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Atomically Precise Advanced Manufacturing (APAM) Robustness

How reliable are APAM devices under high currents and temperatures?

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Introduction

Need:

APAM device reliability is currently an unknown. We will explore fundamental failure mechanisms under high temperatures and high current densities.

Premise:

We do not know how APAM devices will fail. We will be using standard electromigration testing methodology to benchmark our setup and begin both room and elevated temperature lifetime studies of APAM devices.

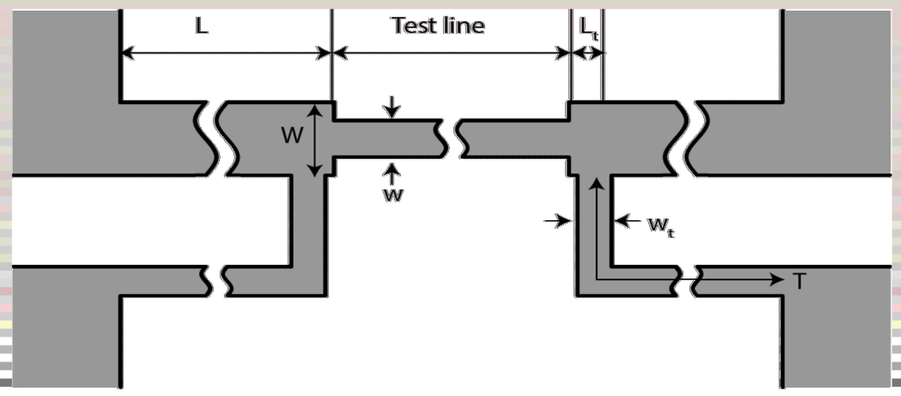
Impact:

Determining a failure mechanism and time to failure will help to inform application spaces for APAM, as well as revisions that can be made to avoid these modes of failure in future devices.

Methodology

Approach:

- Using ASTM guidelines for electromigration testing, we have determined suitable test structures for both the metal and APAM test devices
- To accelerate the aging process, test structures will be run at high current densities and elevated temperatures

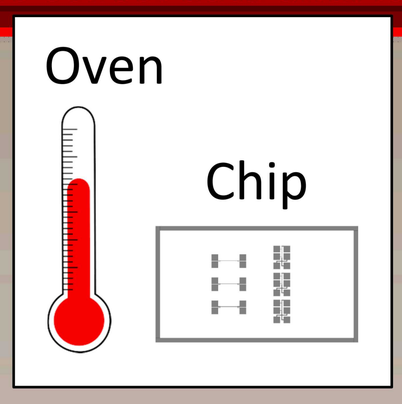


Testing Specifics:

- A traditional aluminum structure and APAM delta-layer will be tested and compared
- Current force/sense will be provided by high accuracy source-measure unit
- Test setup will reside in oven at up to 300°C
- Desired current density is 2.0 µA/nm
- Source-measure unit and oven will be controlled and monitored though LabVIEW interface
- Median time to failure will be determined for both structures to draw comparisons

Accomplishments

Built new setup with precision controlled oven and source meters collect data until failure.



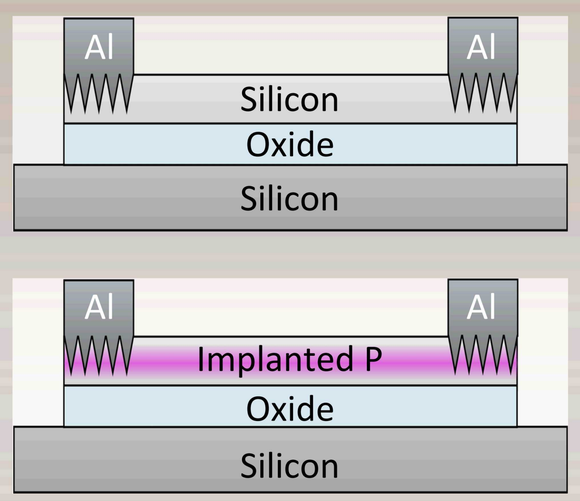
- Mean time to failure
- Current density
- Temperature

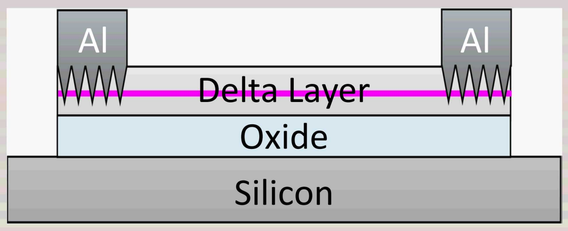
Source Meters

Metal Control:
Validate setup with electromigration test chip

Control Samples:

- Undoped silicon
- Ion implanted simulation of delta layer
- Control for substrate effects and contacts





APAM Device:
Phosphorus delta layer

Future Directions

Start Testing:

Devices are in fabrication. Will begin testing in late Nov.

Determining Failure Mode:

After the device fails, we will use standard failure analysis techniques to determine where and why the device failed. This will include SEM, FIB, TEM and TIVA techniques all available through Sandia's FA team.

Impact:

Through testing, robustness will be determined, and thus can provide insight into changes that can be made to improve reliability and expand the application space for future APAM devices.

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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