Electron Yield Analysis of Surface Roughening on Cu and Al

Trace Taylor, Matthew Robertson, and JR Dennison

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SRS STUDENT RESEARCH SYMPOSIUM

UTAH STATE UNIVERSITY MATERIALS PHYSICS GROUP

Overview

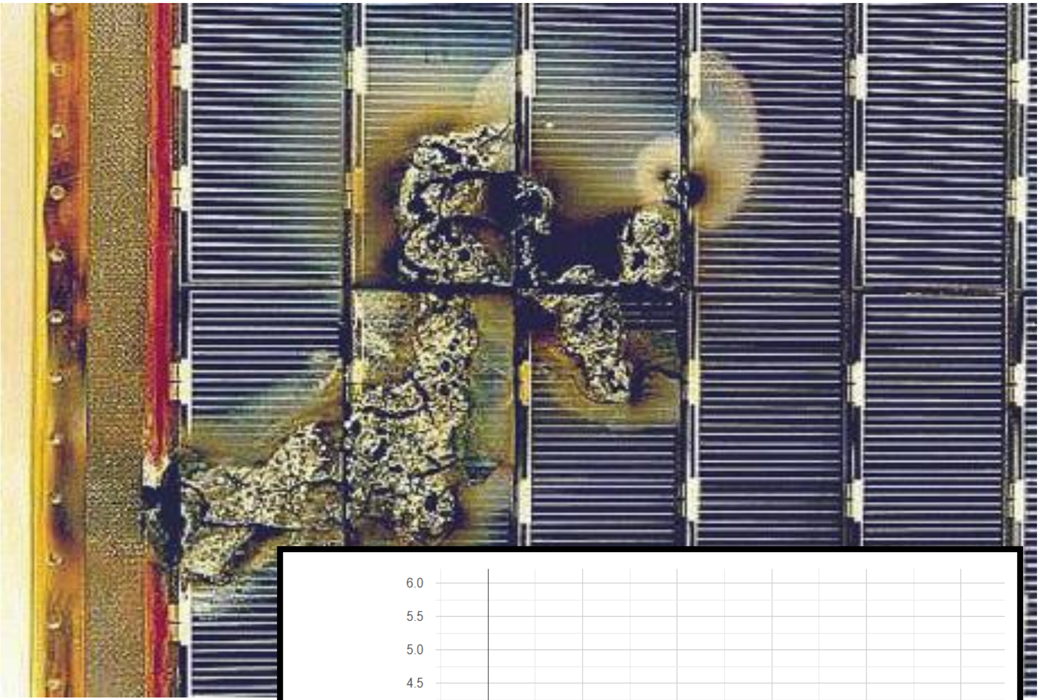
- Why Surface Roughness and What Is Electron Yield?
- Cu and Al Samples
- Sample Characterization: Scanning Electron Microscopy (SEM), Energy-dispersive X-ray Spectroscopy (EDX), and Confocal Microscopy
- Electron Yield Data
- Conclusions
- Future Work

Why is Electron Yield Important?

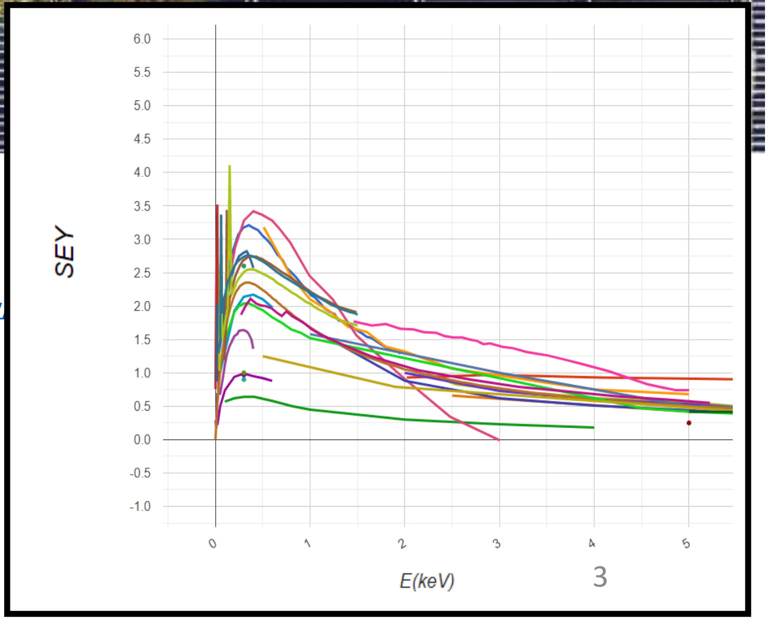
- Spacecraft charging may cause electrostatic discharges [1]
- The majority of space-induced satellite anomalies are caused by spacecraft charging [1]
- Electron yield causes differences in electrical potentials by liberating electrons from the material[2]
- Wide range of reported values of electron yield

<u>Key Questions</u>

- How does surface roughening affect the EY?
- How would it affect satellite performance?



https://www.nasa.gov/ spacecraft-charging



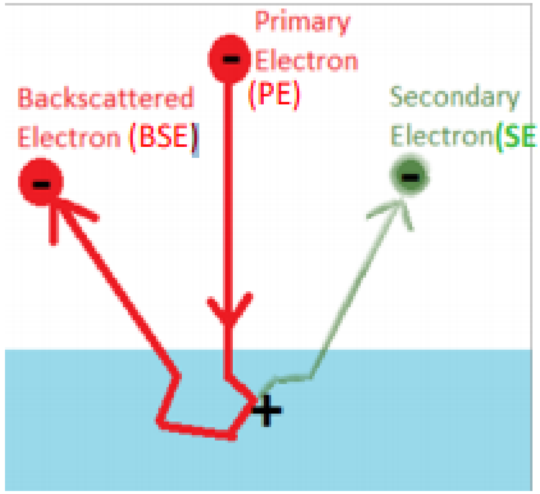
Electron Yield

- Number of electrons emitted/ number of incident electrons[2]

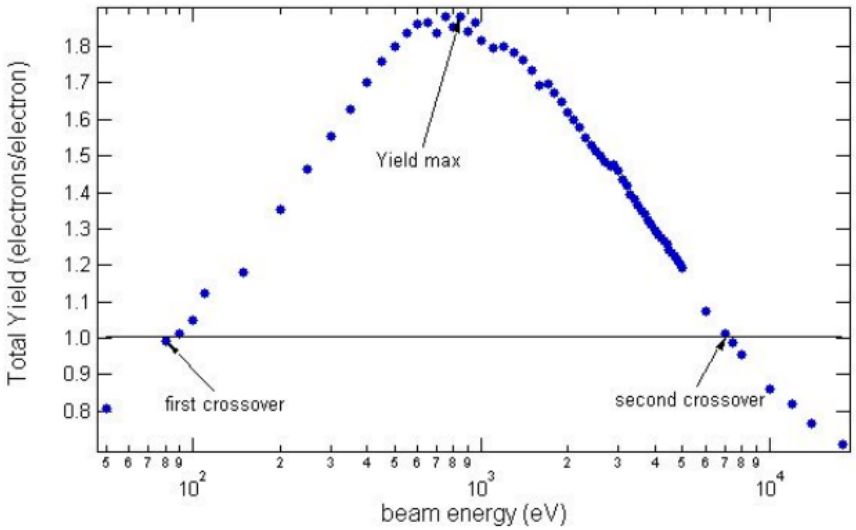
- Secondary Electron Yield (δ) originates from within the surface and backscattered electron yield (η) from the incident electron beam[2]

- The max yield, δ_{max} ,and its corresponding energy value, E_{max} , and the are of particular interest for characterization and modeling[4]

$$\sigma_{Total}=\delta+\eta$$



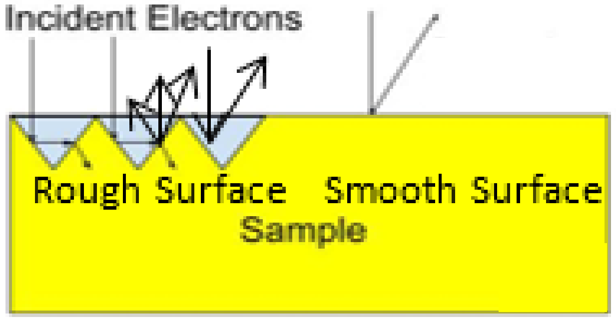
(Christensen, 2017)

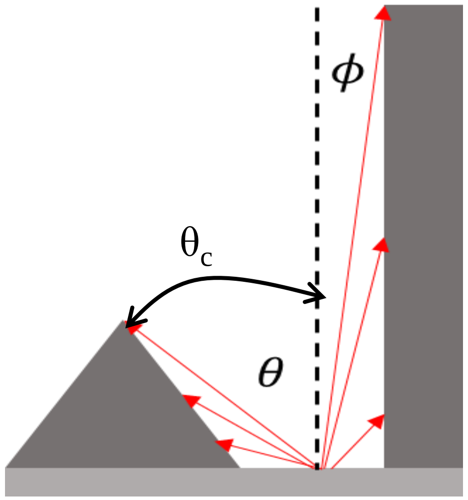


(Dennison, 2006)

Surface Roughness and Electron Yield

- Affected by surface roughness, and contamination [3]
- Roughness may increase or decrease EY depending on the surface morphology and incident energy[3]
- Alters electron escape angles[3]
- Larger impact on SEY than BSEY[4]

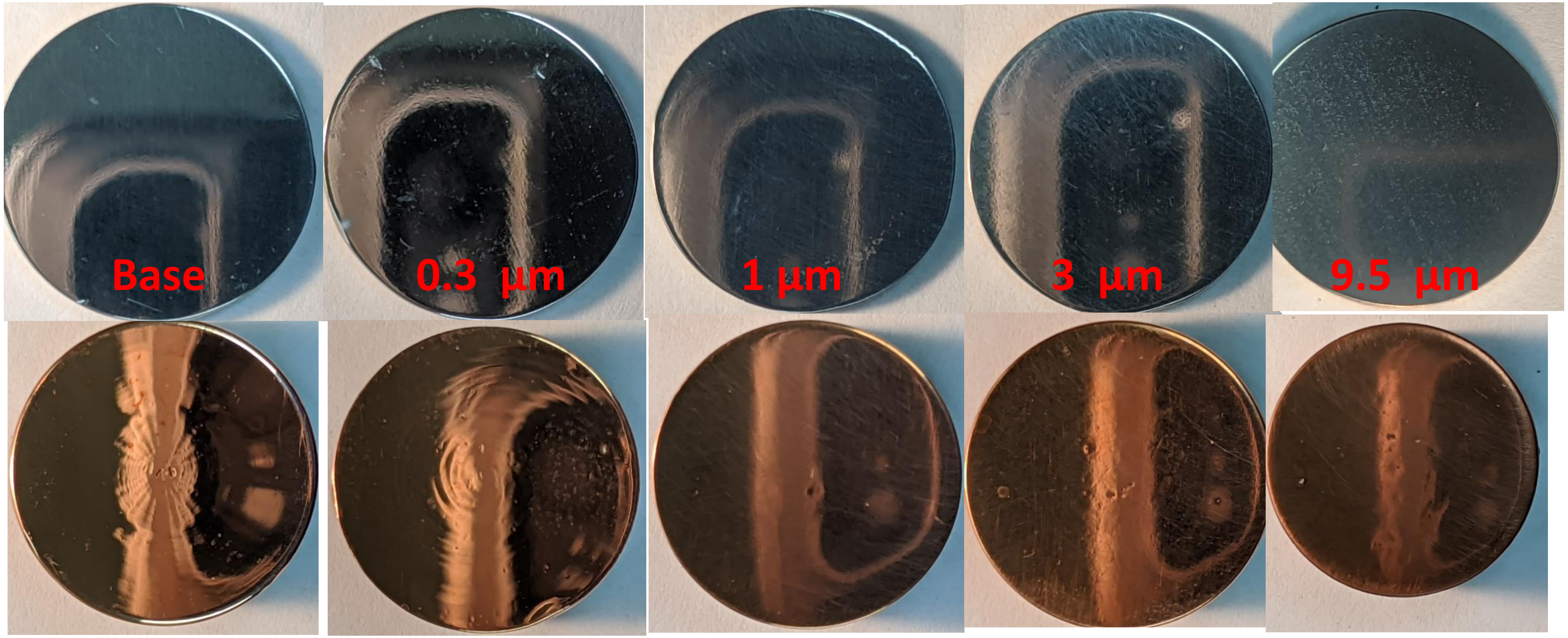




(Wood, 2019)

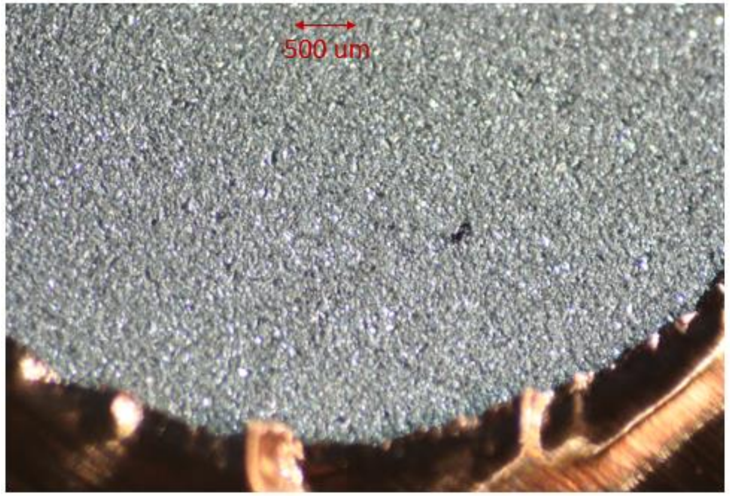
Cu and Al Samples

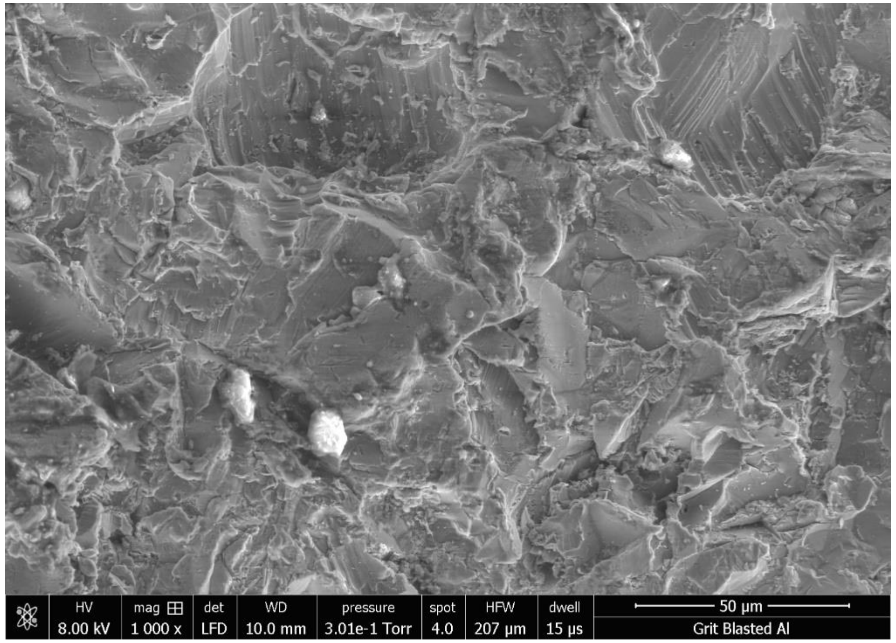
- 0.3 µm, 1 µm, 3 µm, 9.5 µm grit polishing compound applied after polished to ~100 nm and a ‘grit blasted’ Al sample
- Well documented and conductive



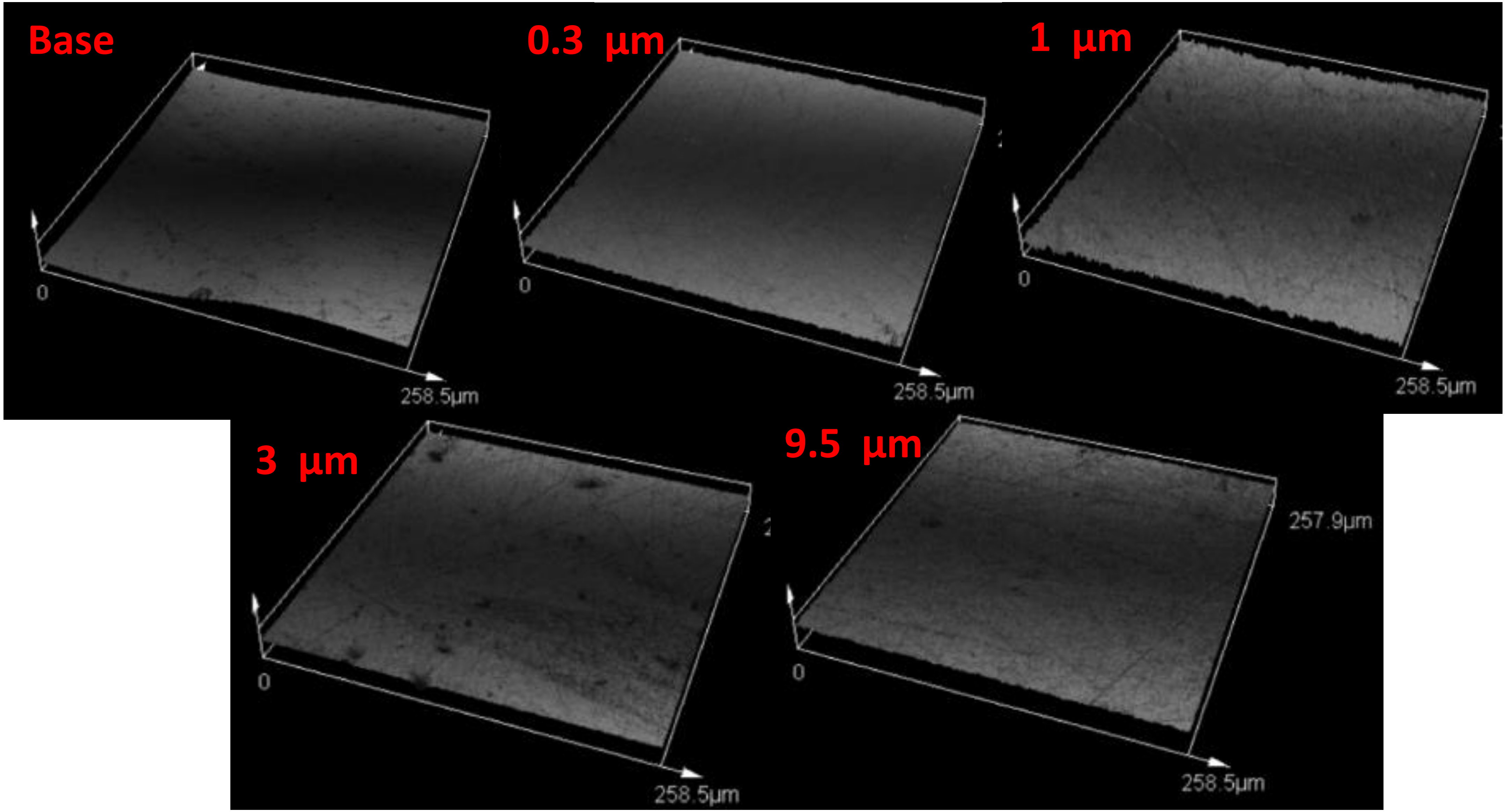
Grit Blasted Al

- More random pattern than polished samples with a much higher density of scratches
- Grit roughness of ~1-6 µm

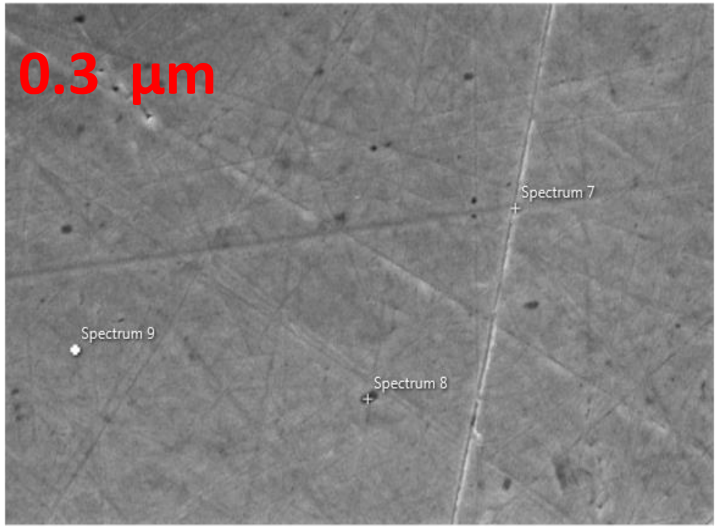


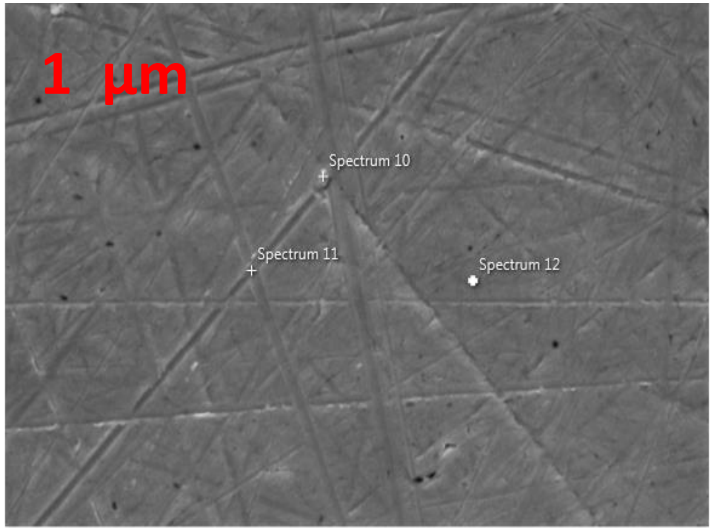


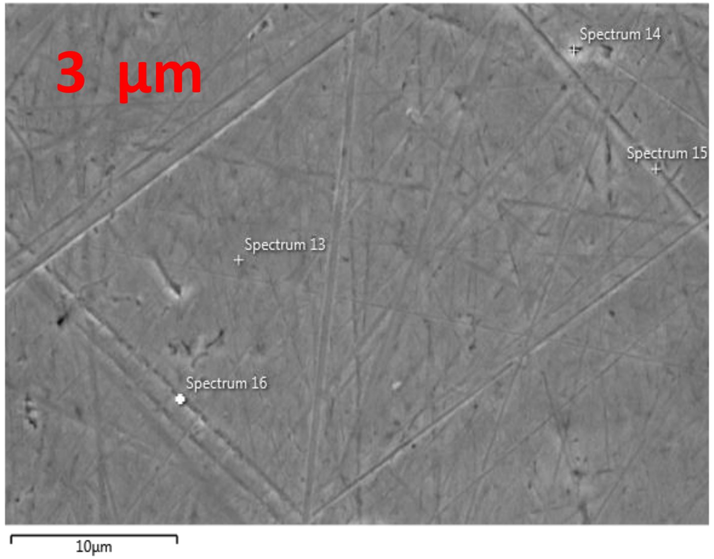
Cu Confocal Microscopy

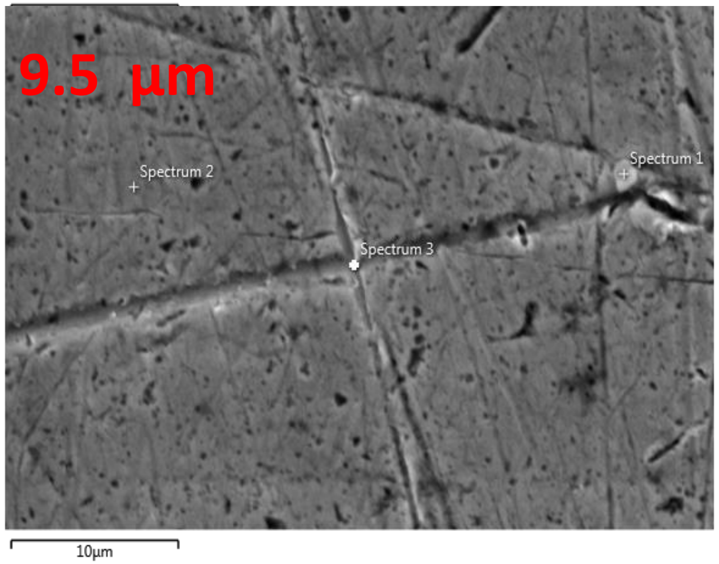


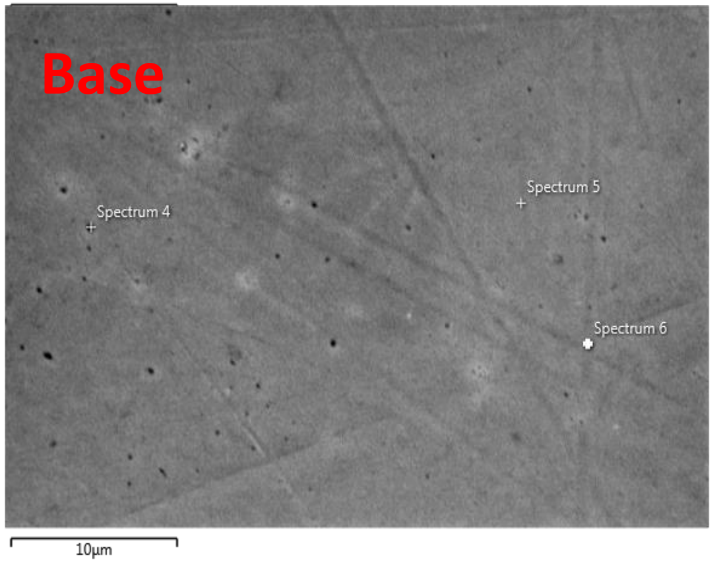
Cu SEM and EDX











Base - 3 µm

Map Sum Spectrum

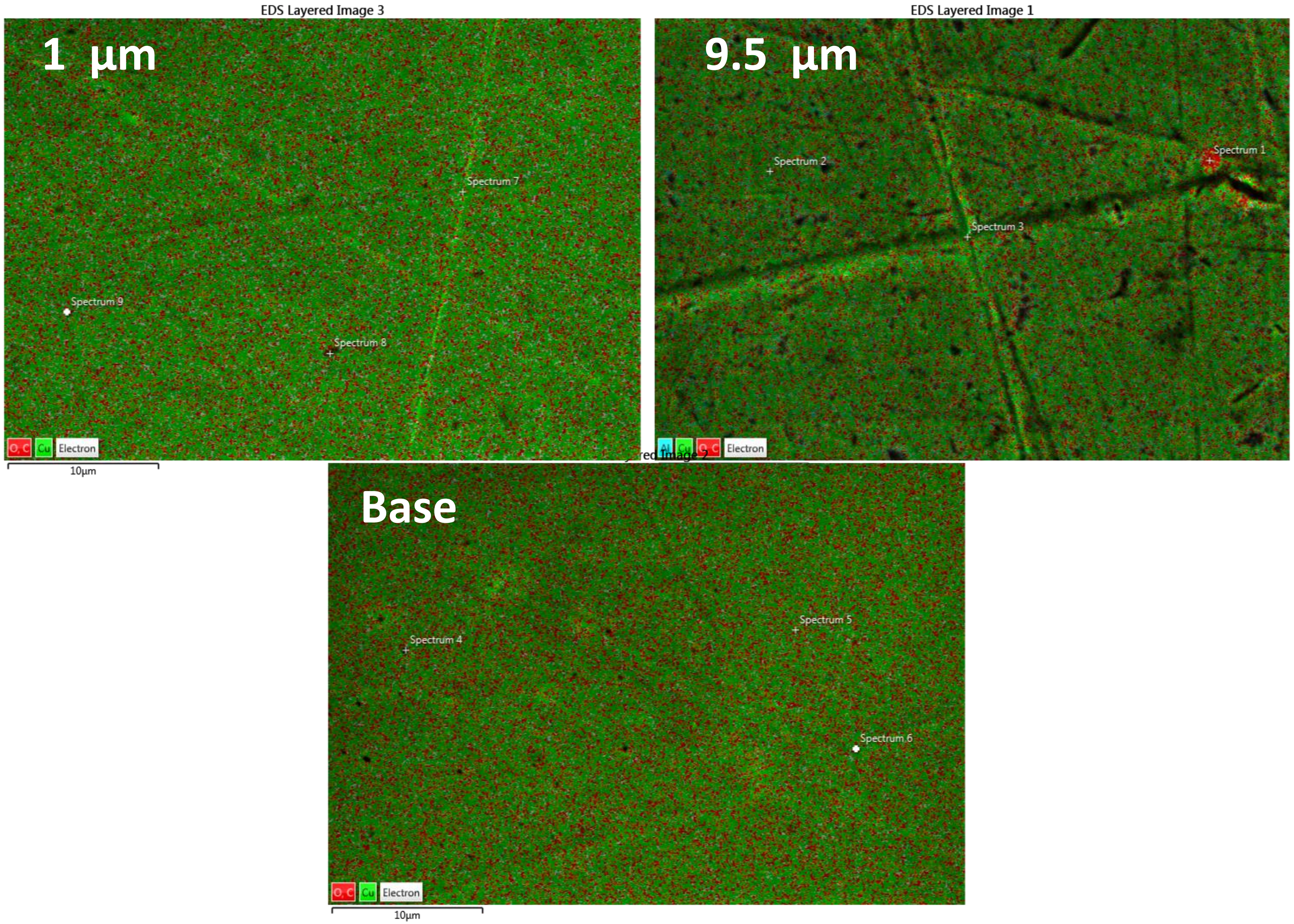
	Wt%	σ
Cu	93.8	0.2
C	5.6	0.2
O	0.6	0.1

9.5 µm

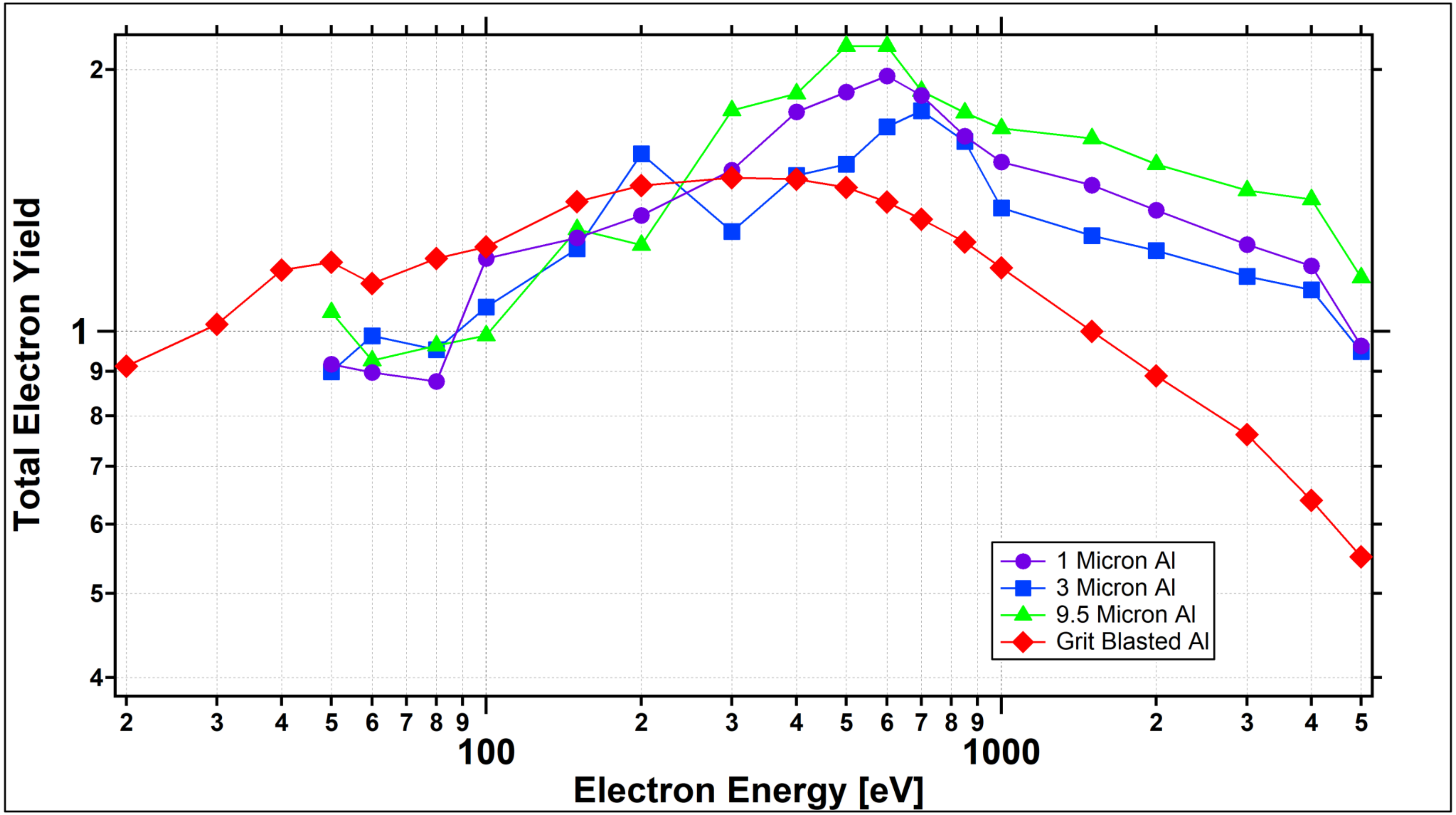
Map Sum Spectrum

	Wt%	σ
Cu	89.9	0.2
C	6.8	0.1
O	2.1	0.0
Al	1.2	0.0

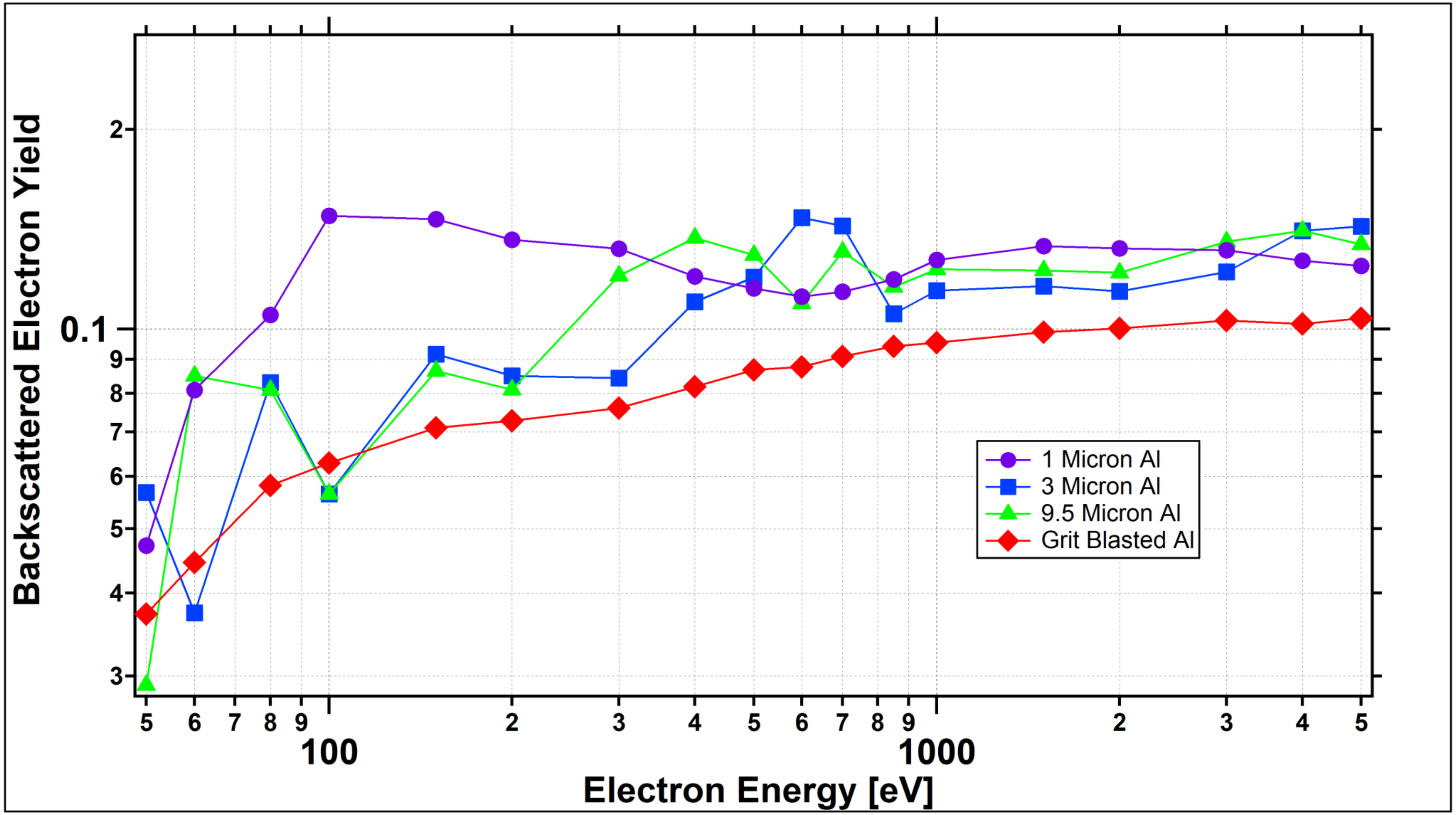
Cu SEM and EDX



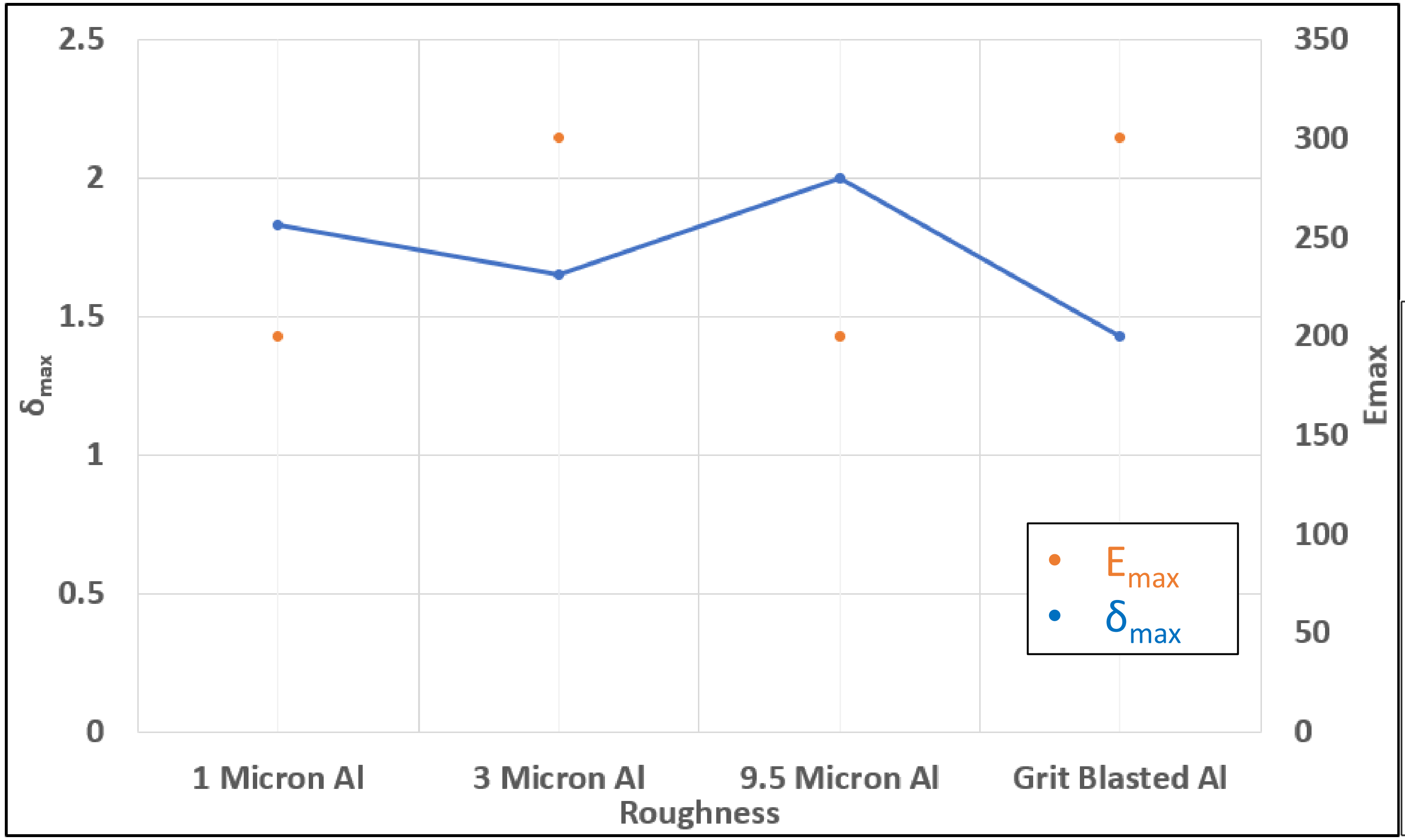
Total Electron Yield Data

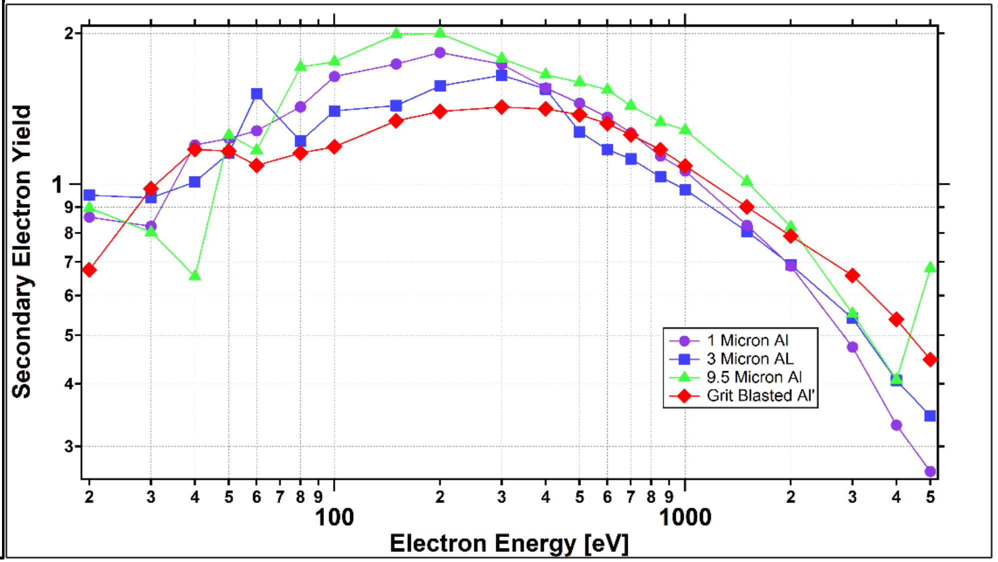


Backscattered Electron Yield Data



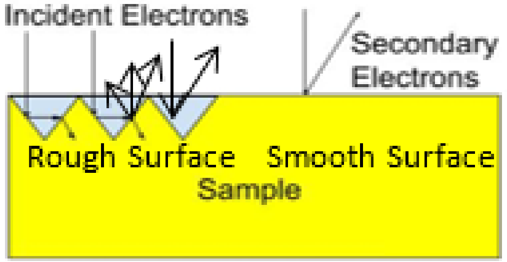
Secondary Electron Yield Max Yield Comparison

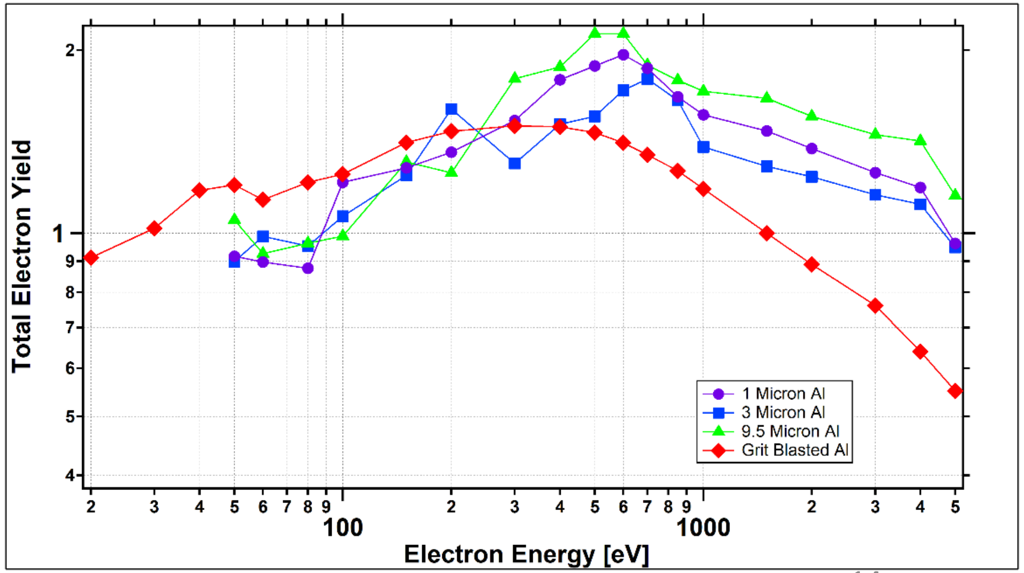




Conclusions

- Roughness appears to decrease yield
- ~30% decrease of maximum total electron from 1 µm to grit blasted Al.
- Contamination may have altered the yield for the 9.5 µm sample





Future Work

- Acquire and analyze electron yield data for Cu and Al
- Acquire SEM and EDX for all Al samples
- Measure roughness (depth and width of scratches)
- Develop quantitative patch SEY model
- Expand to more complex materials

References

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3. B. Wood, J. Lee, G. Wilson, T.-C. Shen and J. R. Dennison, "Secondary Electron Yield Measurements of Carbon Nanotube Forests: Dependence on Morphology and Substrate," in IEEE Transactions on Plasma Science, vol. 47, no. 8, pp. 3801-3809, Aug. 2019.
4. P. Lundgreen, J. R. Dennison, "Strategies for determining electron yield material parameters for spacecraft charge modeling". Space Weather, 18, 2020.
5. J. R. Dennison, A. Sim and C. D. Thomson, "Evolution of the Electron Yield Curves of Insulators as a Function of Impinging Electron Fluence and Energy," in IEEE Transactions on Plasma Science, vol. 34, no. 5, pp. 2204-2218, Oct. 2006, doi: 10.1109/TPS.2006.883398.
6. Christensen, J. Electron Yield Measurements of High-Yield, Low-Conductivity Dielectric Materials. USU, Masters Thesis, 2017.

Acknowledgements

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Thank you!
Questions?