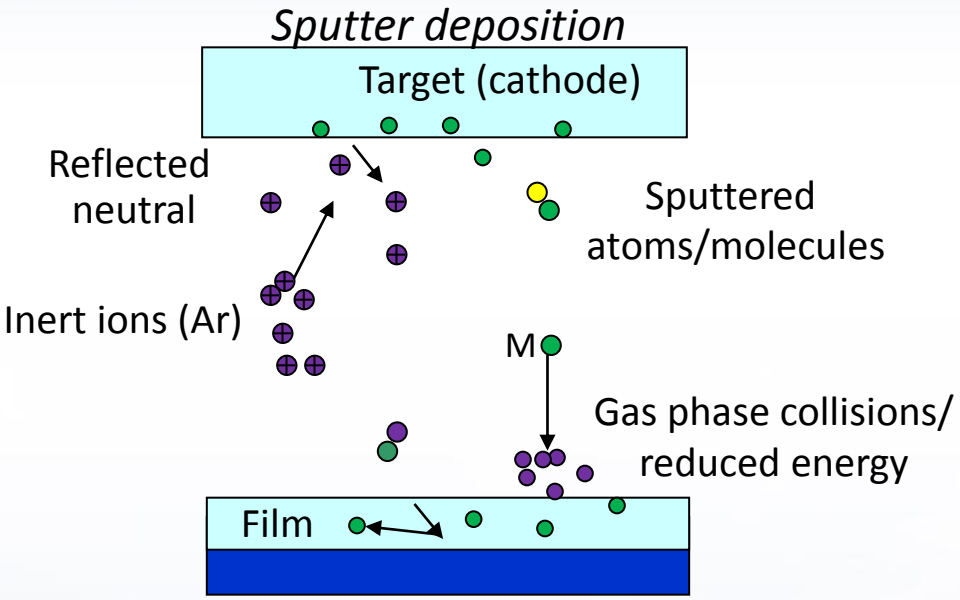
Two 2” sputter targets

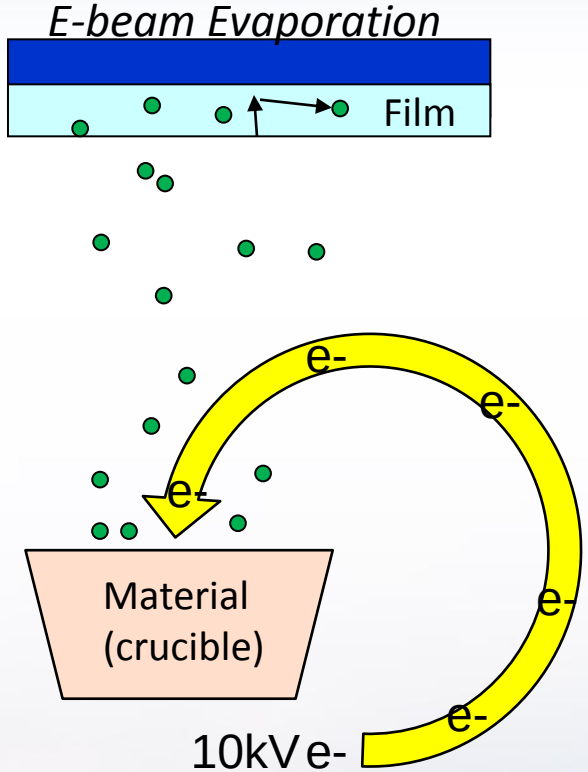
Substrate at 45° to both deposition fluxes



Glow discharge during dep.

Physical Vapor Deposition (PVD)



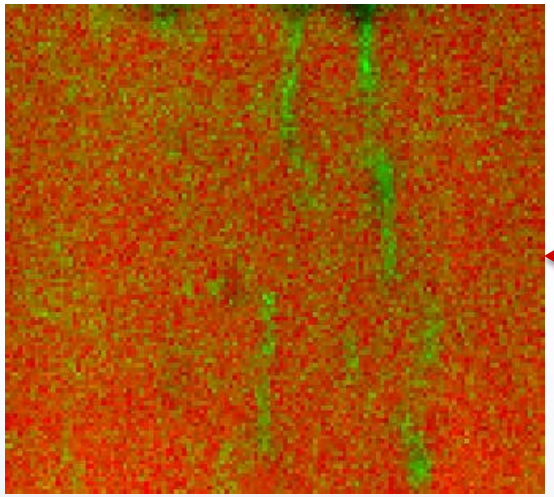


- Target material removed by kinetic energy of inert ions
- Requires plasma ignition for ionization of sputter gas (Ar)
- Minimum energy for ignition limits deposition rate ratio ~ 50:1 (2%)
- Good control over film properties (pressure, power, biasing, temperature)

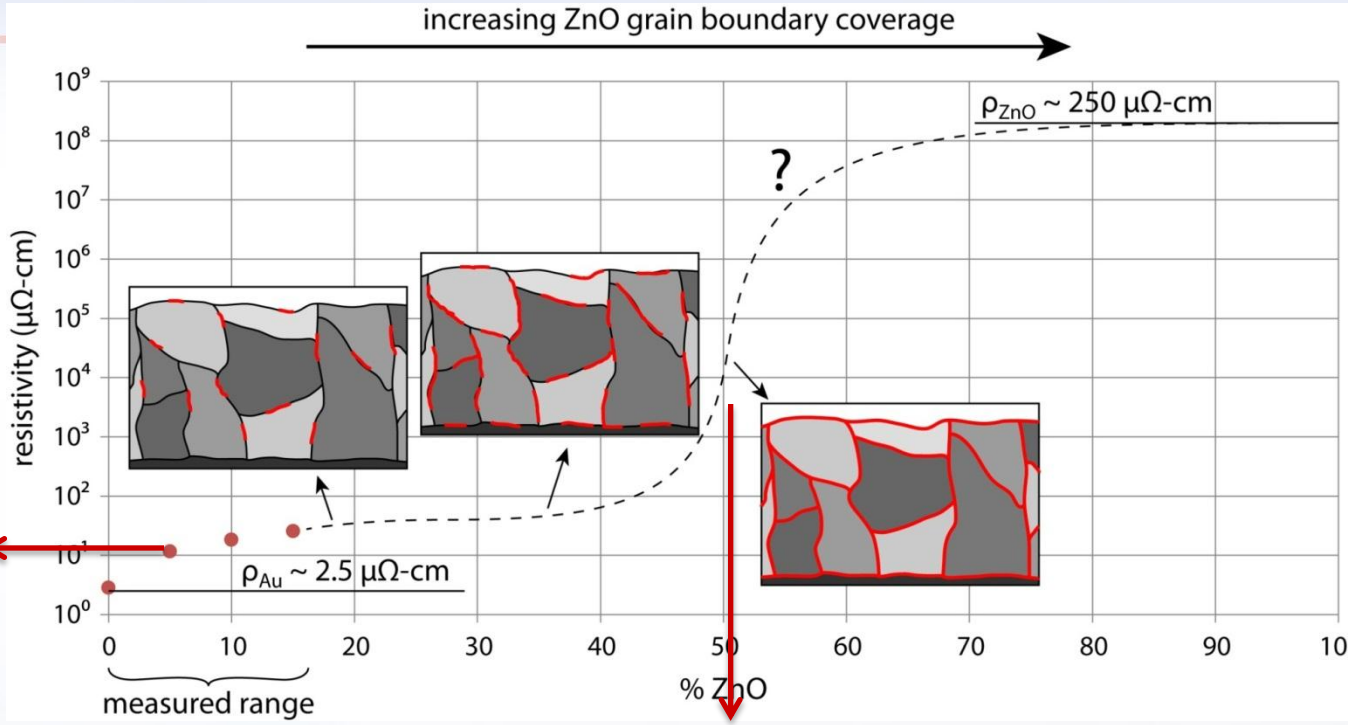
- Target material vaporized by thermal energy from electron beam
- Terrific rate control with feedback from QCM
- Can deposit at extremely slow rates (ppm level composition control)

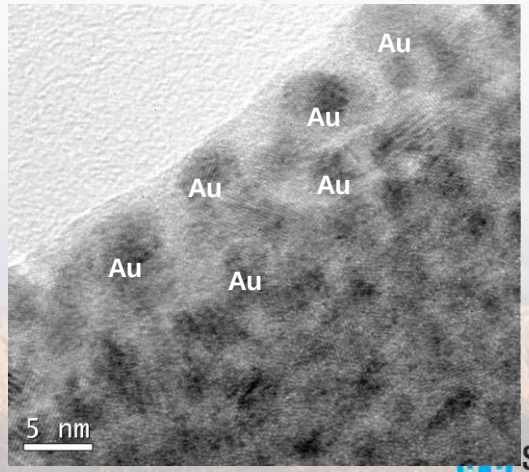
Bulk Resistivity of Nanocomposite

FIB Section
Spectral Image Au-ZnO (5%)



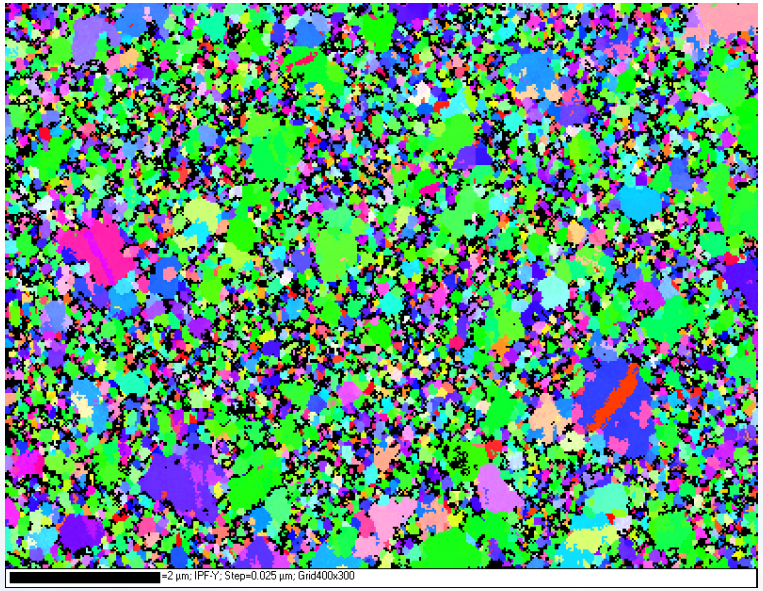
Red = Au
Green = Zn-O



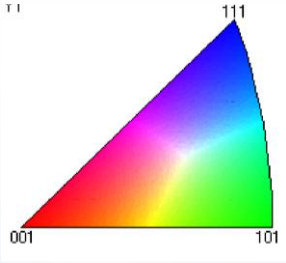


Electron Backscatter Diffraction

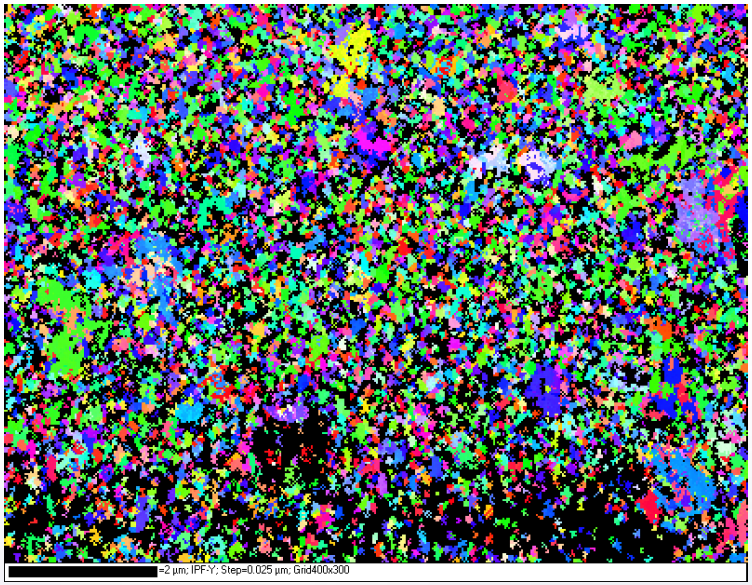
Pure Au



EBSD
E-beam films

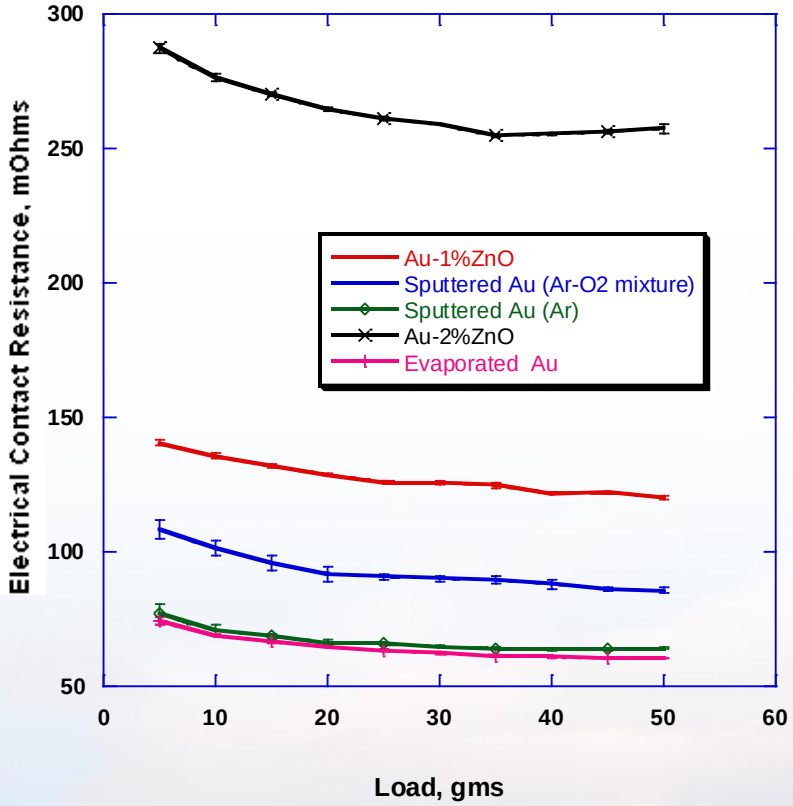


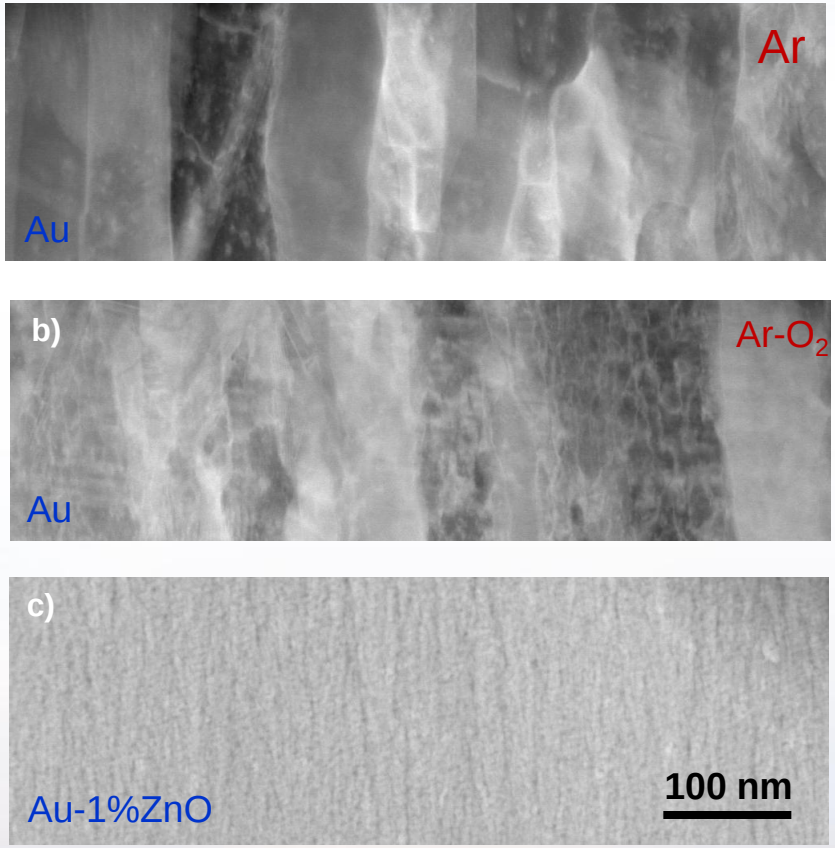
Au-0.1% ZnO



Sandia National Laboratories

ECR (Static) and XTEM





Static ECR

STEM Images

Sandia National Laboratories

Concluding Thoughts

- ECR and Friction are systems properties
- Fundamental understanding of the formation, chemistry (at the nanoscale) of transfer films is the key towards the development of a robust ECR material

Acknowledgements

- Joe Michael for EBSD analysis
- Rand Garfield for ECR-Friction measurements