# Missile Defense Agency PMP Update
# For the 2016 Space Parts Working Group


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# Introduction

- New technology poses reliability issues for DoD and Space systems
  - Copper wire bonds are prevalent in COTS (Commercial Off The Shelf) parts
  - 3D packages and ICs are beginning to enter the COTS market
- Collaborating with academia and high-reliability industries to understand new technology reliability issues
- Leveraging radiation effects community knowledge

# Copper Wire Bonds

- Military applications are unsure of copper wire bonded parts and generally in a qualification and evaluation phase
- DLA issuing new VIDs (Videos) that *exclude copper wire-bonded parts*
- IC (Integrated Circuit) manufacturers *including disclaimers for copper wire-bonded parts* NOT to be used in military/aerospace applications
- DPA (Destructive Physical Analysis) decapsulation methods are still being perfected
- Copper wire bond transition status sometimes difficult to determine from PCNs (Parts Change Notice) or industry information

## Copper Wire Bond Indicators by Mfr

| | |
|---|---|
| **Altera** | Letter "C" at the end of the lot number. |
| **Atmel** | Adds a "C" to the orderable part number to specify copper only on sample parts. Production parts have no physical indicator. |
| **Central Semiconductor** | No physical indicator |
| **Cypress** | "C" on device packaging. |
| **Diodes Inc.** | Indicator is not always available and varies according to the site of manufacture (may be a dash over the date code). Review the PCNs for additional guidance. |
| **Exar** | No physical indicator |
| **Freescale** | No physical indicator |
| **IDT** | "Y" suffix on lot number. |
| **International Rectifier** | Underscore after lot code (XXXXP_) |
| **Intersil** | "M" site code = copper, "H" site code = gold |
| **Lattice** | Numeric value in the fifth position of the Lot/Date Code (XXXX#XXX) |
| **Marvell** | No physical indicator |
| **Micro** | Letter "C" at the end of the date code. (YYWW C) |
| **Microsemi** | No physical indicator |
| **Microchip Technology** | No physical indicator |
| **National Semiconductor** | No physical indicator |
| **NXP** | Site/Year/Month (SYM) part date code format changed to Site/Year/Week (SYWW) |
| **On Semiconductor** | No physical indicator |
| **Texas Instruments** | No physical indicator |
| **Vishay** | No physical indicator |
| **Xilinx** | No physical indicator |

# State of Affairs for Cu Wire Bonds

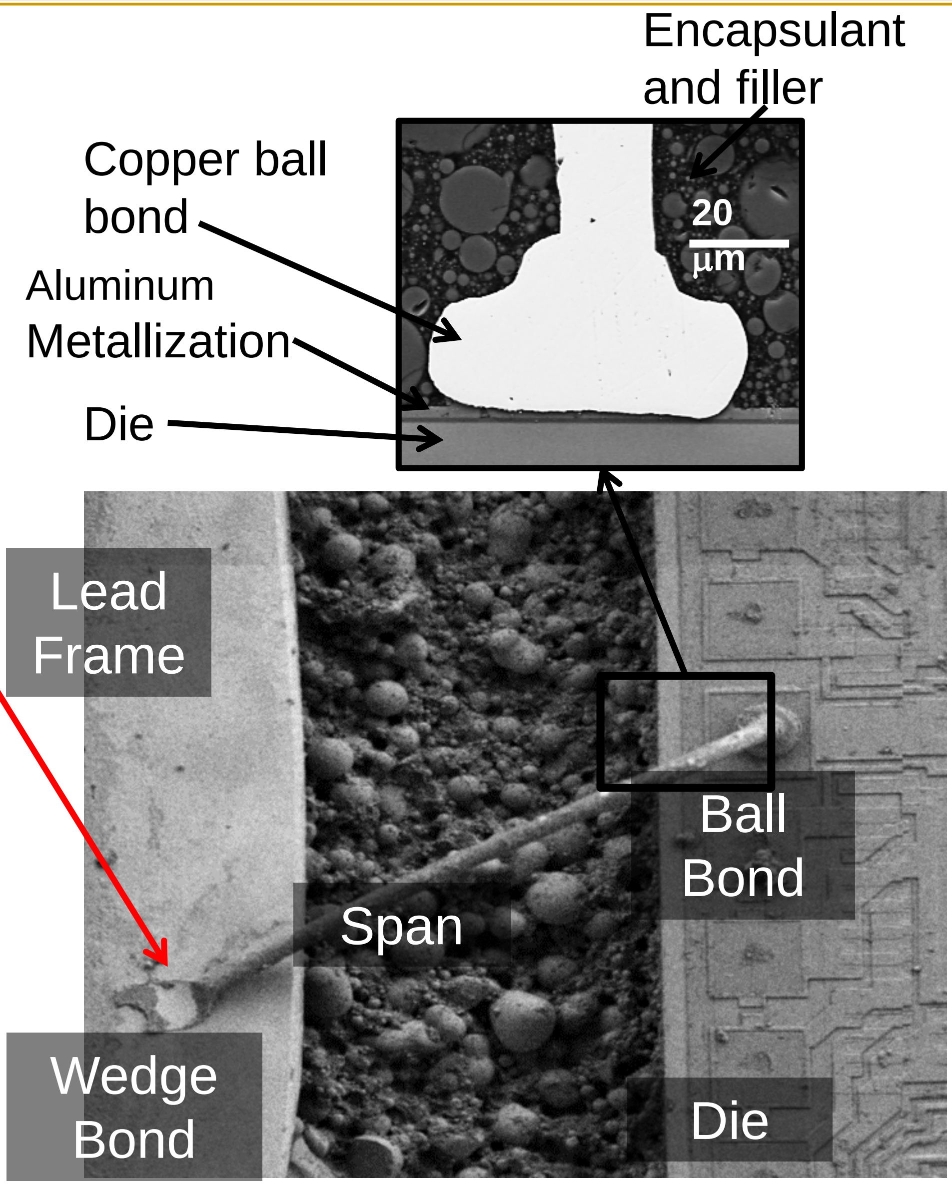
- PEM manufactures moving away from gold (Au) wire bonds to copper wire bonds
- Automotive Industry revised all qualification requirements for Cu (Copper) Wire Bond parts. Qualification levels were doubled for some environments using Cu Wire Bond Parts (June 2015).
- Military has not yet followed, but Defense Logistics Agency (DLA) is not allowing Cu Wire Parts for Military Qualified parts.
- Texas Instruments (TI) has been transitioning to copper wire bonds over the past several years, yet still includes the following notice in their whitepaper "TI's Journey to High-Volume Copper Wire Bonding Production":

*"Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have not been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use."*

- Qualification procedures have been designed around the failure mechanisms associated with gold and aluminum (Al) wire bonds (NOT Cu)
- **Current qualification and screening procedures are not appropriate for copper wire bonded PEM's in <u>Military systems</u>?**

# Anatomy of a Copper Wire Bond

- A copper wire bond connects the lead frame to the die
  - Wedge (stich) bond to lead frame
  - Ball bond to die
- Configuration is the same as a gold wire bond
- Die, lead frame, and wire are encapsulated in a plastic loaded with silicon dioxide filler

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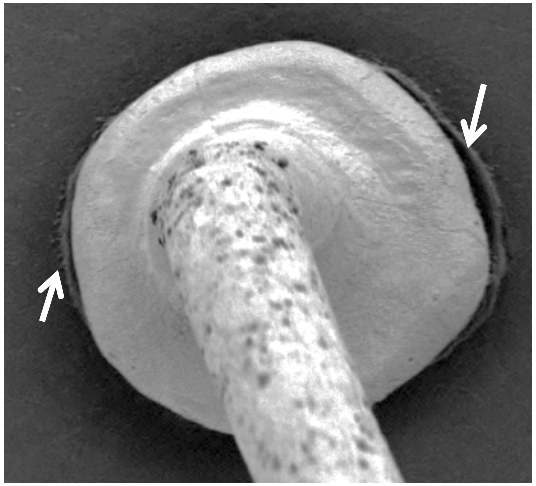
# Different Properties, Different Concerns

Manufacturing | Qualification and Screening | Shelf Life / Application

- **Propensity to oxidize**
- **Propensity to corrode**
- Inter-diffusion rates
- **Mechanical properties**



Aluminum splash around a copper wire bond.

- Cu has higher propensity to oxidize
  - Bonding performed in a forming gas to ensure good metallic bonding
- Cu has a higher propensity to corrode
  - Different plastic encapsulant material may be used to lower the concentration of corrosive ions
  - Cleaning processes (during manufacturing and assembly) must be proven effective
- Cu is stiffer
  - Increased probability of Al splash
  - Increased probability of die cracking
- Cu work-hardens
  - Increases probability of cracking of stich bond

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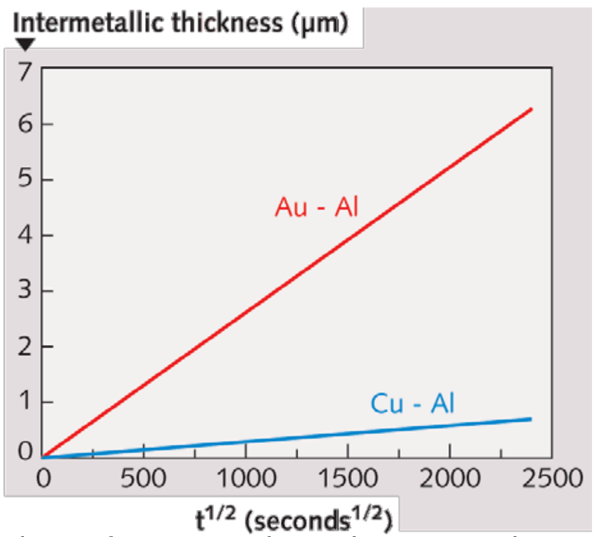



Comparison of Cu-AL and Au-Al IMC growth rate at 175°C. Figure taken from *Copper Wire Bond Failure Mechanisms* (Schueller, DfR Solutions) and recreated from Copper vs. Gold Ball Bonding (Breach)

- Cu has a higher propensity to corrode
  - Electrically biased temperature/humidity accelerated aging testing more likely to result in a failure
- The rate of Cu-Al intermetallics (IMC's) is substantially slower than Au-Al IMC's
  - Higher temperature storage less likely to result in a failure
- Cu is stiffer than Au
  - Higher stress and different failure modes during mechanical testing

# Different Properties, Different Concerns

Manufacturing → Qualification and Screening → **Shelf Life / Application**

- **Propensity to oxidize**
- **Propensity to corrode**
- **Inter-diffusion rates**
- **Mechanical properties**

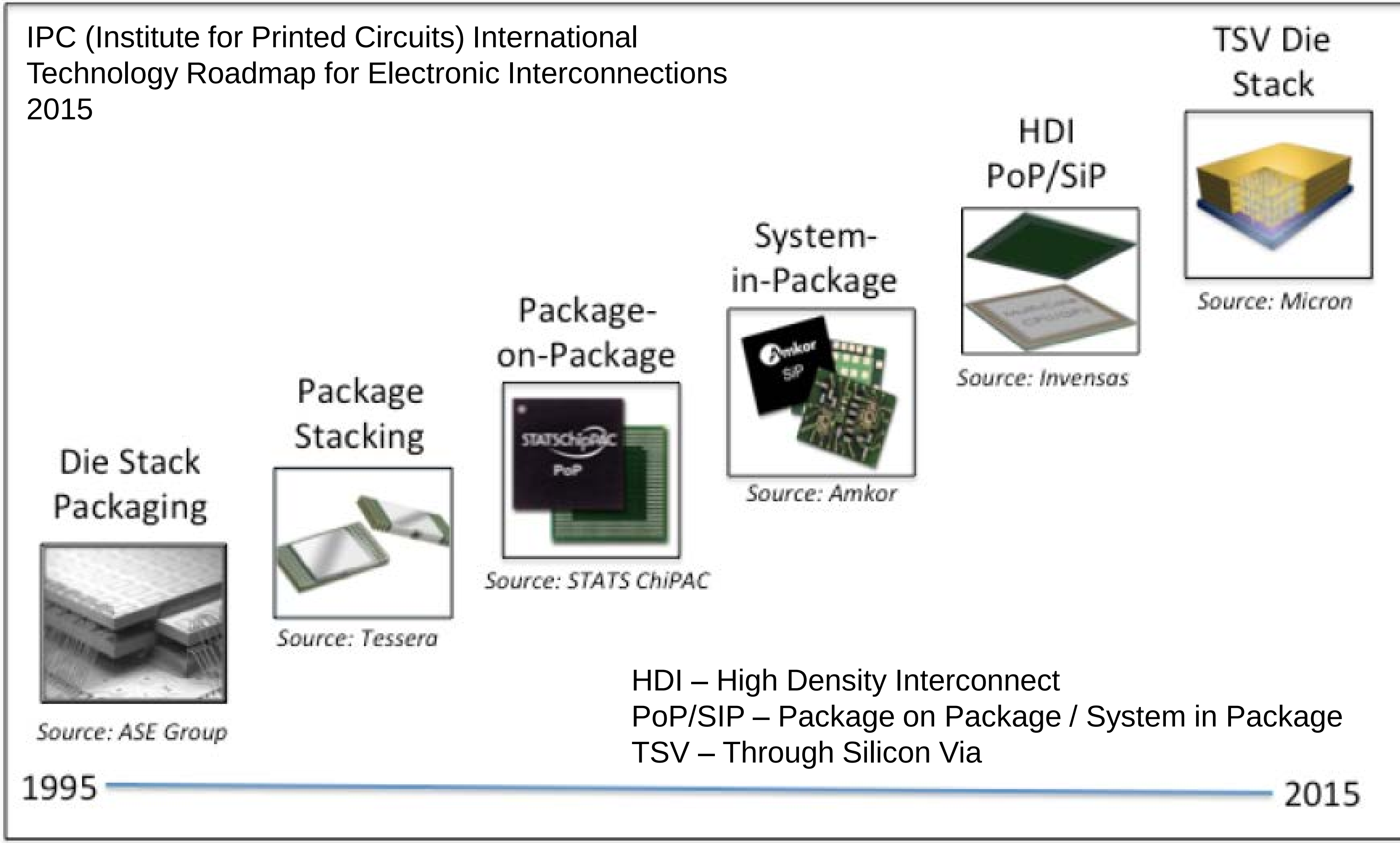
- Potential to be less robust:
  - Corrosive ions are present in the encapsulant or on die surface
  - Latent defects created during bonding (e.g. die cracking, oxidized wire preventing metallic bond, heal cracking, etc.)
  - Encapsulant material is prone to delamination
- Potential to be more robust:
  - Decreased IMC growth rate decreases degradation with time

# Motivation for 3D-ICs in DoD

- 2013 House Armed Services Committee Report 113-102 states, "The committee encourages the Department to comprehensively evaluate the place 3D-ICs might fit in the Department's overall microelectronics strategy …"
- Tezzaron announces "successfully manufacturing world's first eight-layer 3D-IC wafer stack containing active logic", www.3DInCities.com, August 30, 2015.
- 3D-IC technology is already used in DoD (Department of Defense) research programs and in commercial devices
  - DARPA (Defense Advanced Research Projects Agency) 3D-IC, DAHI
  - Micron, Intel, Samsung, IBM, Xilinx …

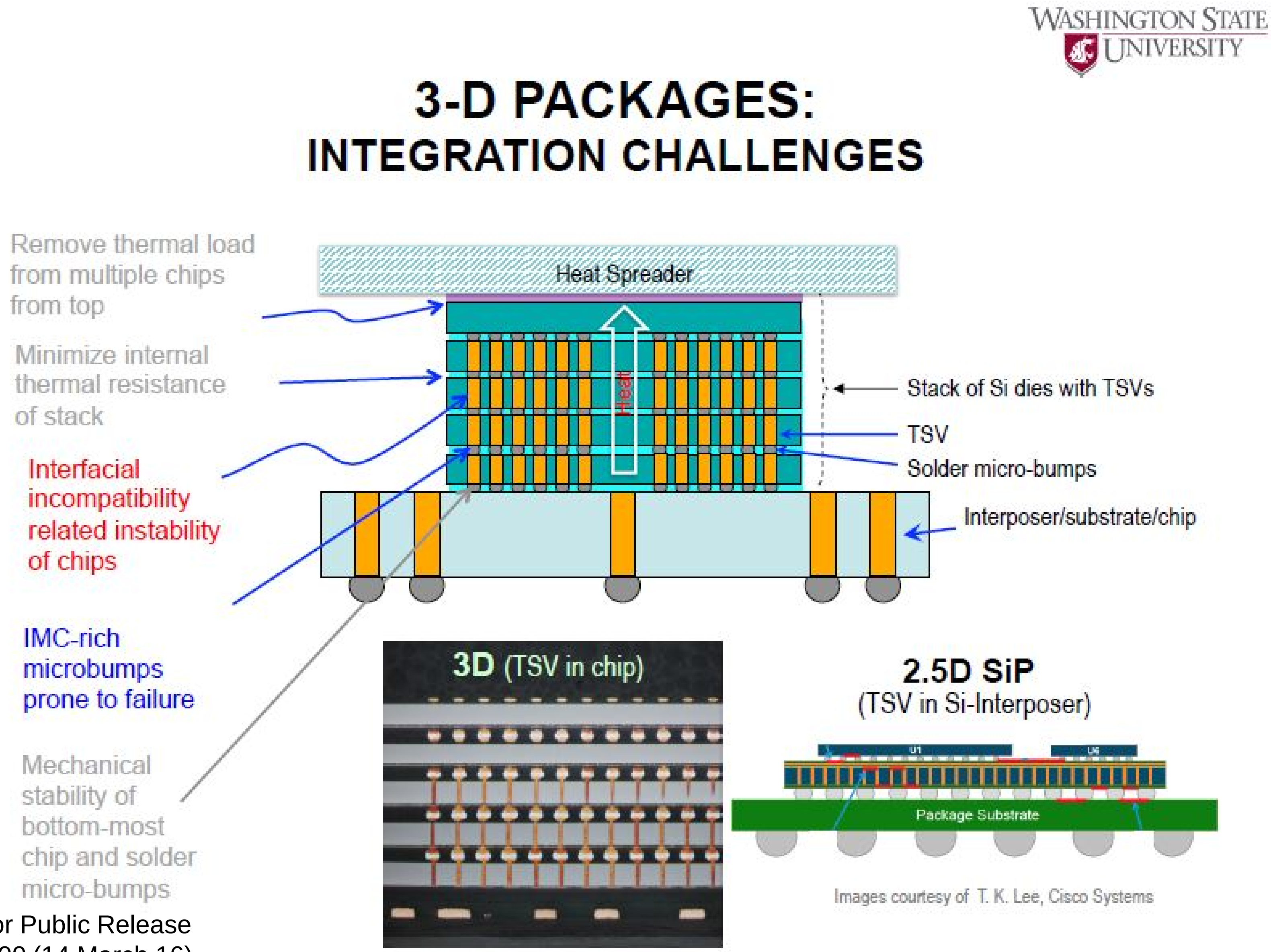
# Evolving High Density Package Solutions

IPC (Institute for Printed Circuits) International Technology Roadmap for Electronic Interconnections 2015




HDI – High Density Interconnect
PoP/SIP – Package on Package / System in Package
TSV – Through Silicon Via

# 3-D Challenges

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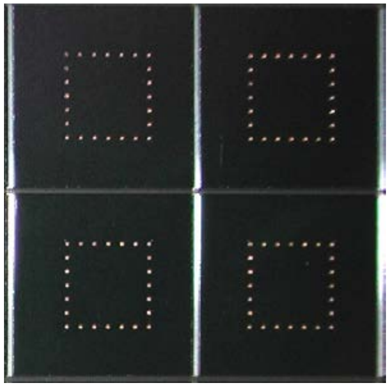
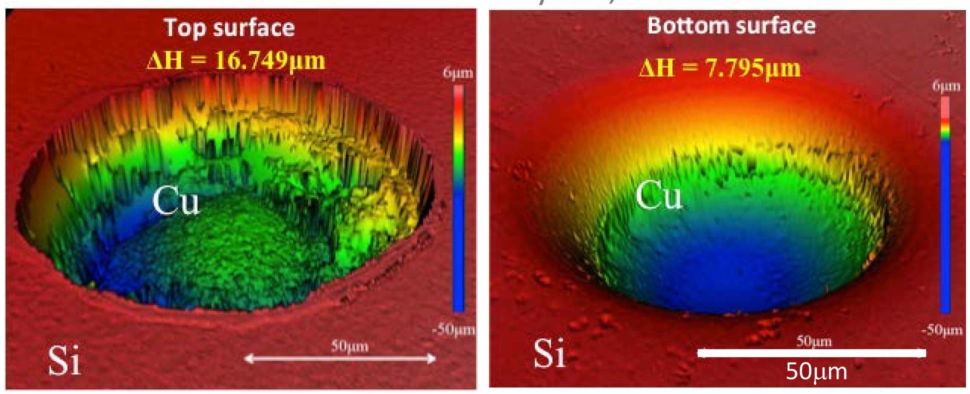
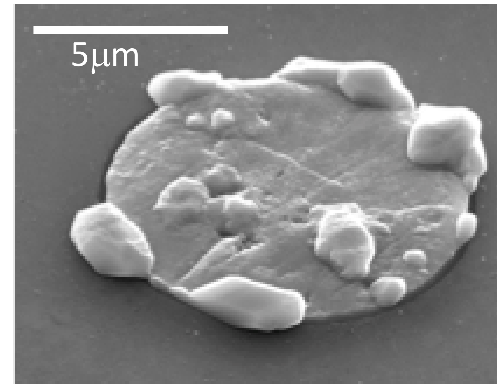
# Near-Interface Effects in Cu-filled Through Si Vias during Thermal Cycling

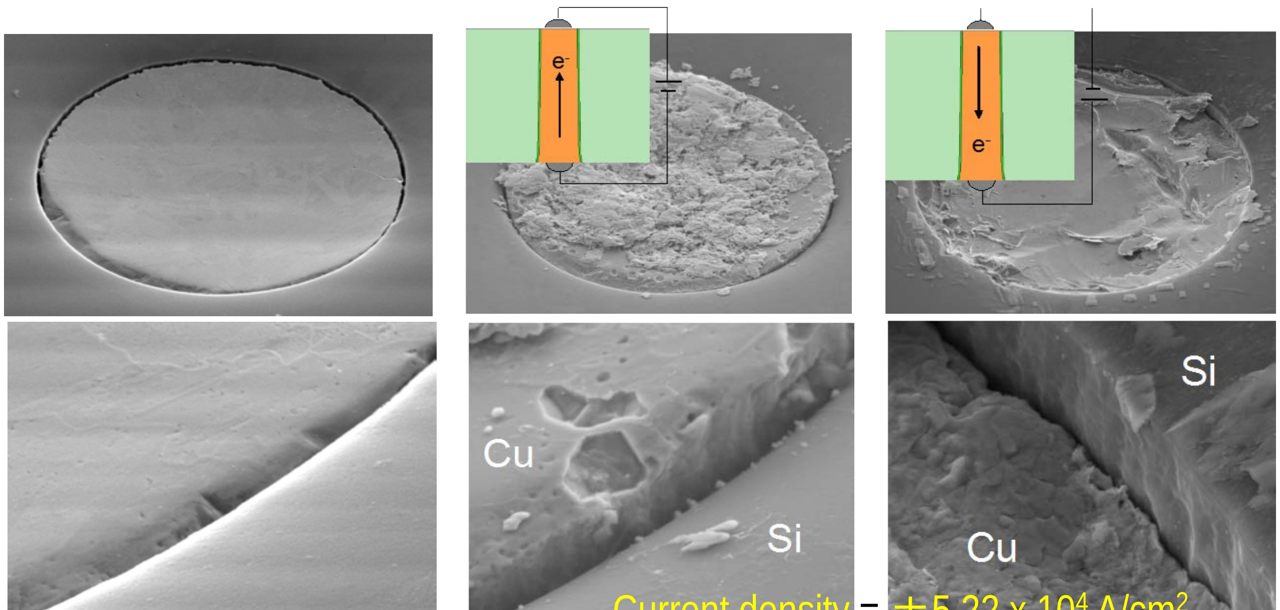


TSV Intrusion: 20 Fast Cycles, -25-140°C




Cu Grain Extrusion: 425°C, 30m




- Electromigration biases interfacial sliding direction
- Current reversal changes protrusion to intrusion

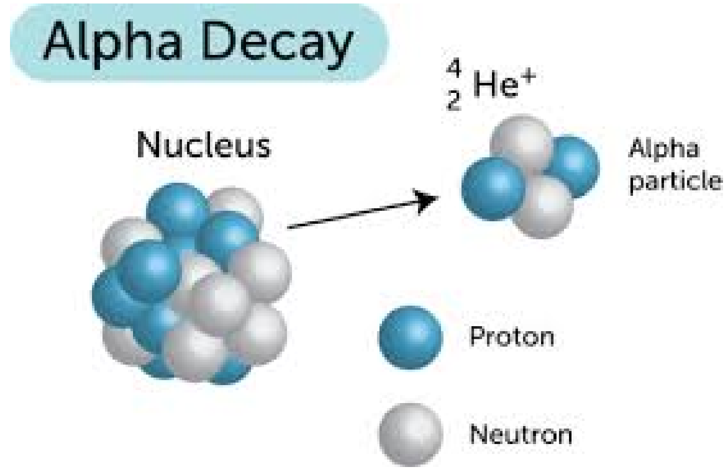

- *P. Kumar and I. Dutta, Acta Mater., 59 (2011) 2096*
- *I. Dutta, P. Kumar and M. S. Bakir, J. Metals 63(10) (2011) 70*
- *P. Kumar, I. Dutta and M. S. Bakir, J. Electron. Mater. 41 (2012) 322 – 335*

# Radiation Effects

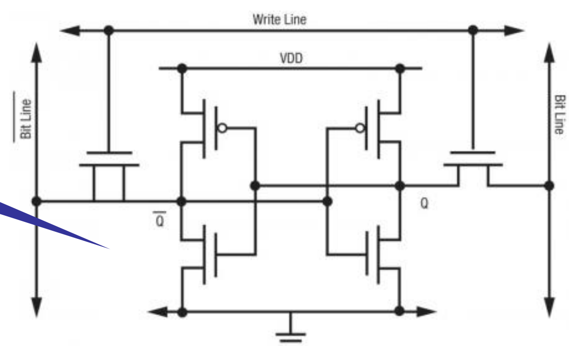
- Actively participating in Title III Trusted Radiation Hardened Field Programmable Gate Array (FPGA) program
  - Many devices made to meet space radiation requirements and not strategic radiation requirements
- Working with NAVSEA-Crane (Naval Sea Systems Command) to characterize and understand susceptibility of devices in various radiation environments

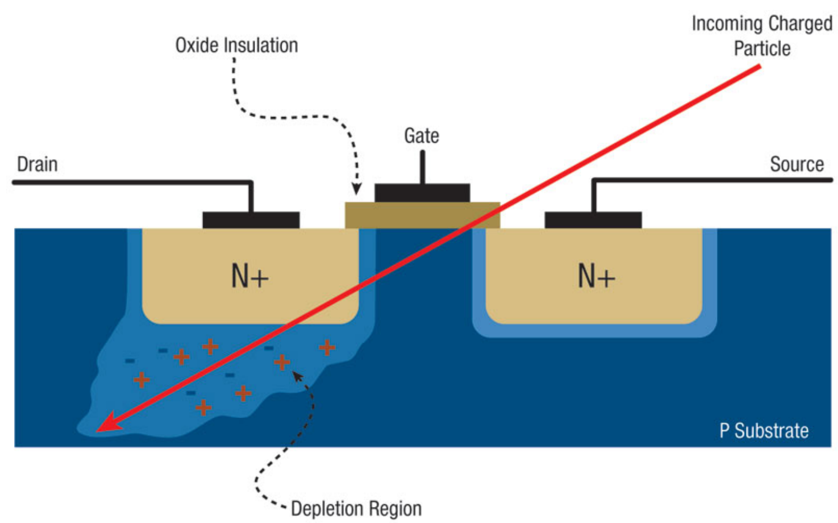
# Soft Errors in Microcircuits

- A vendor had a complaint for increased field failures involving their 72Mb 65nm memory device.
- These lots have evidence of a significantly higher failure rate than the vendor's baseline which has been correlated to an increase in Soft Error Rate (SER) due to increased alpha emissions from **part molding material.**




Typical SRAM Cell



# Summary/Conclusion

- Understanding the reliability issues new technology poses for DoD and Space systems
  - Copper wire bonds are prevalent in COTS (Commercial Off The Shelf) parts
    - Silver wire bonds are starting to enter market
  - 3D packages and ICs are beginning to enter the COTS market

- Collaborating with academia and high-reliability industries to understand new technology reliability issues

- Leveraging radiation effects community knowledge

# Missile Defense Agency
# Quality, Safety and Mission Assurance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