

**Electromigration Failure in Au and Joule Heating Induced Oxidation in Cu Conductors - Part 2**

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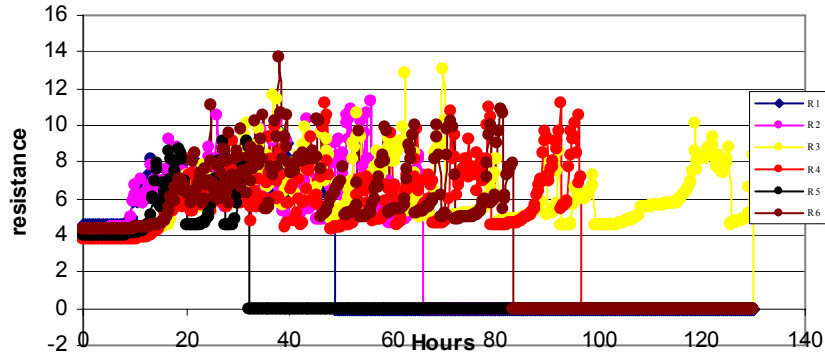
**Structure design, fabrication and Magnetic tests:** Erik Brandon, Victor White, Emily Wesseling and Udo Lieneweg

# Experimental procedures:

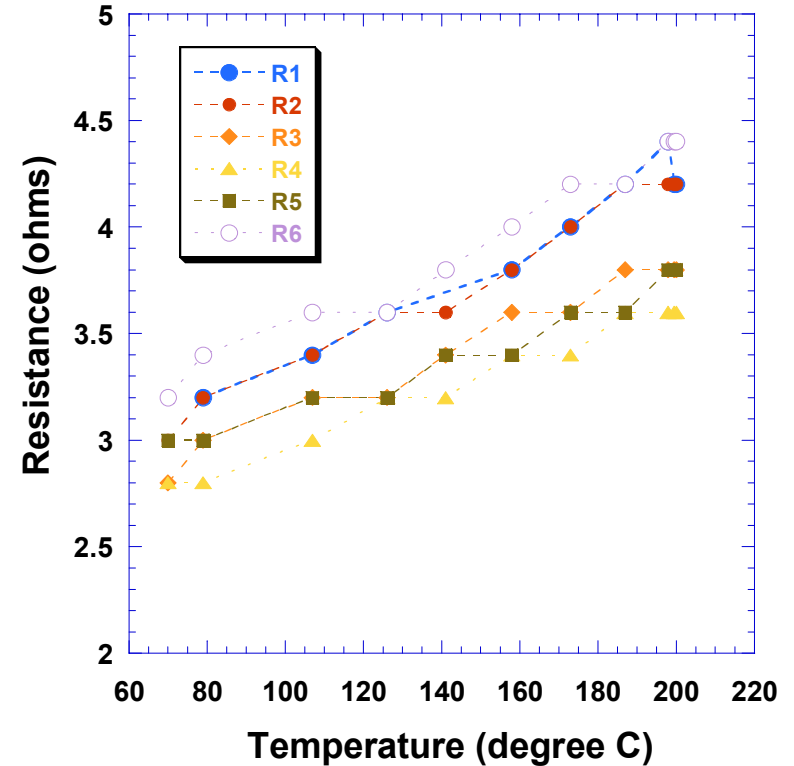
- **Thermal treatments were done for Gold interconnects in environmental test ovens at temperatures of 200°C and 240°C, in air and at one atmosphere.**
- **The Currents used were 500, 100, 50 mA, which correspond to current densities of  $9.26 \times 10^5$ ,  $1.85 \times 10^5$  and  $9.26 \times 10^4$  A/cm<sup>2</sup>.**
- **The increase in resistance with temperature was also monitored, using very small current densities, to ensure that no Joule heating occurred with the test current densities.**

# Test Results:

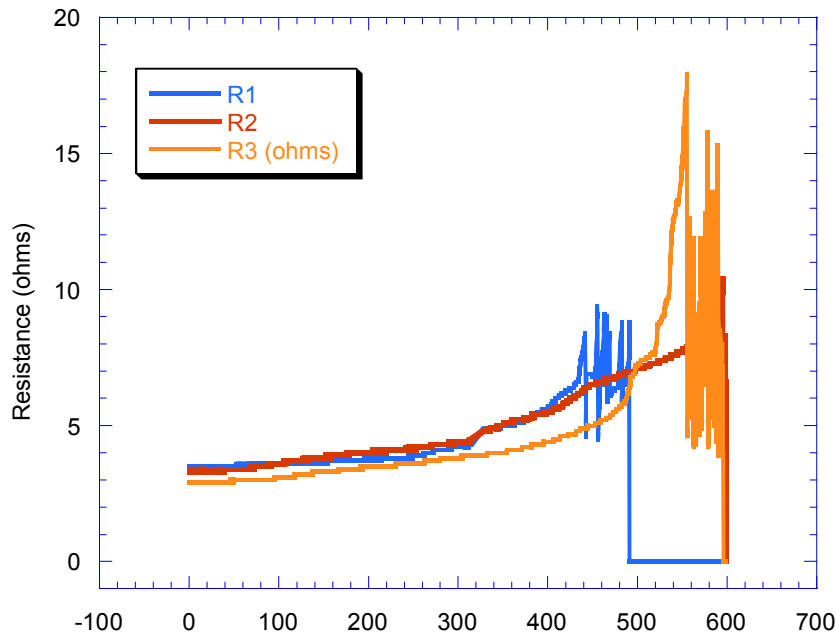
200 c at 100mA Au2



**Time vs. Resistance at 200°C and 1.85e5 A/cm<sup>2</sup> in Au test structure**

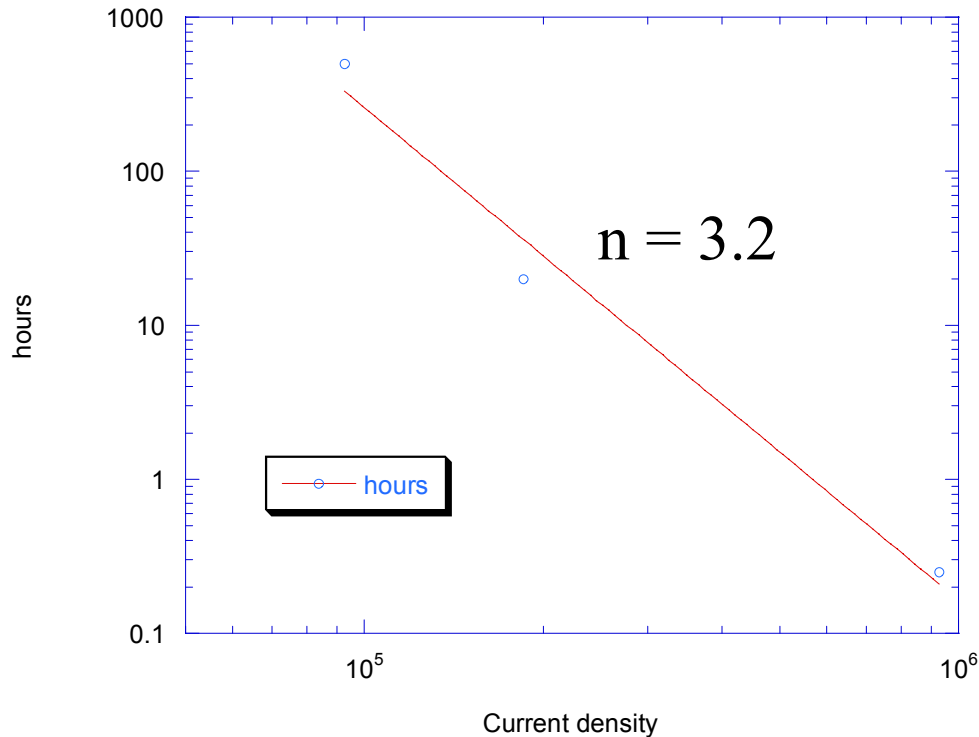


**Resistance vs. Temperature in Au conductors using 0.005A**



**← Time vs. Resistance at 200°C and 9.26 x 10<sup>4</sup> A/cm<sup>2</sup> in Au test structure**

# Current density vs. time to failure



*From the time to failure vs. current density, we can evaluate the value of the exponent for current density in Black's equation:*

$$t = A j^{-n} e^{E_a/kT} = A j^{-3.2} e^{E_a/kT}$$

t is time to reach failure (or allowable % degradation)

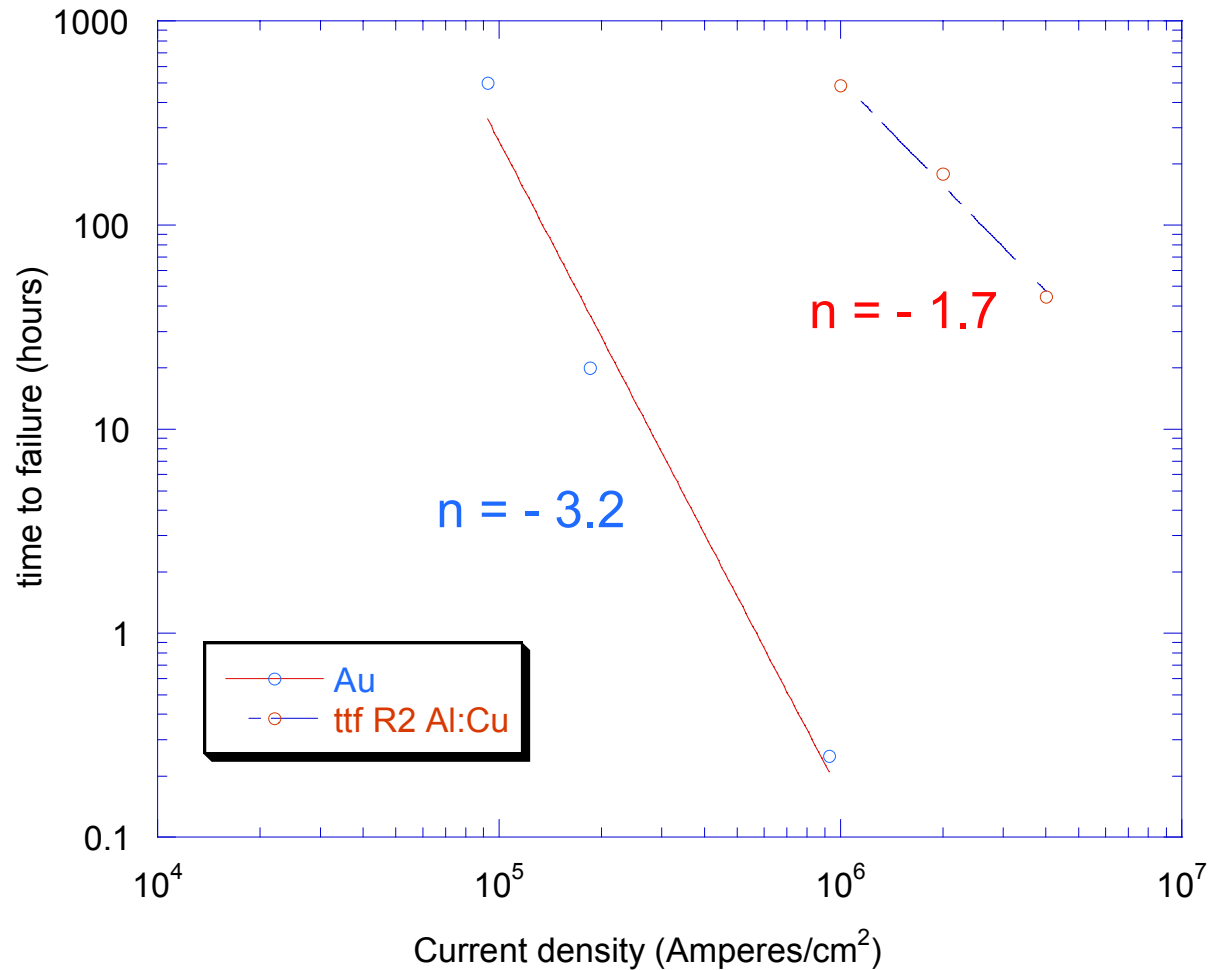
j is current density

$E_a$  is activation energy (in eV)

k is Boltzman's constant

T is temperature

## Time to fail vs current density Au at 200C and Al:Cu at 240C



This graph compares the time to failure as a function of current density for Au SoC structures and commercial Al:Cu structures with tungsten vias. Activation energies for electromigration ( $E_a$  in the equation in previous page) could not be determined due to insufficient samples. From these results, a good guess for  $E_a$  would be 0.6 or 0.7 eV (as compared for 1eV obtained with the Al:Cu structures)

# **Failure analysis**

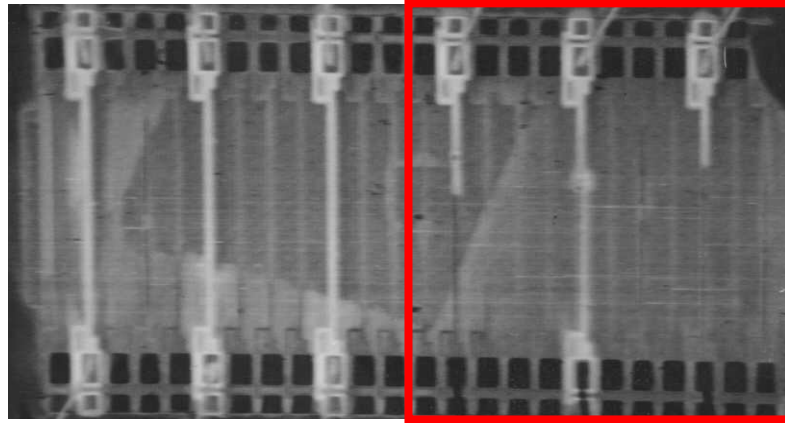
- **Three SEM modes were utilized to identify where the failure occurred:**

**Backscattering mode is an interaction between the electron beam and the specimen atoms which results in a change in the primary electrons trajectory and/ or energy.**

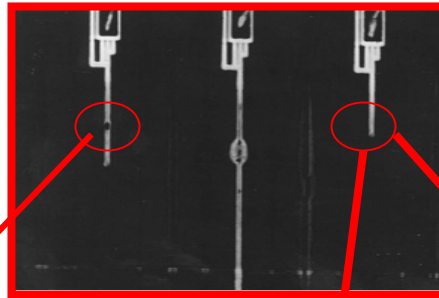
**Electron Bean Induce Current (EBIC) represents current flow of electrons passing trough the portion of the semiconductor material “SiO<sub>2</sub>” expose to the primary beam of the SEM.**

**Secondary Electron mode electrons emerge from the surface of a specimen from the interaction of the primary beam and the specimen.**

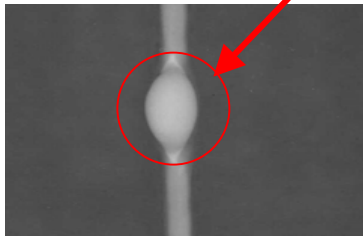
Failure Modes 1 and 2: open circuit due to void formation. Hillock formation is also observed, with the potential for causing short circuits.



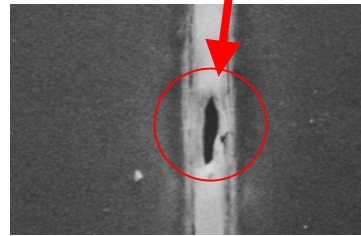
**R1 through R6 at 15x, 20 kV,  
secondary electron mode**



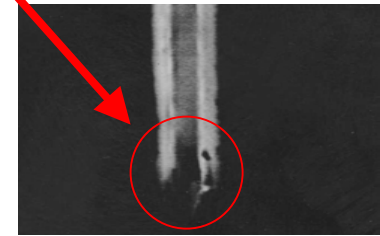
**R1, 2, and 3 at 30x, 20 kV,  
EBIC mode**



**R3 hillock at 400x, 20 kV,  
backscattering mode**



**R3 void at 400x, 20 kV,  
secondary electron mode**



**R1 void at 400x, 20kV,  
EBIC mode**