Statistical Electromigration Analysis: Constant Current vs Constant Voltage
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Objective:
Compare and contrast statistical electromigration (EM) data retrieved from Constant Current and Constant Voltage accelerated electromigration tests in order to better predict reliability lifetimes of Cu interconnects.

Background:

What is electromigration?:
- Definition: The transport of material caused by the gradual movement of the ions in a conductor due to the momentum transfer between conducting electrons and diffusing metal atoms. (Figure 1)
- Affects devices with high current densities (Nanoelectronics).
- Typical current density in a lamp cord ~ 1 A/cm²
- Typical current density in copper interconnects ~ 10⁴ A/cm²
- Voids are formed typically near the via, killing your devices. (Figure 2)

Accelerated Electromigration Testing:
- We need to be able to get 10 year lifetimes in a matter of hours.
- In order to do that, we test specific test structures and elevate the temperature and voltage applied to the structure. (Figure 3)
- We take the data from test structures containing a single failure element and we need to relate that to the failure of a chip with perhaps 100,000 to 1,000,000 failure elements.
- We plot lognormal failure distributions and extrapolate fitting parameters in order to get useful information.

Current Situation and Methods
- Traditionally Electromigration (EM) testing is performed using constant current.
- However, variations in geometry (line width, thickness, cross section) will produce corresponding variations in current density if the same current is passed through each structure. This contributes to the variation in lifetime, σ.
- For a given length of conductor, the electric field along the conductor will be identical at a given applied voltage regardless of the cross sectional area.
- Although cross sectional area can vary significantly across a wafer (thickness and conductor width) the length proportionately does not.
  - Therefore, at constant voltage the current density will be constant regardless of these inherent variations.

Motivation
- Electromigration is the main reason why high performance nanoelectronic devices fail over time.
- The reliability of nanoscale electronics is very important to industry and corporations to bring down RMA and return expenses. The customer and Manufacturer are happier as a result.
- Electromigration has been difficult to treat in the past. This is mainly due to the difficulties in testing large sample populations.

Results

<table>
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<th>Test #</th>
<th>Wafer #</th>
<th>CC</th>
<th>CV</th>
<th>CC</th>
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</table>

Lots of roughly 16 samples were run under accelerated testing conditions on 5 different wafers using Constant Current and Constant Voltage methods.

Conclusion
- Constant Current vs Constant Voltage shows some clear differences.
- The standard deviation, σ, which represents the spread of failure times, is showing a decrease in value for all of our Constant Voltage tests up to a factor of 2.
- Most T-50’s that we’ve recorded, which is the median time to failure, have been within an order of magnitude difference. We can note that constant voltage on average seems to take less time to fail. This could be due to under-stressing the constant current tests.

References