



Jet Propulsion Laboratory
California Institute of Technology

Advanced Packaging Overview

Dr. Douglas J. Sheldon

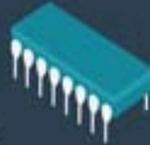
Assurance Technology Program Office (ATPO) Manager
Office of Safety and Mission Success
Jet Propulsion Laboratory, California Institute of Technology

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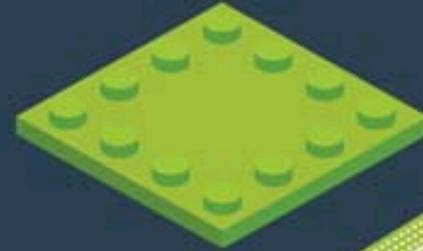
FROM DIPs TO SiPs: AN EVOLUTION OF SEMICONDUCTOR PACKAGING



1970s



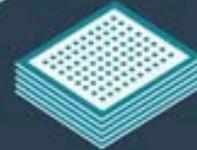
1980s



1990s



2000s

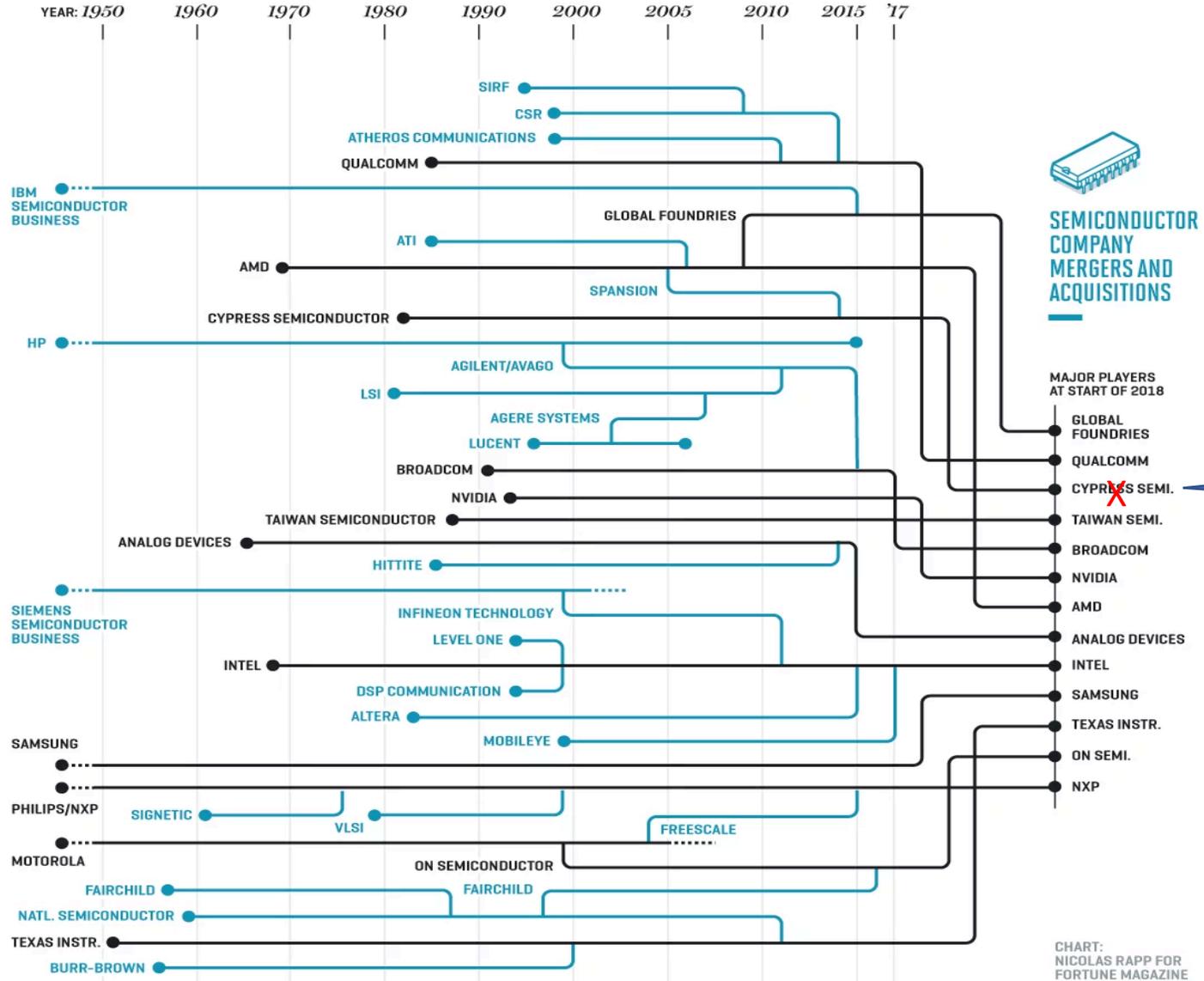


TODAY



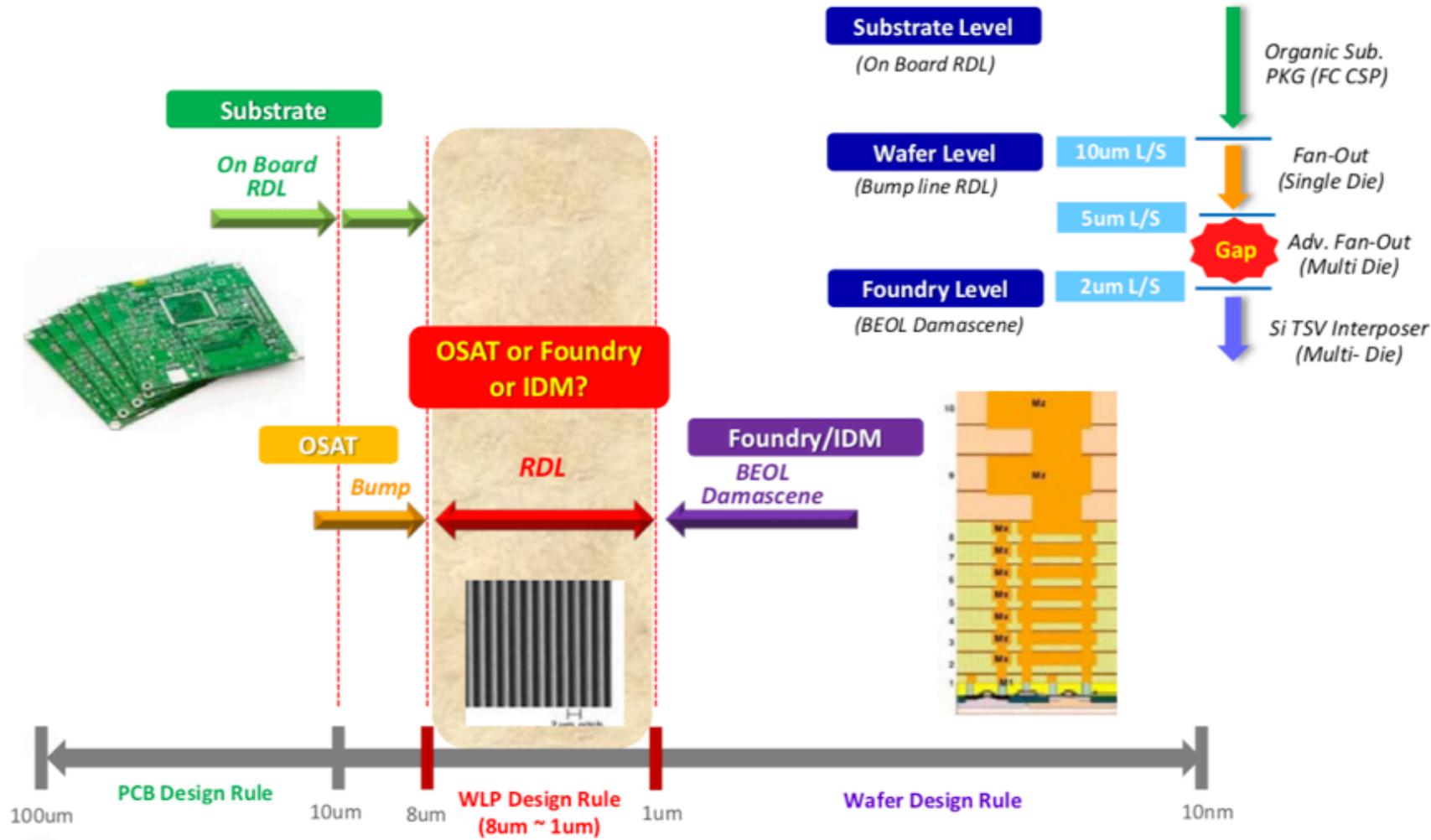
THE FUTURE?

Changing vendor landscape w/ Mergers and Acquisitions



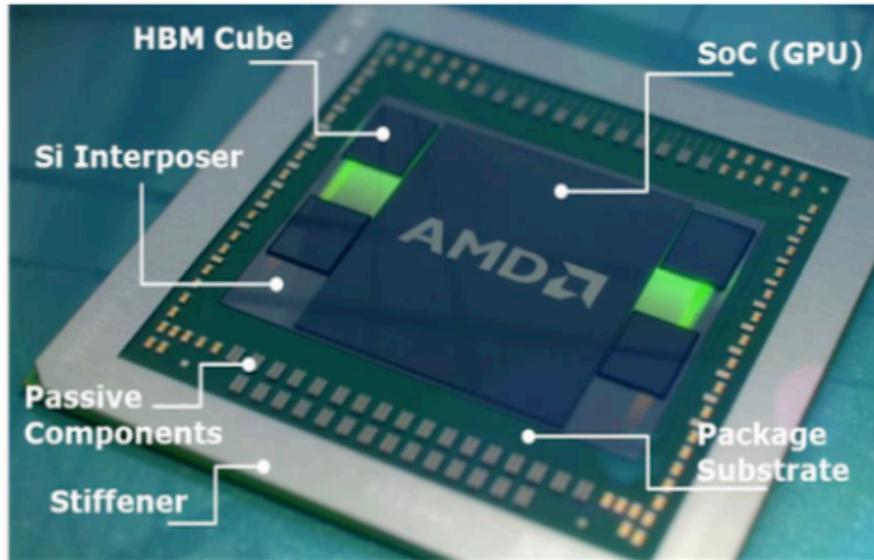
Infineon buys Cypress for \$10B June 2019

Packaging Technology Has Changed the IC industry

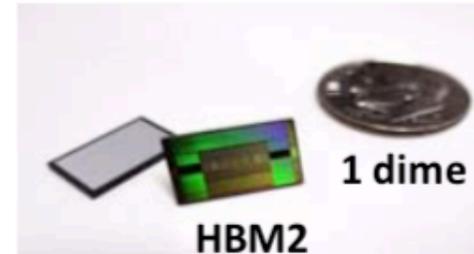
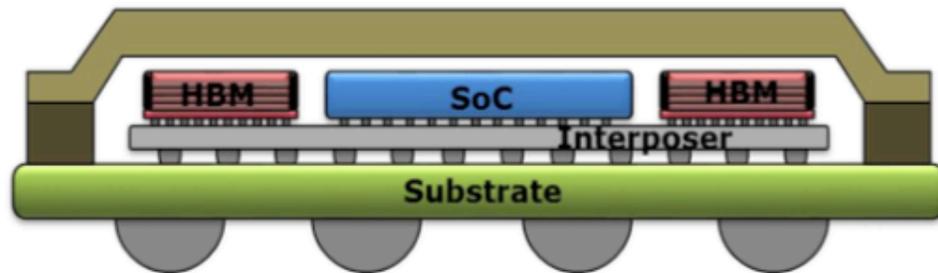


- The historical distinction between wafer fab and packaging vendor has disappeared
- Stacking technologies are wafer based requiring wafer technology expertise
- Dimensions are the same that appear in the wafer fab
- NASA's approach to IC packaging needs to evolve just as the supplier base has evolved

Example of latest state of the art



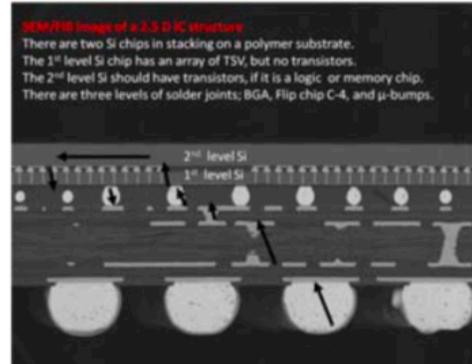
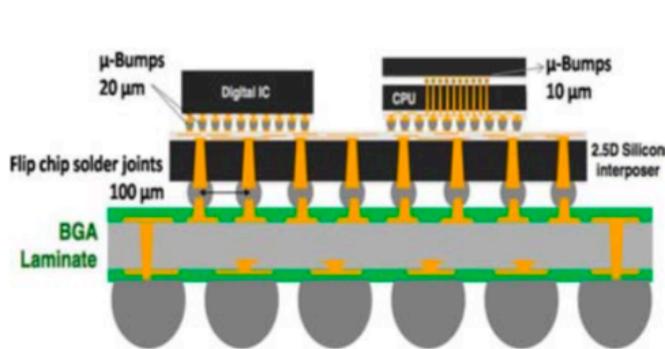
Source) AMD



- PKG Size ; 1000 ~ 2500mm²
- Interposer Size ; 500~1500mm²
 - Over than 1 Photo shot (Stitch process needed)
- HBM die size ; 90~110mm²
 - Fit-in of multiple HBM cubes in interposer die

Nicky. Kim, IEEE IEDM, 2018

Reliability Issues are focus for use at NASA

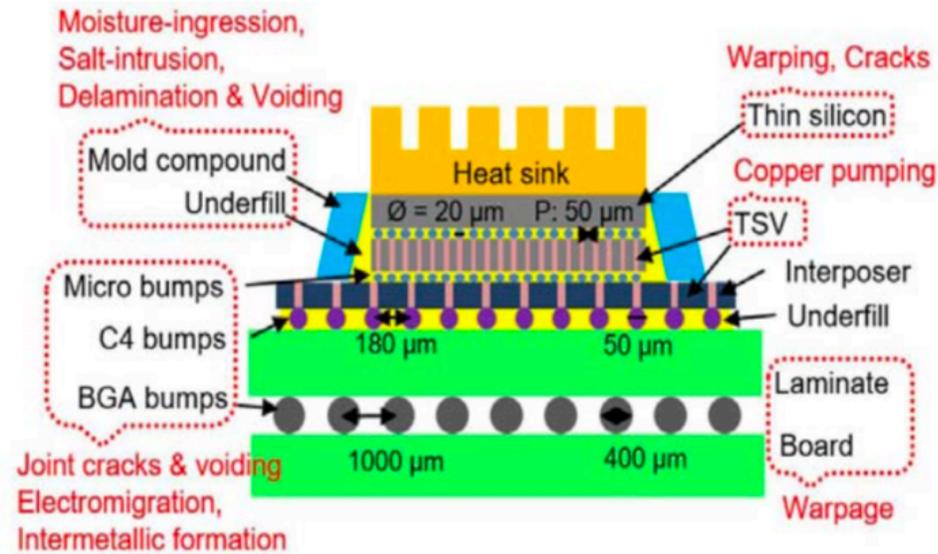


Three-level Joints ;

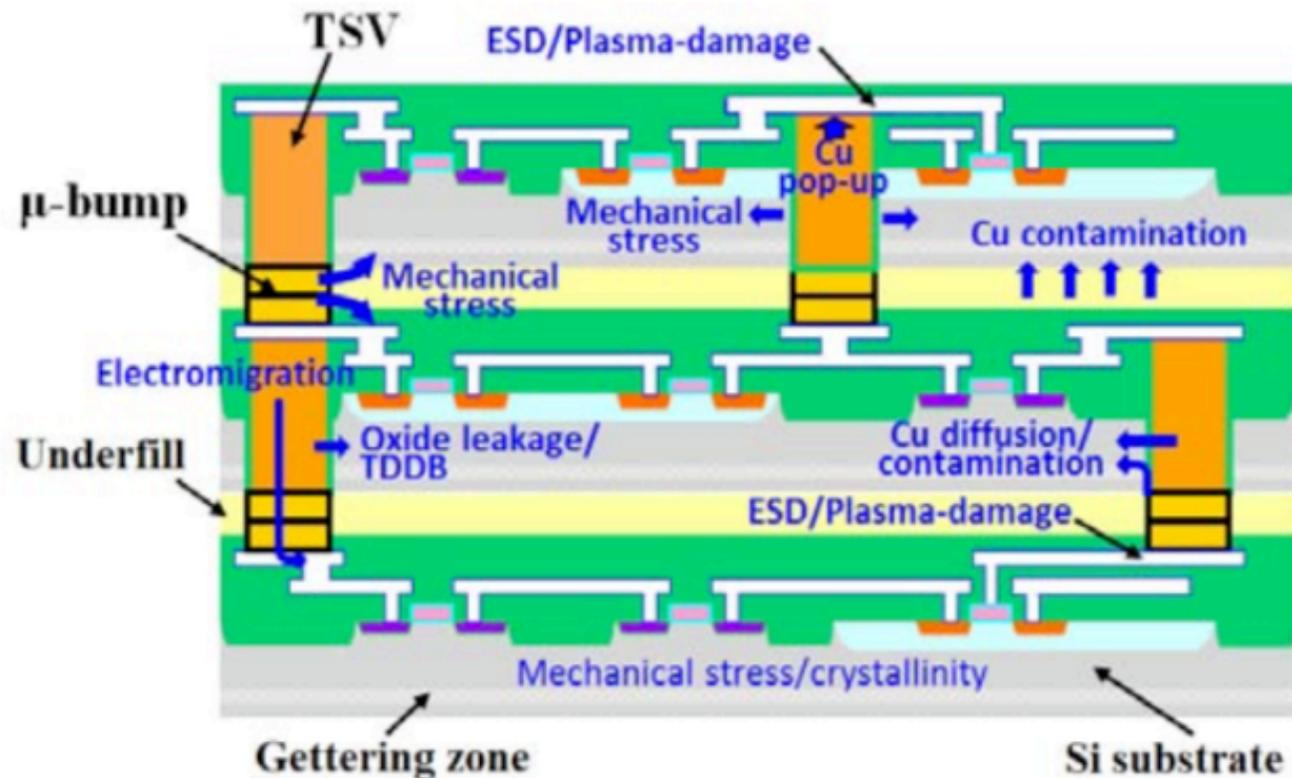
- 1) Micro-bumps
 - HBM Inside
 - HBM/SoC to Interposer
- 2) Flip Chip C4
 - Interposer to PKG Substrate
- 3) BGA
 - PKG to Board

K.N.Tu, Applied Physics Review (2017)

- Orders of magnitude dimensionality changes along with many new materials developments have made reliability evaluation challenging
- Changes are driven by market requirements (size, performance, etc.) NOT reliability
- Reliability is focused on meeting usage conditions for very specific circumstances (consumer, automotive, etc.)



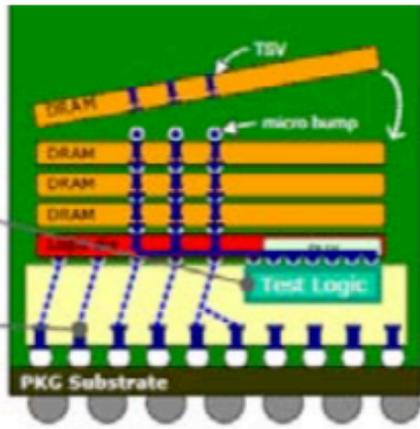
Specific Reliability Concerns



K.W. Lee et al., IEEE IEDM, 2013

- Mechanical stress and strain by Cu TSVs and metal micro-joining
- Si strength and crystallinity changing by Si thinning
- Metal contamination from Cu TSVs and thinned backside surface
- EDS/Plasma damage
- Electromigration of TSV and metal bump
- Oxide leakage / TDDB

Example of evolution in Reliability evaluation

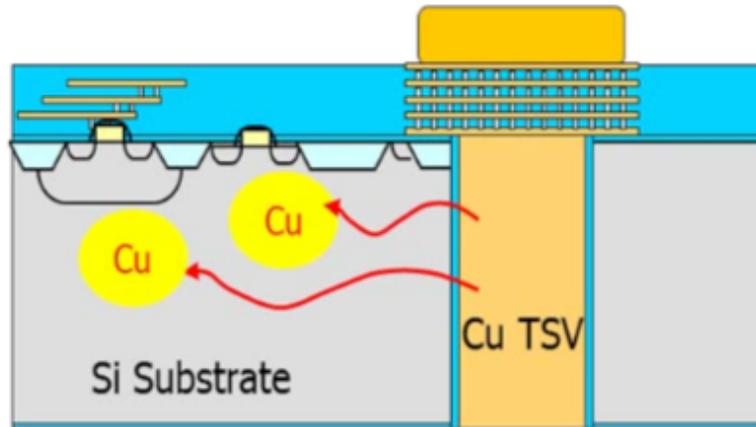


- **BISS (Built-in Self Stress) replace burn-in test in conventional PKG**
- **Proxy PKG used for lifetime and long-term reliability testing**
 - . Active area; Logic test w/ direct PHY connection (I/O evaluation)
 - . Passive area; Merely provide a path btw DA pas and PKG ball (Cell Characteristics)

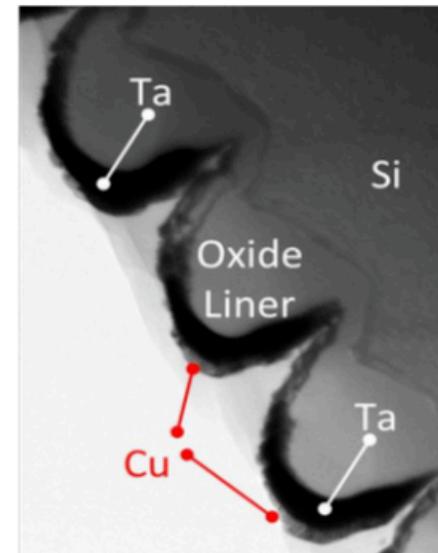
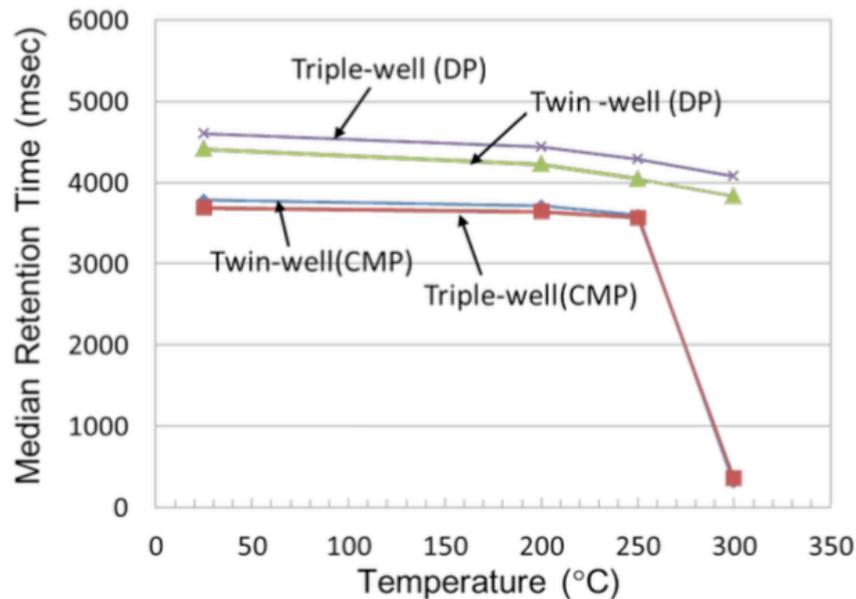
Nicky. Kim, IEEE IEDM, 2018

- Vendors must deal with issues of die and wafer yield at internal processing steps as well as at the final product step
- NASA needs detailed understanding of manufacturing process to effectively evaluate fitness for use in space

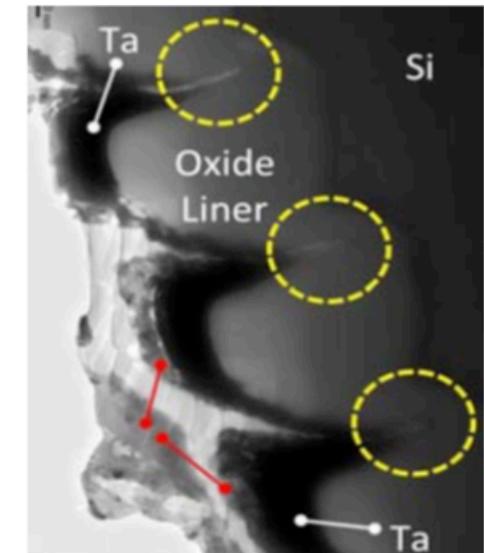
Diffusion of Cu as a reliability concern



- Cu diffusion can have significant degradation on MOS performance (decrease minority carrier lifetime, reduce TDDDB by infusion into gate oxide)
- Strongly correlated to overall temperature profile of process

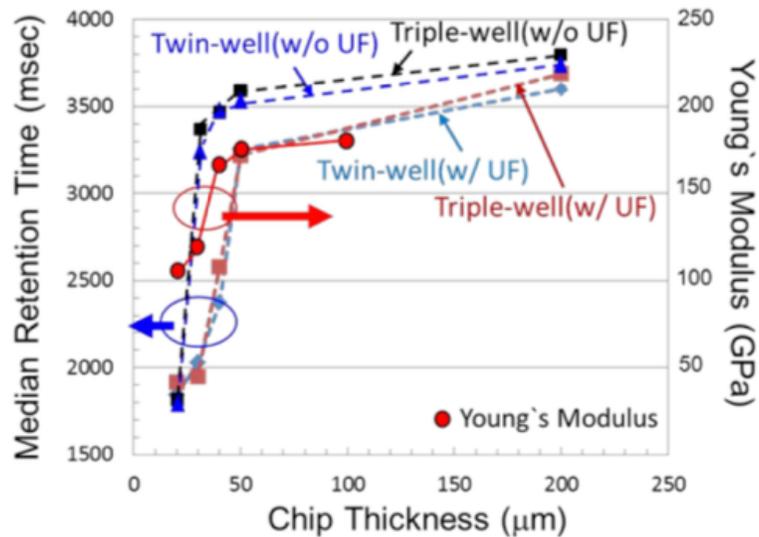
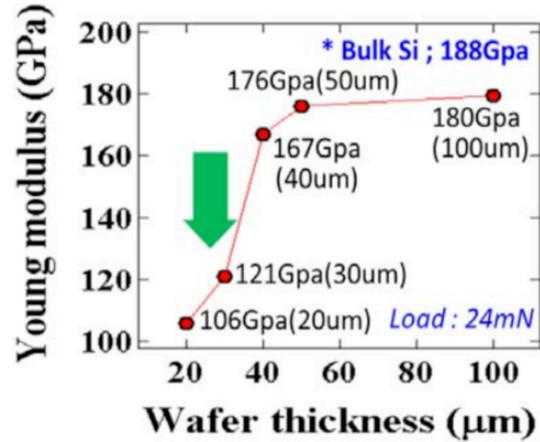


(a) as Cu deposition

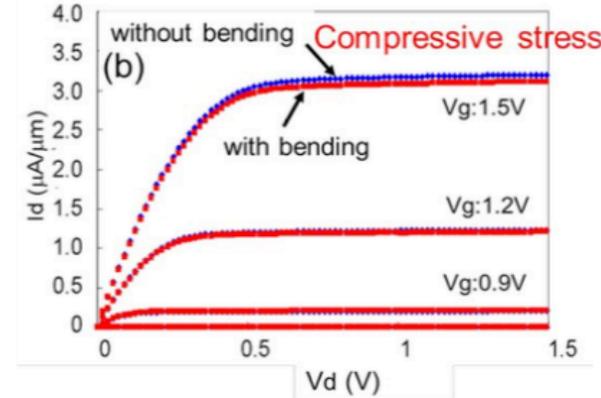
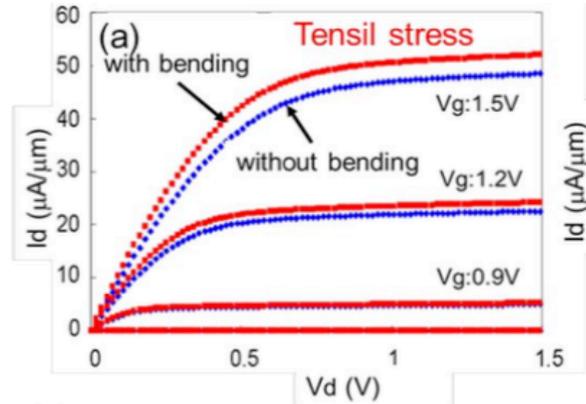


(b) after annealing at 400C

Ultra thin die as a reliability risk



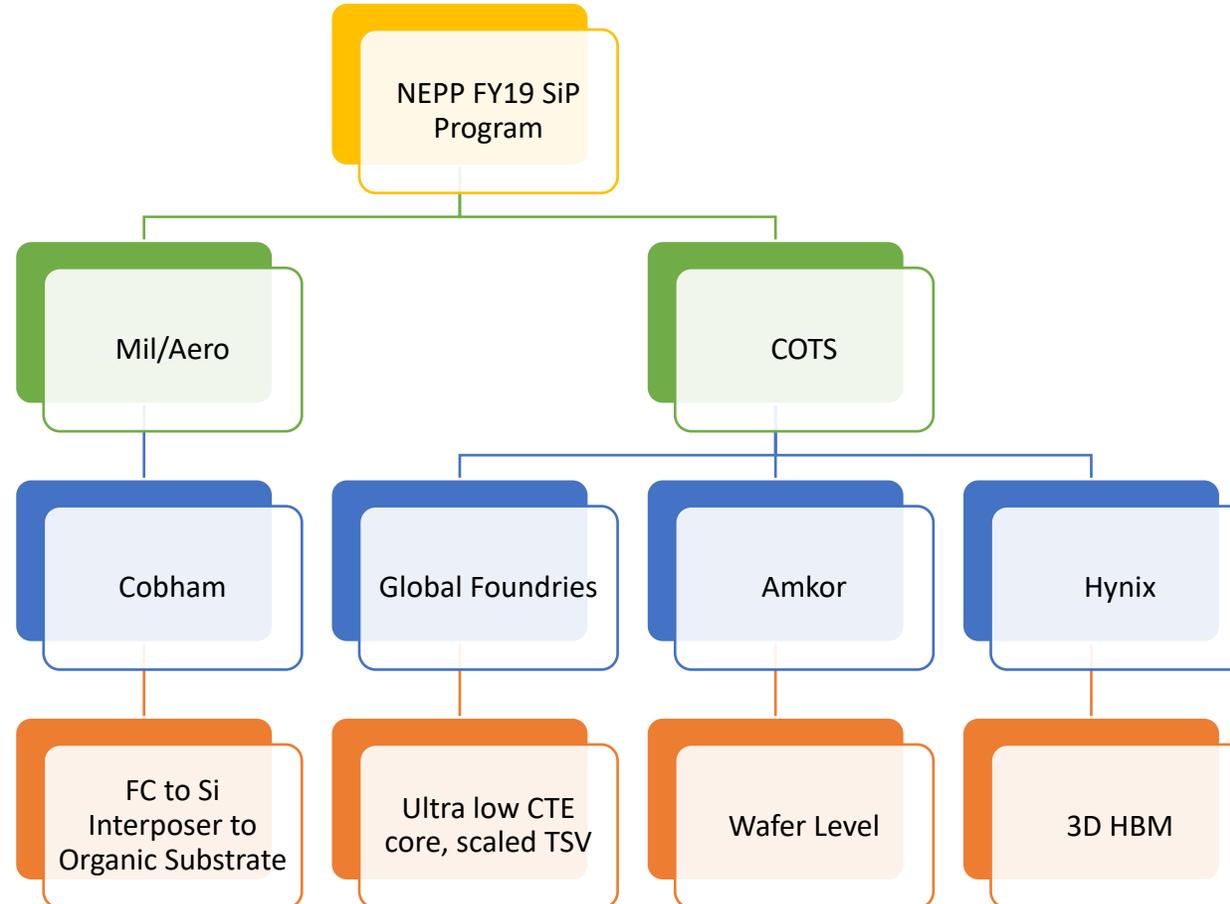
K.W Lee, et al., IEEE T-ED 2014



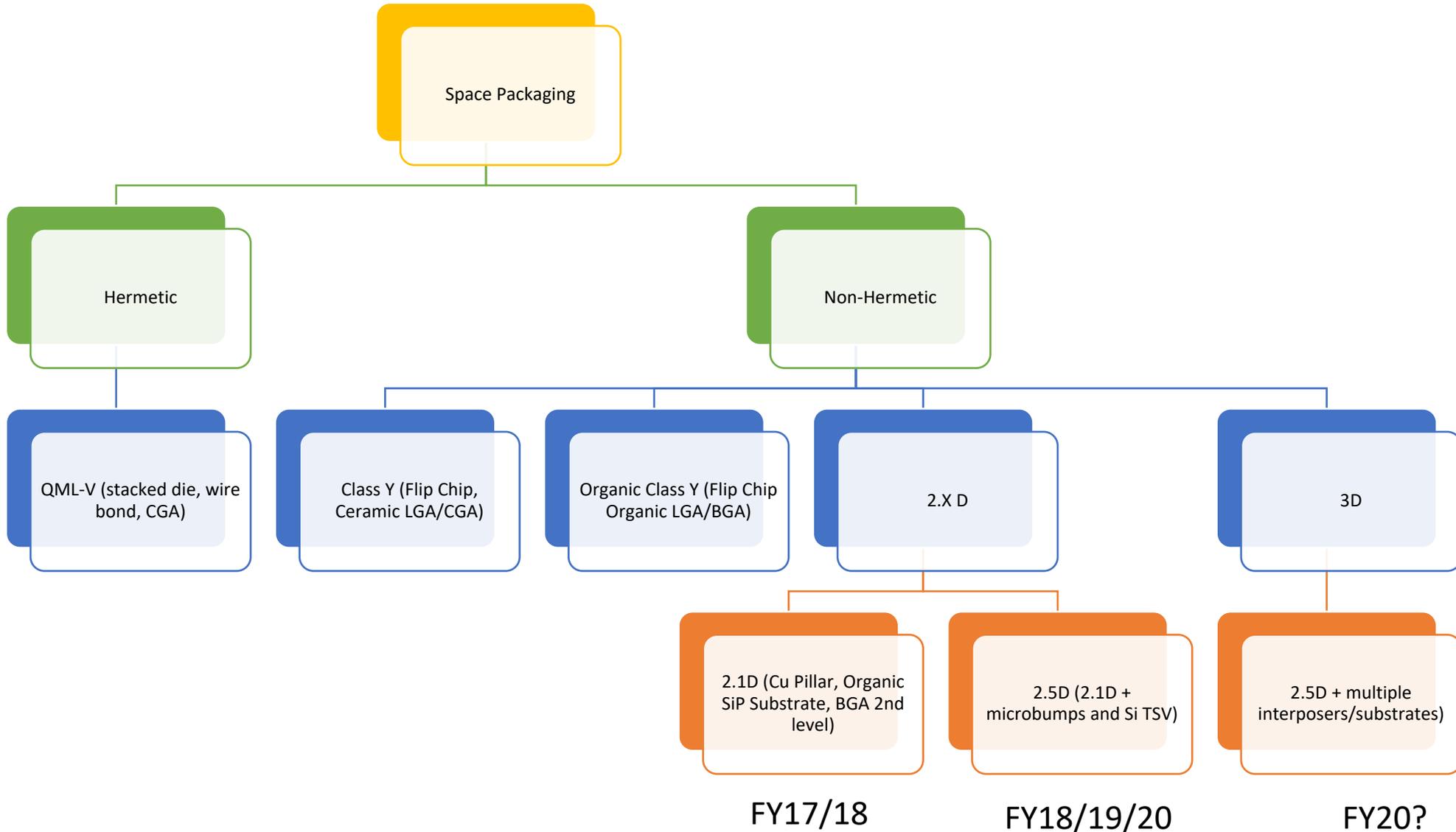
M. Koyanagi, IEEE IRPS 2011

- Young's modulus (mechanical strength) of Si substrate decrease with the reduction of Si thickness, especially dramatically decrease below 30-um thickness
- Large distortion of the lattice structure in thin Si substrate induces the reduction of Young's modulus, consequently deteriorate the mechanical strength
- Effects are on device parameters as well overall mechanical robustness

NEPP FY19 SiP overview



NEPP and Cobham Space Parts Packaging Roadmap



Moving forward

- Leverage 2.5/3D telecon as platform for technology exchange and partnership formation
- Increase outreach to understand options for custom 2.5D at NASA
 - COTS SiPs are specifically developed for a market
 - For NASA to leverage this a specific packaging “task” or “demand” needs to be defined (if it exists)
- Continue analysis research into additional reliability stress conditions and analysis methodologies
 - 3D CAD analysis
 - Step stress, pre-condition steps, monte carlo analysis, etc.



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