

# Materials Integration for CHIPS

Mark Goorsky

King-Ning Tu

Materials Science and Engineering



# Materials Science and Engineering: Research and Future Directions

## Top Tier Efforts in:

### – 21<sup>st</sup> Century Society Challenges:

#### Energy and Infrastructure: New Solutions through Novel Materials

DOE EFRC Molecularly Engineered Energy Materials;  
Perovskite and polymer solar cell, Integrated solar cells,  
porous media, nanocatalysts, hydrogen storage,  
computational materials, biofuel cells, 3-D batteries

#### Electronics and Information Technology: Materials Beyond the Roadmap

Interconnects and packaging, quantum wires,  
heterogeneous materials integration, graphene,  
nanodots, dielectrics, nanomagnetic materials, polymer  
memory

#### Bio-inspired Materials: Nano-Engineering with Nature

Virus-based nanoarchitecture assembly, biomolecular and  
bio-hybrid materials, electroelastomer muscles...

- **ArchaeoMaterials**

Conservation, ancient materials and societies

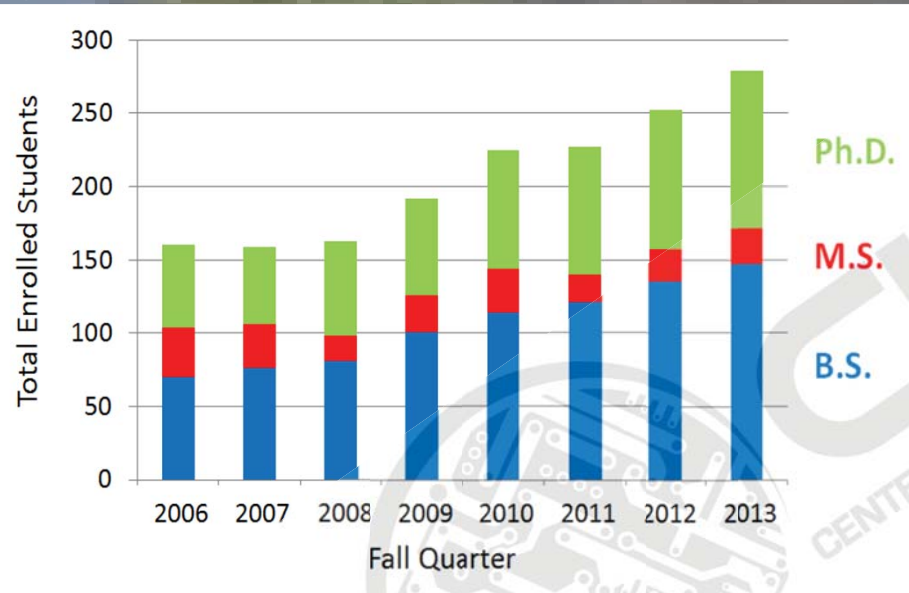




# Materials Science and Engineering

- 2015 QS World University Rankings: 16<sup>th</sup>

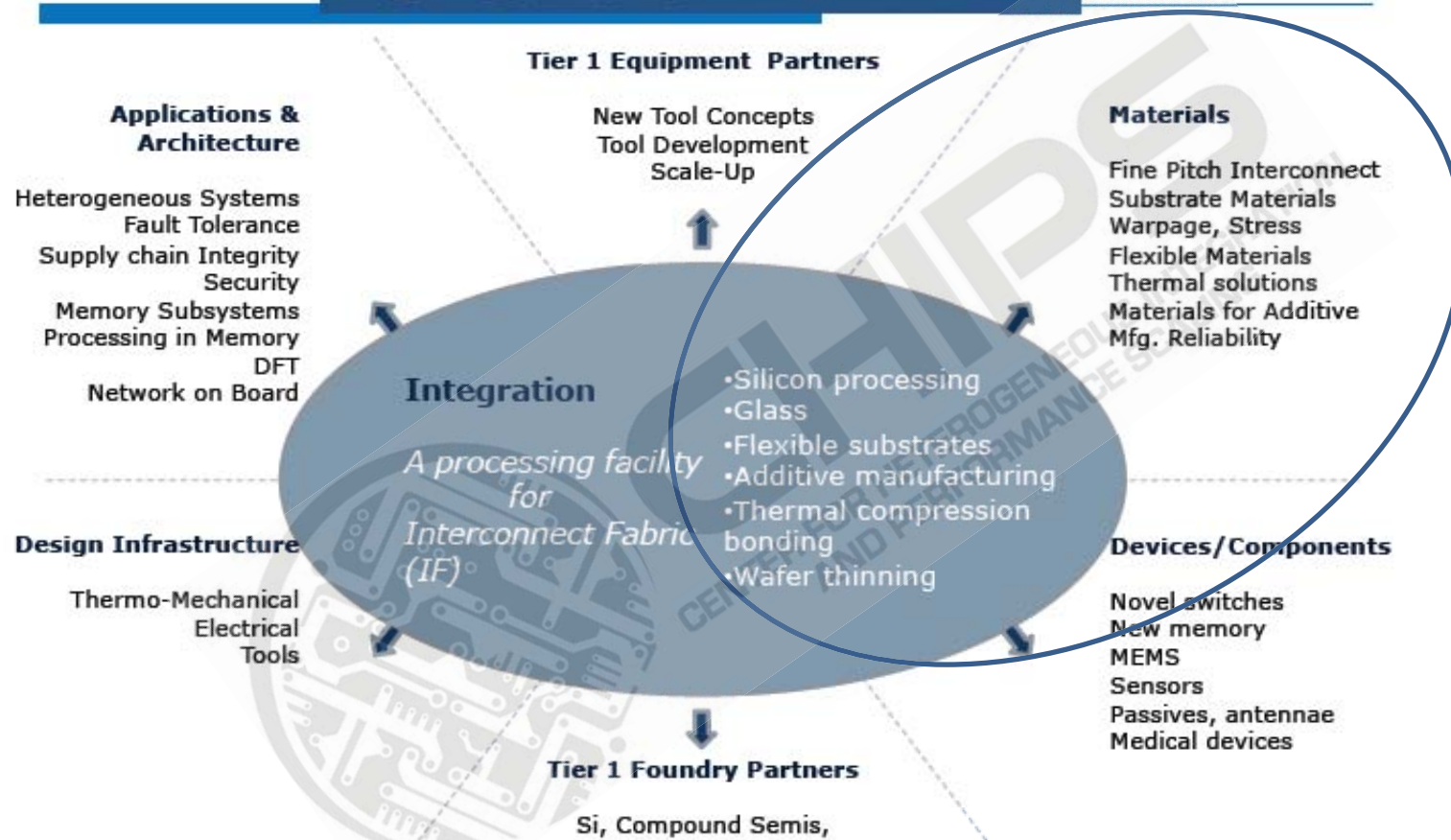
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## 2007 – 2013 Research Funding Expenditures

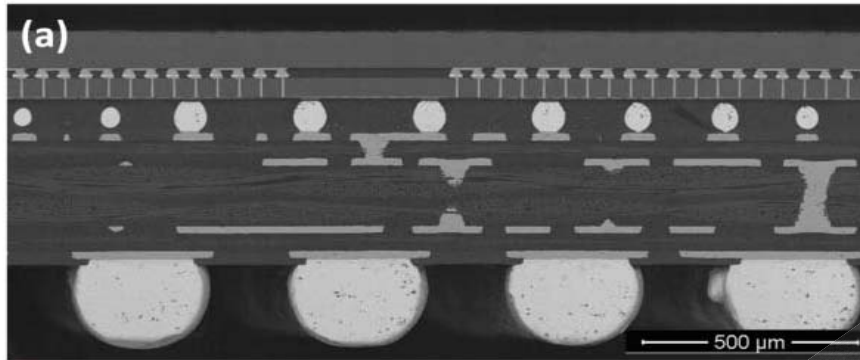
2006 - 2007	\$5,089,711
2007 - 2008	\$6,210,320
2008 - 2009	\$5,523,285
2009 - 2010	\$6,252,166
2010 - 2011	\$7,746,634
2011 - 2012	\$7,015,862
2012 - 2013	<u>\$7,886,133</u>
<b>Total</b>	<b>\$45,724,110</b>

# UCLA CHIPS



# 3D IC Packaging Reliability Research

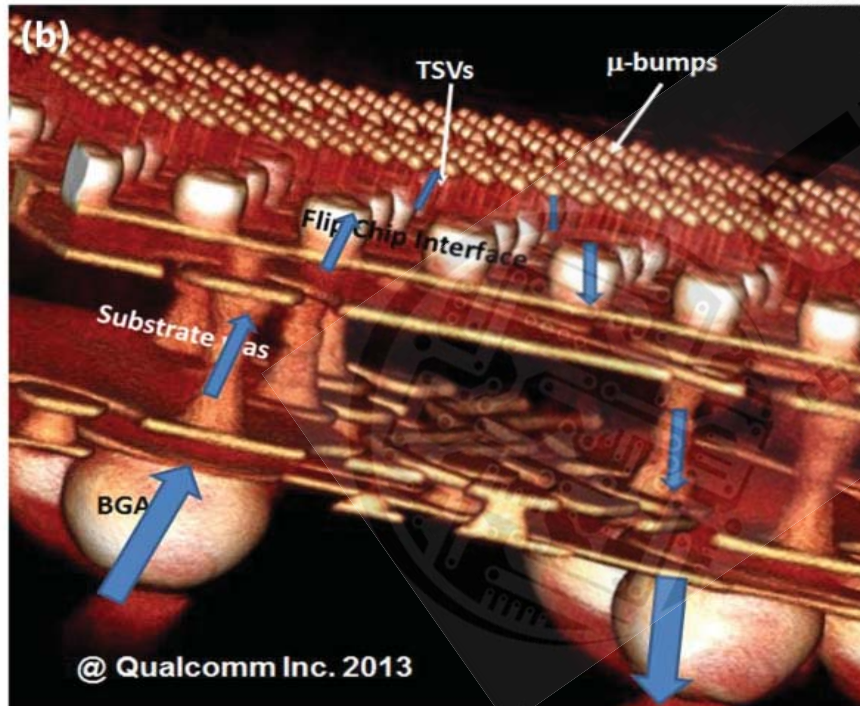
K. N. Tu, Dept. MSE, UCLA



(a) SEM image of cross-section of a stacking of two Si chips, on the top side.

The lower Si interposer chip has TSV.

There are three levels of solder joints; BGA, C-4 joint, and  $\mu$ -bump.



(b) Synchrotron radiation tomography of the 2.5D IC structure shown in (a).

The blue arrows indicate the path of applied current in electromigration study.

Yingxia Liu, et al, "Synergistic effect of electromigration and Joule heating on system level weak-link failure in 2.5D integrated circuits," J. Appl. Phys., **118**, 135304 (2015).

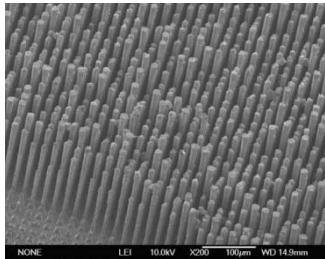
ECTC 2015 Intel best student paper:  
Yaodong Wang "Size Effect on Ductile-to-Brittle Transition in Cu-Solder-Cu Micro-Joints"



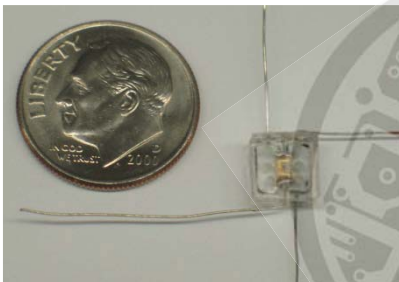
# 3-D Batteries: A New Direction for Portable Power

Bruce Dunn, MSE, UCLA

High aspect ratio Zn arrays

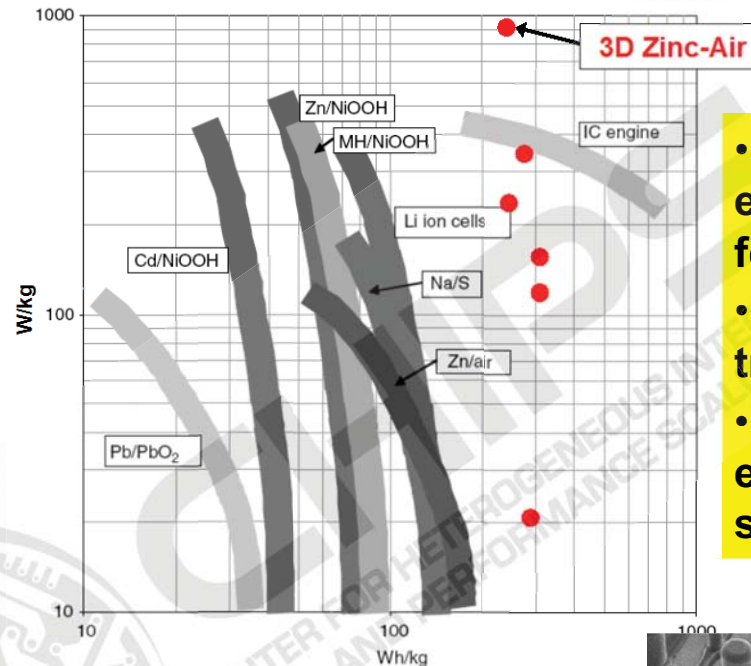


3-D Zinc-air microbattery



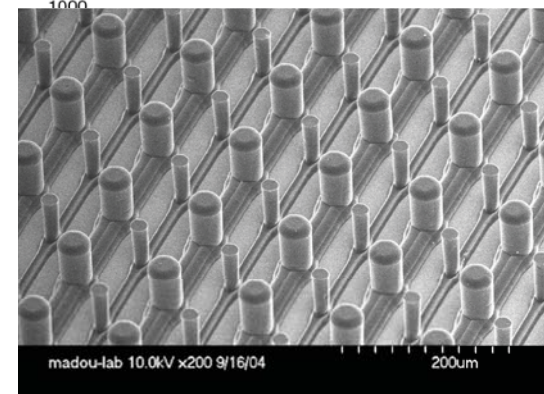
**Lithium-ion secondary battery**

- Interdigitated design
- Alternate rows of carbon and polypyrrole rods



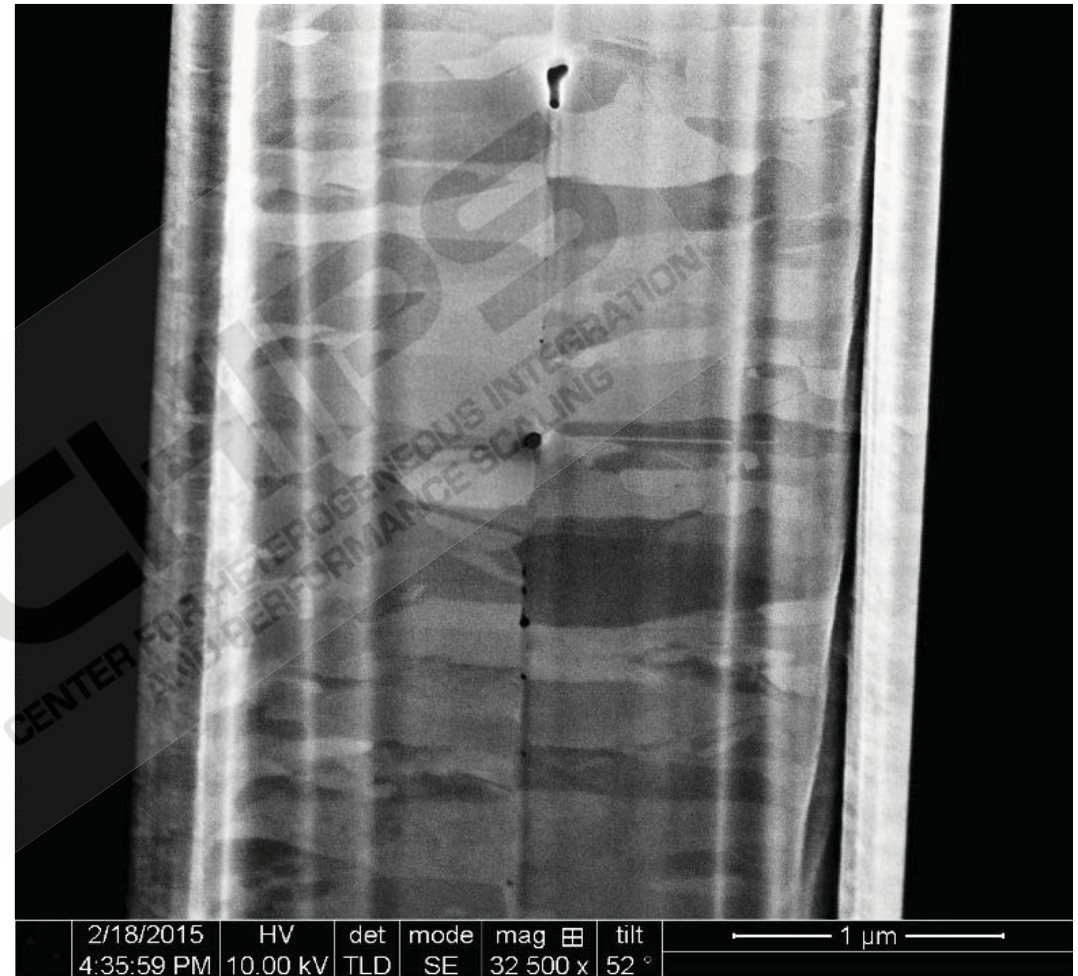
**3-D battery architectures**

- Maximize power and energy density in small footprint area
- Maintain short ion transport distances
- Micromachined electrodes for precise spatial control



# Thermocompression Bonding: Cu and Au

- Grain evolution, bonding and electrical integrity

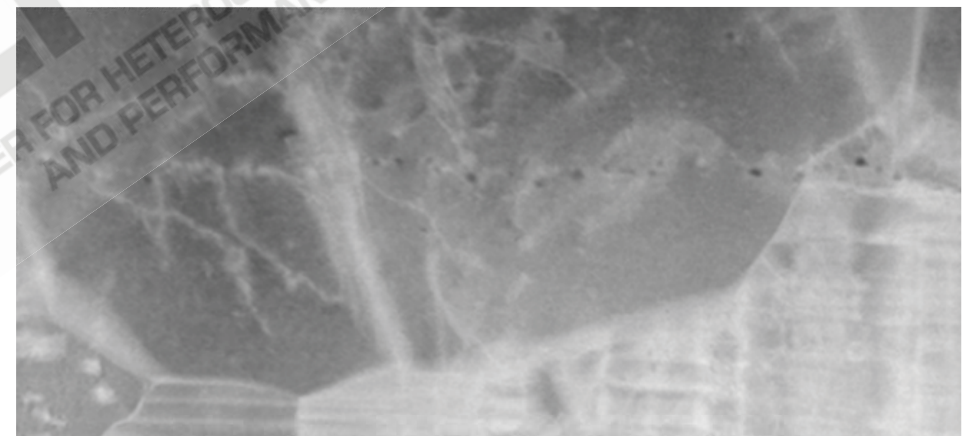
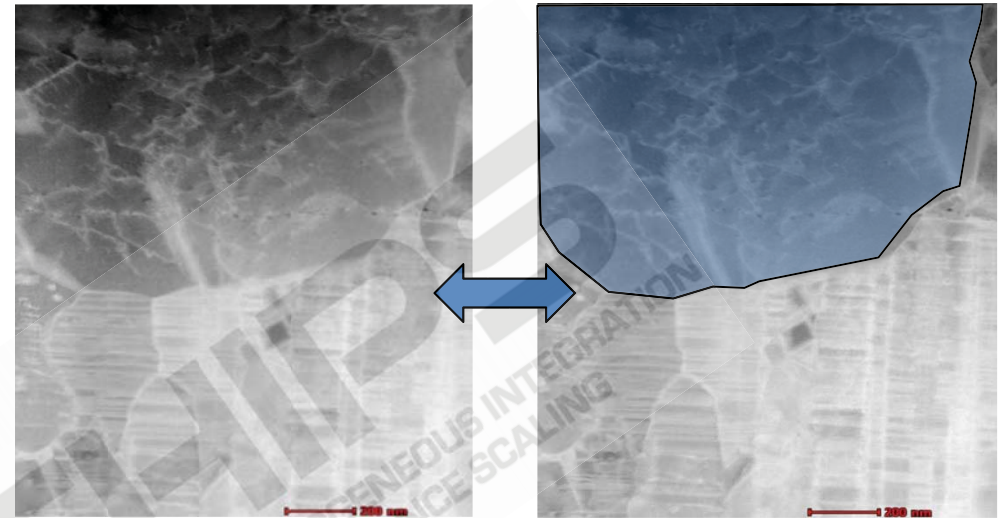
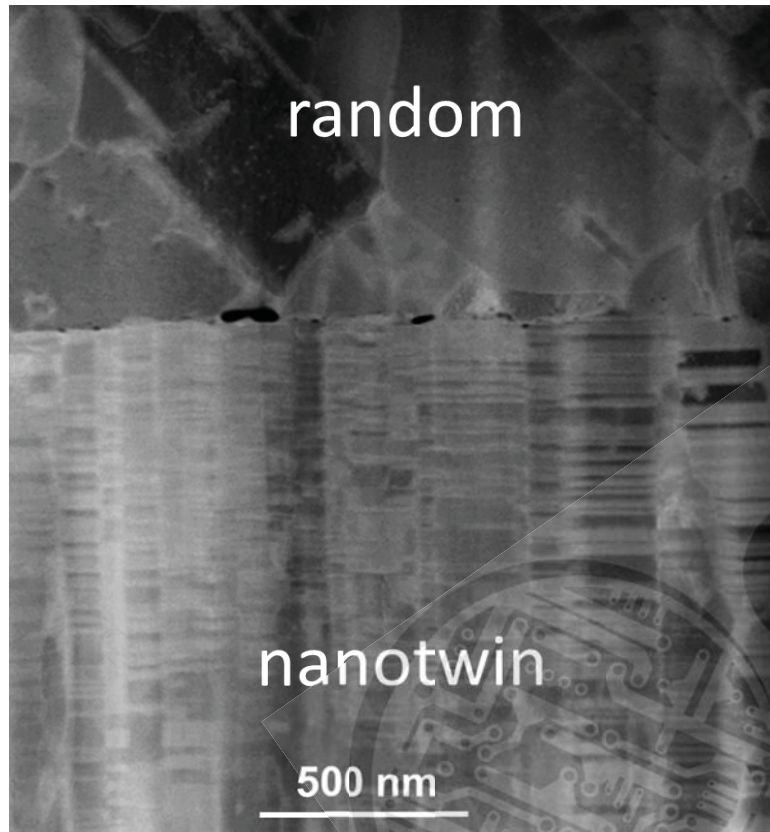






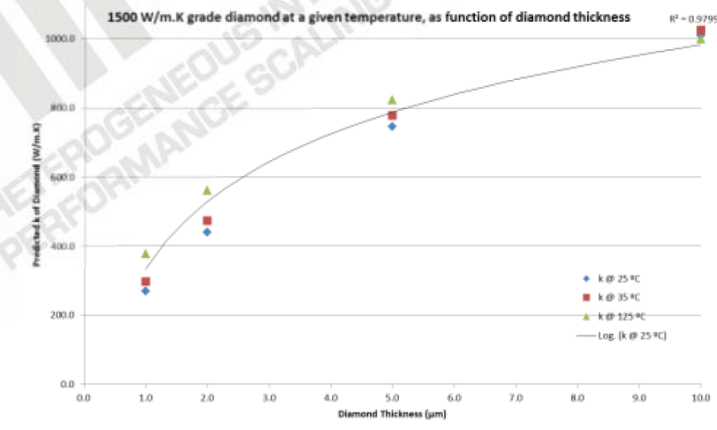
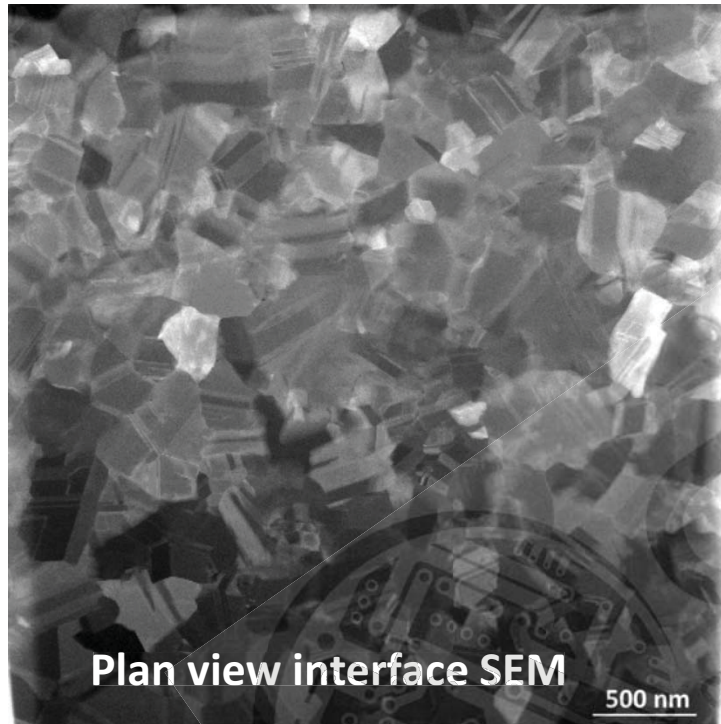


# TEM of Bonded Interfaces: Nanotwin



- Conditions for nanotwin transformation: Grain orientation

# Novel Diamond Materials for Fundamental Thermal Understanding and Round Robin Measurement Study



- Role of nucleation layer, grain size, dislocations unknown for thermal performance



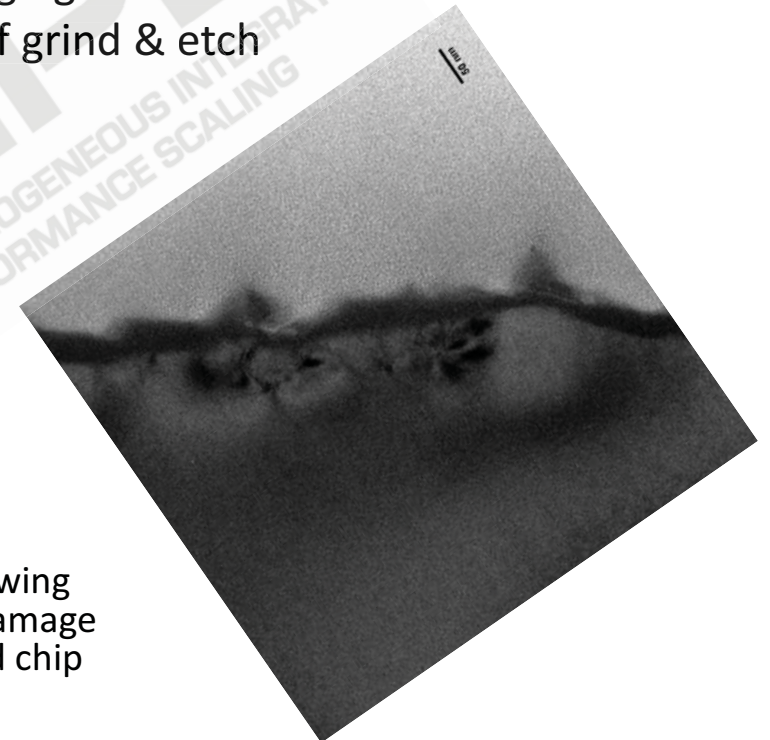
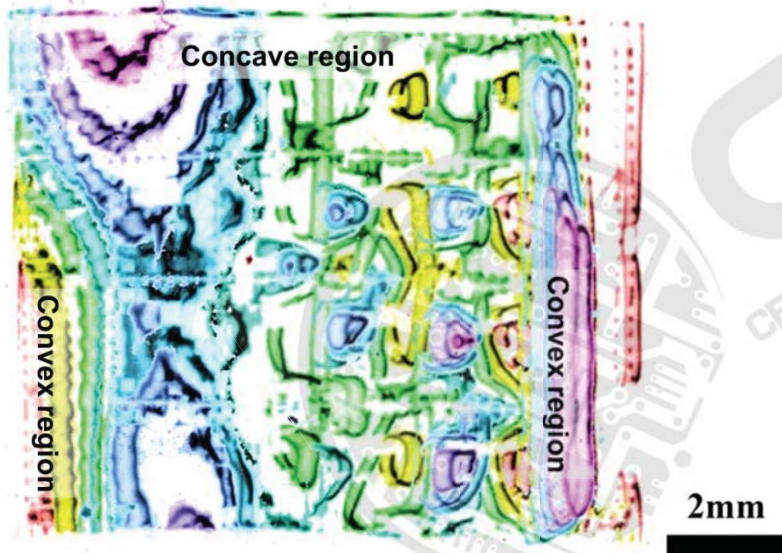
# Warpage / Stress Assessment & Thinning

X-ray diffraction imaging  
Quantify strain / stress through  
imaging techniques to  
determine strain in bonded  
chips

Stress introduced in thinning procedure  
Wafer grinding  
Cracks, breakage

Etching  
Importance of damage-removal etch  
Diffraction imaging and HRXRD to assess  
effectiveness of grind & etch

-300" -150" 0" +100" +150" +200" +300" +400"



# MSE Summary

## UCLA CHIPS

