Characterization of AlSi and AlSi-$TiSi_2$ Metal-Semiconductor Contacts

Mark Davis, Advisor: Dr. Michael Jackson

Motivation

- Previous work in the RIT SMFL found defects in Flash Evaporated AlSi Films post 450^{o}C Sinter
  - This defect is hypothesized to be Junction Spiking due to a Silicon-starved deposition
- A self-aligned $TiSi_2$ buffer on the contact regions should prevent this defect from occurring

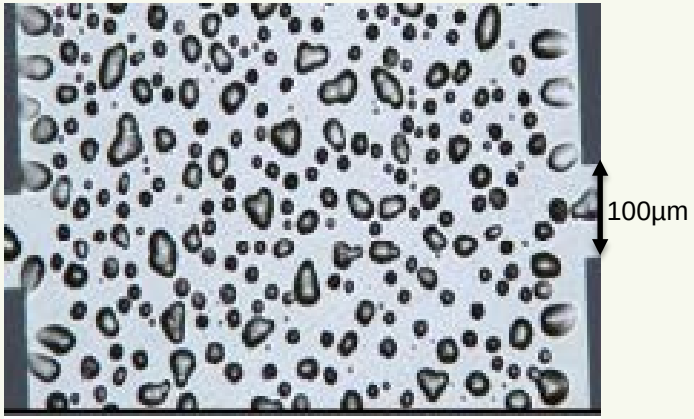


Figure 1. Defective Post Sinter AlSi Flash Evaporated Layer. [1]

Junction Spiking

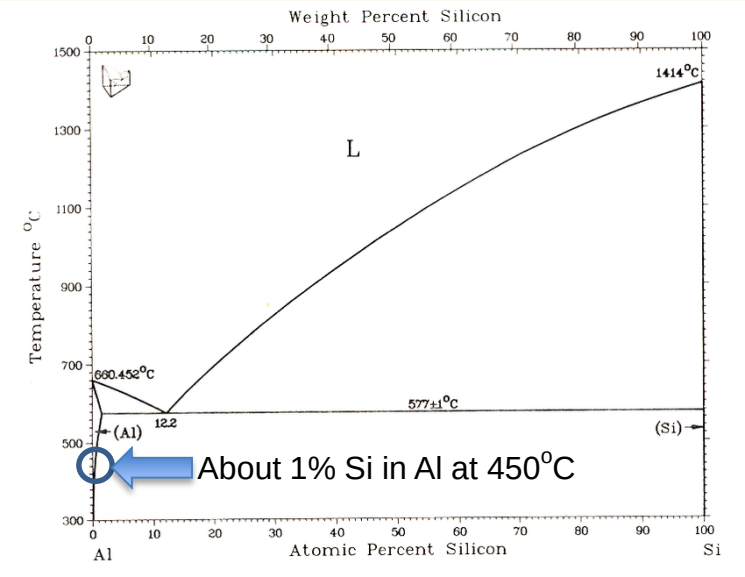


Figure 2. Aluminum-Silicon Phase Diagram. [2]

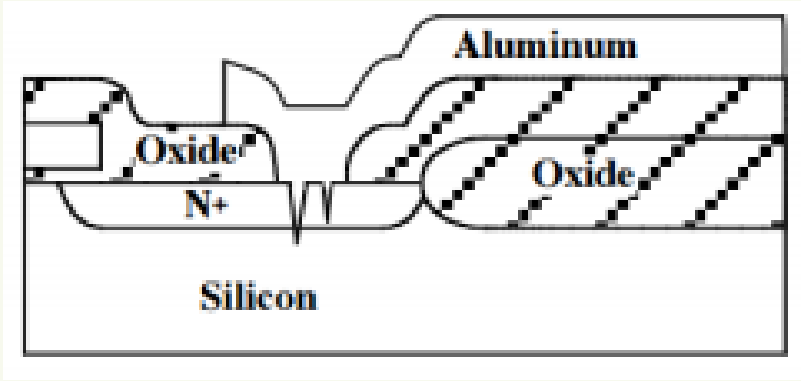


Figure 3. Cross Section of Junction Spiking. [3]

- At 450°C, Si Diffuses into Al ~100µm in 30 minutes

Al Deposition at RIT

Figure 4. CVC Flash Evaporator. [4]
Aluminum Defect Observed

Figure 5. CVC601 DC Sputter. [4]
High Bulk Resistivity Measurements

Figure 6. CHA Thermal Evaporator. [4]
Used as a Control

Defect Characterization

X-Ray Photoelectron Spectroscopy (XPS)

Characterize the Silicon content of each film

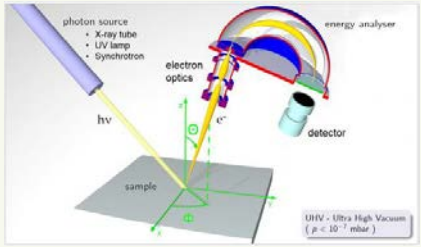


Figure 7. XPS Operation. [5]

Transmission Line Measurements (TLM)

Characterize the Contact Resistivity of each film

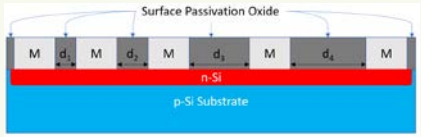


Figure 8. TLM Cross Section.

Junction Spiking Detection Diodes

Electrically detect a spike through the diffusion region

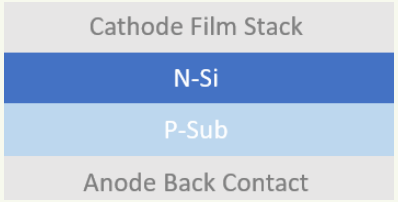


Figure 9. Diode Cross Section.

Visual Surface Analysis

Characterize the defect density and size

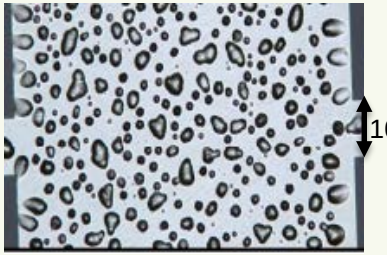


Figure 10. Al Film for Visual Analysis. [1]

Fabrication

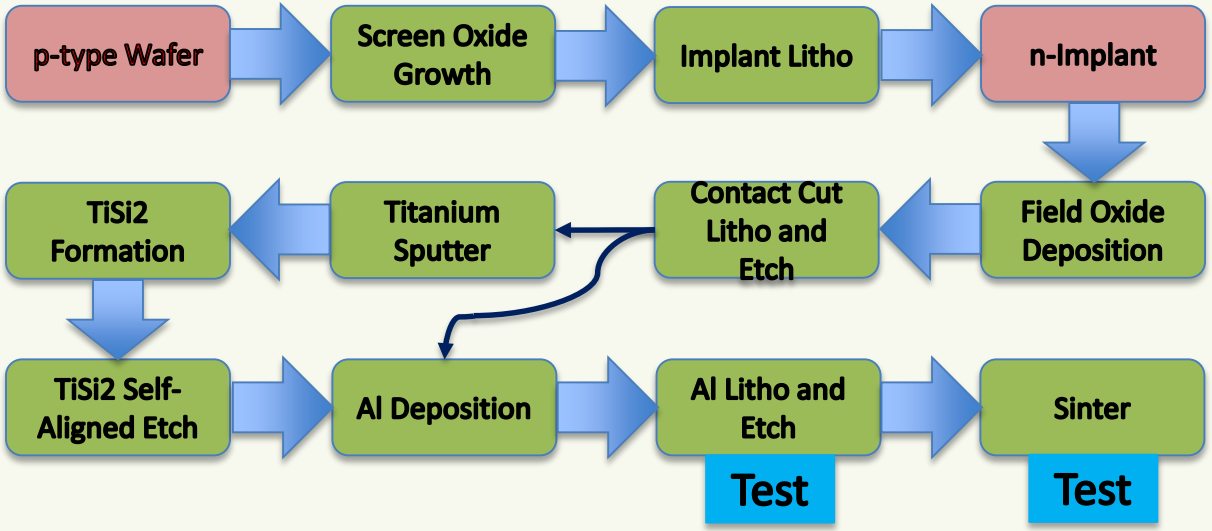


Figure 11. General Process Flow.

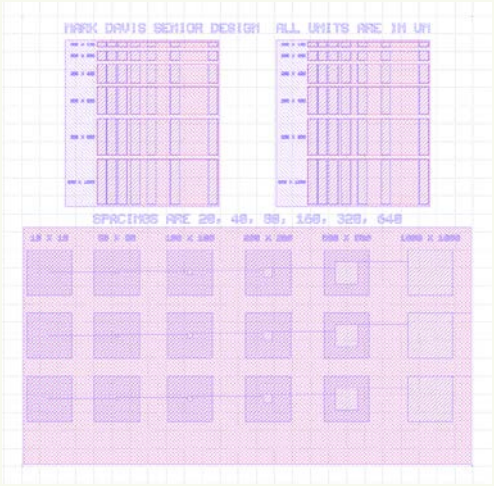


Figure 12. Mask Layout.

Process Issues:

- Selecting a p-Substrate caused the Al on n-type M-S contact to rectify
- P31 Implant Dose of 4E12 cm^{-2} was far too low

XPS Results

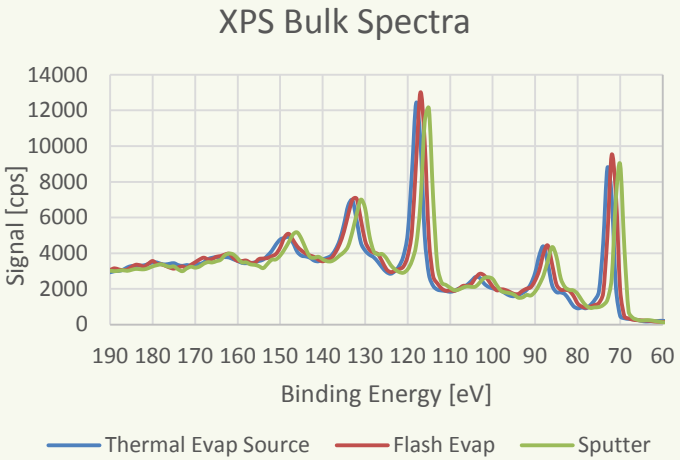


Figure 13. XPS Spectra of Film Samples.

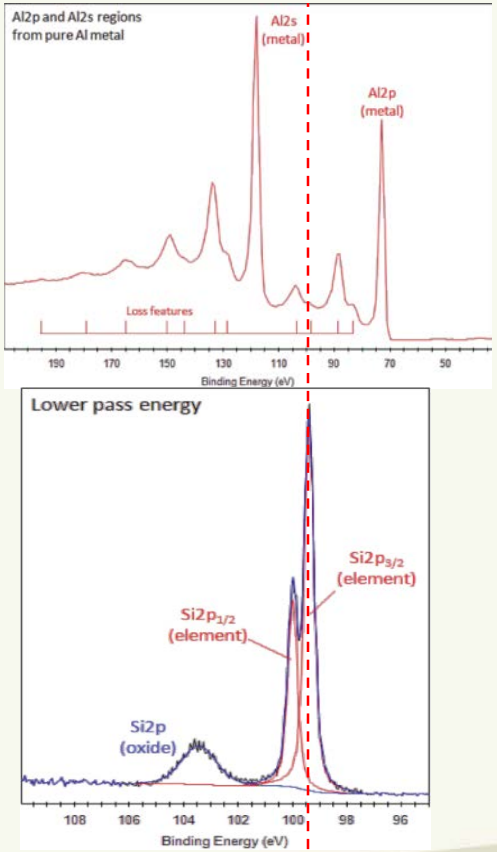


Figure 14. Characteristic XPS Spectra of Al and Si

- XPS of Aluminum encounters Plasmon Peaks, which are energy loss features from the primary peaks
- Al2p's second Plasmon Peak interferes with the Silicon's peaks, causing low concentration Si readings in an Al matrix to be difficult to measure

XPS Results

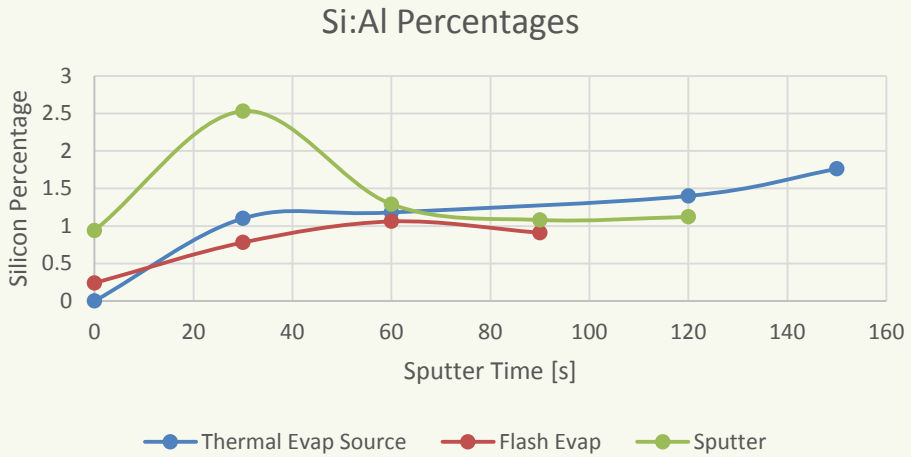


Figure 14. Si Percentage vs FIB Sputter Time.

- The FIB Sputter time is proportional to depth in the sample

Expected Results	
Sample	Silicon Percentage
Thermal Evap	0.8-1.2
Flash Evap	0.4-0.8
Sputter	1.2-1.6

Figure 15. Expected Si Percentage Results.

- The steady-state bulk Si percentages were compared to provide the Normalized Percentage

Sample	Bulk %	Normalized Amount
Thermal Evap	1.29	1
Flash Evap	0.916	0.71
Sputter	1.1	0.85

Figure 16. Normalized Bulk Si Percentage.

TLM Results

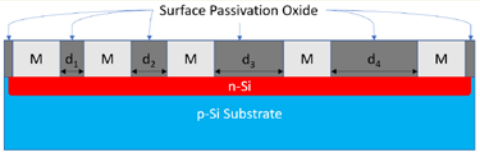


Figure 17. TLM Cross Section.

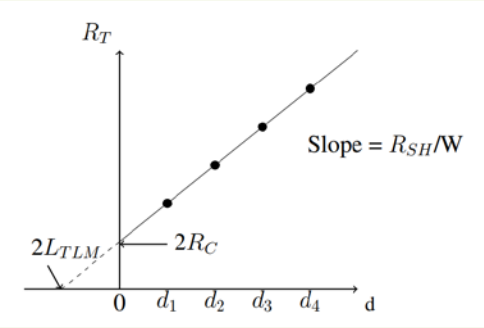


Figure 18. TLM Electrical Characteristics. [3]

- The low implant caused the contacts to rectify, leading to unusable TLMs

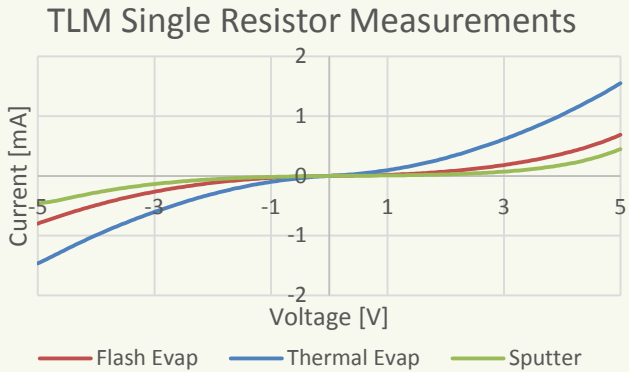
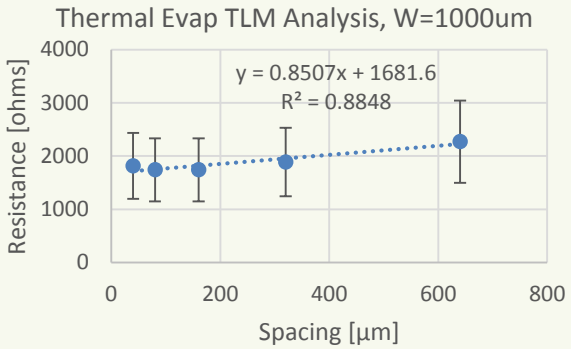


Figure 19. Rectifying TLM Resistor



Extracted Parameters	
R_C [Ω]	840.80
L_T [µm]	988.37
R_{SH} [Ω/□]	850.7

Figure 20. TLM Graph and Extracted Values.

Diode Results

- The $TiSi_2$ Buffer Diodes Exhibited very repeatable characteristics
- After Sinter, every wafers' diode I-V altered in different ways

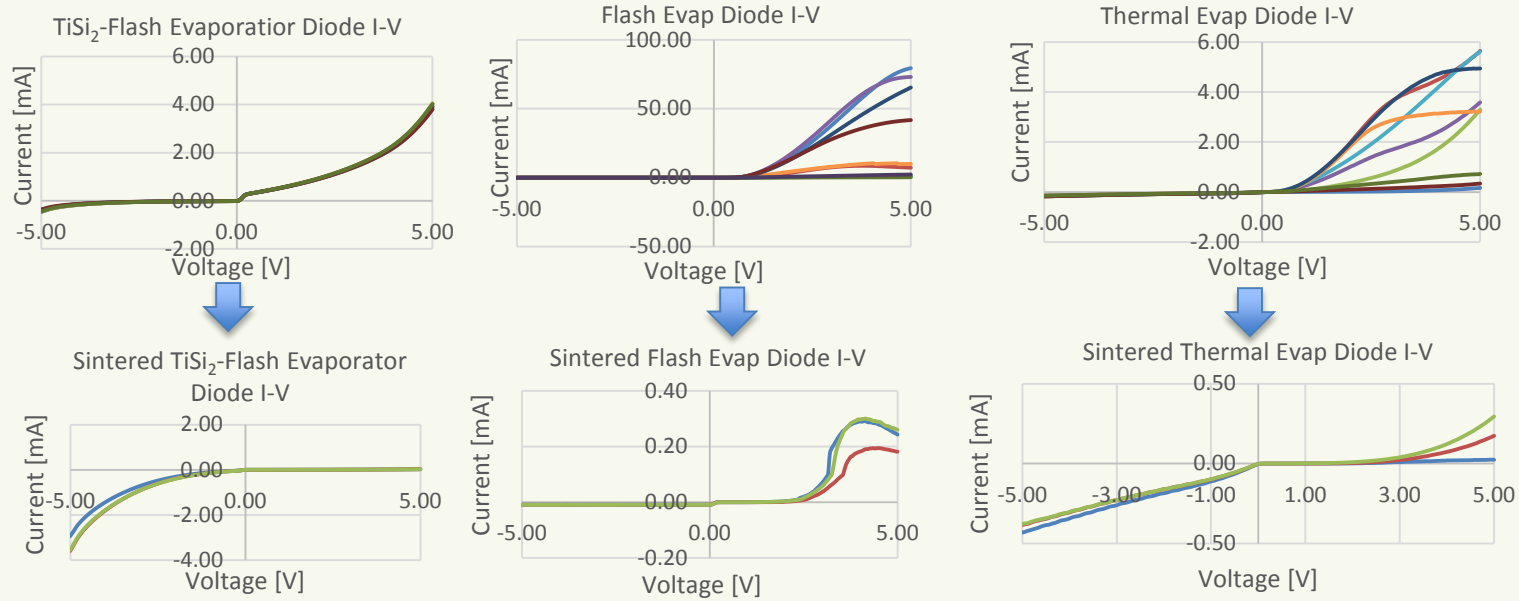


Figure 21. Sinter's Varying Effects on Diode Characteristics.

Surface Analysis

- The Spotted film defect appeared in all films, not just the Flash Evaporator film as hypothesized
- The defect manifested above Si, SiO_2, and $TiSi_2$

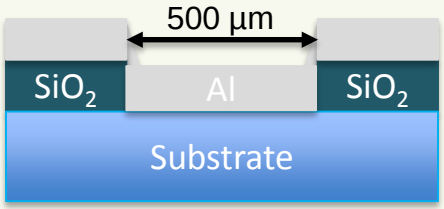


Figure 22. Visual Area Cross Section.

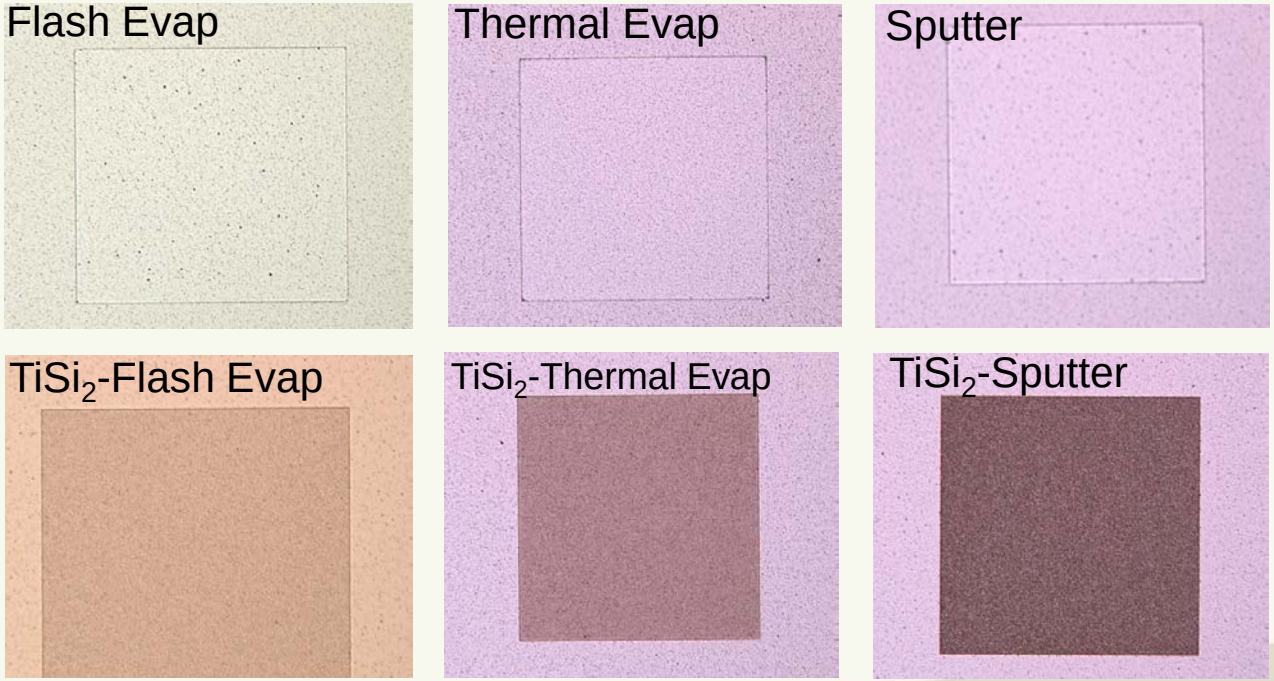


Figure 23. 10x Microscope Images of Sintered Films

Quantitative Surface Analysis

- Images are cropped to remove lighting gradient
- A threshold is applied to convert data to particles and clear film
- Particle Analysis run to quantify defect density and size

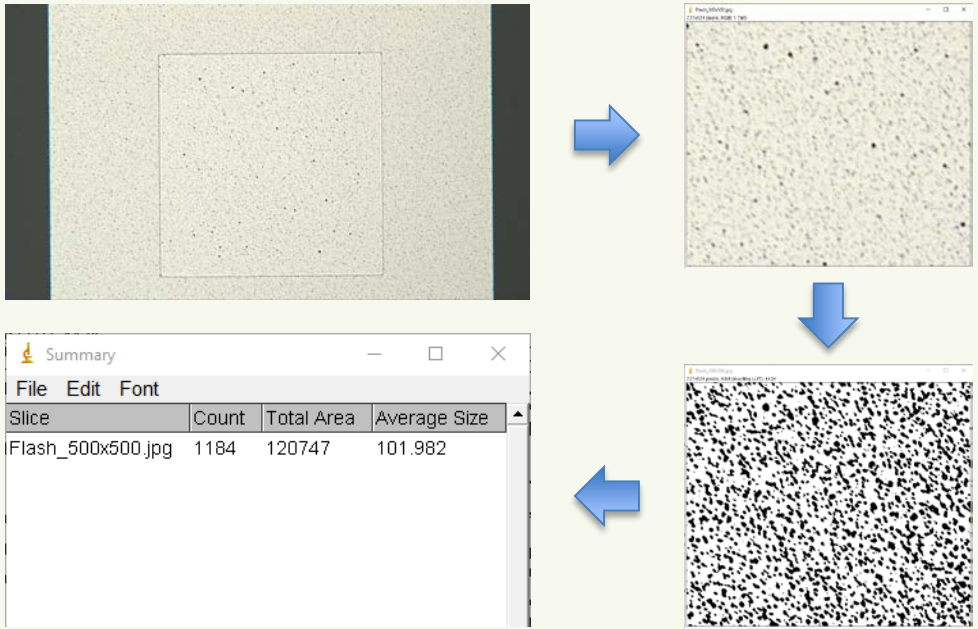
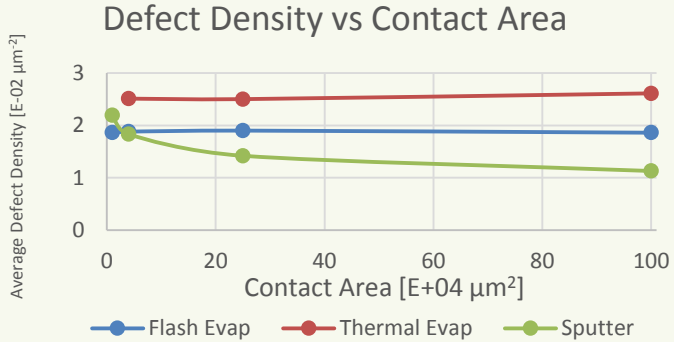


Figure 24. Image Analysis in ImageJ.

Quantitative Surface Analysis



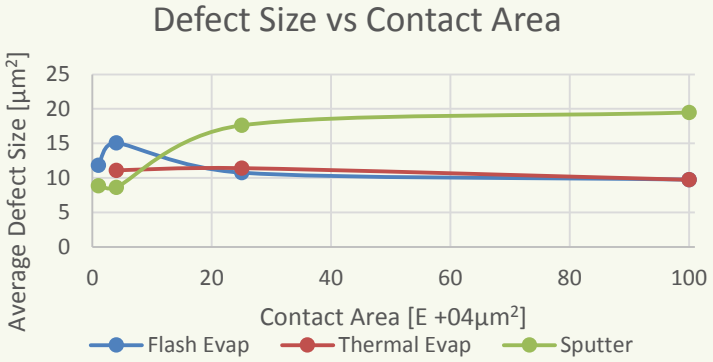
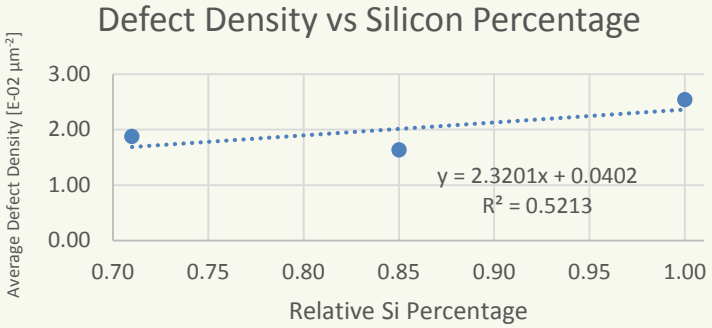


Figure 25. Defect Density and Size vs Contact Area.



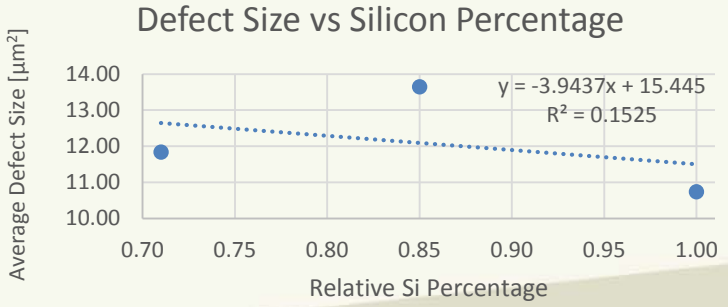


Figure 26. Defect Density and Size vs Relative Si Percentage

ROCHESTER INSTITUTE OF TECHNOLOGY

SEM of Etched Al Film

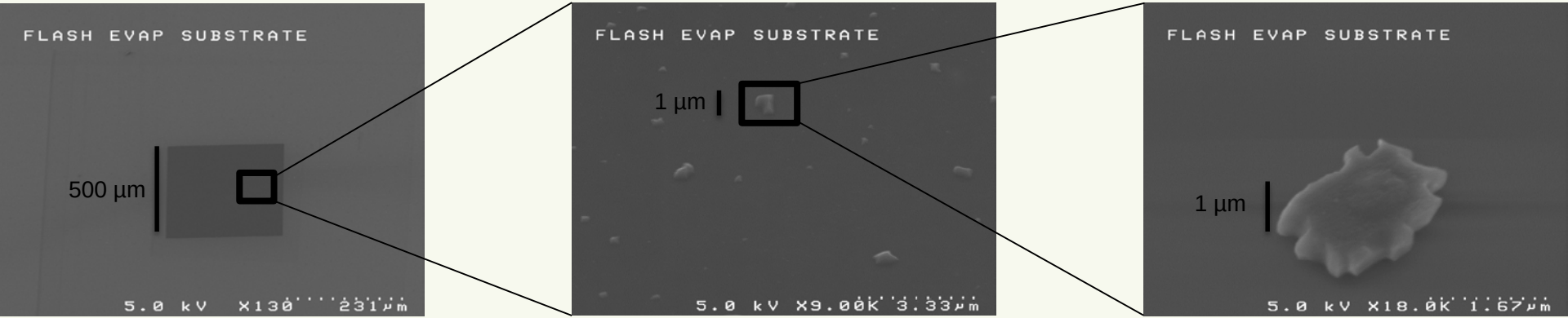


Figure 27. SEM Images of Defects on Substrate

- Pits from Junction Spiking were expected, but the spots were found to be particles on the substrate
- These particles appear to be of similar chemical makeup to the substrate

Particle Height (Average) [Å]	Film Thickness [Å]
1734	4474

Conclusion

- The defect found in the three deposited films is likely not Junction Spiking, but may be a function of the Silicon content in the deposited AlSi Film
- The film roughness appears similar to that of the Flash Evaporator's from earlier studies, but isn't necessarily the same defect

References

[1] K. S. Duggimpudi, "Characterization of Grid Contacts for n-Si Emitter Solar Cells," Microelectronic Engineering, Microelectronic Engineering, Rochester Institute of Technology, 2016.

[2] Shamsuzzoha, Mohammad. (2007). M. Shamsuzzoha and Frank R. Juretzko, “Dual Refinement of Primary and Eutectic Si in Hypereutectic Al-Si alloys”, Aluminium Alloys for Transportation, Packaging, Aerospace, and Other Applications. Ed.: S. Dash, W. Yim. TMS: p. 153-162, (2007)

[3] S. Grover, "Effect of Transmission Line Measurement (TLM) Geometry on Specific Contact Resistivity Determination," Master of Science, Materials Science, Rochester Institute of Technology, 2016.

[4] https://wiki.rit.edu/display/smfl/Tool+Set

[5] http://jacobs.physik.uni-saarland.de/

[6] https://xpssimplified.com/periodictable.php