Rapid Growth of Whiskers in Evaporated Tin Films Under Influence of Electric Field

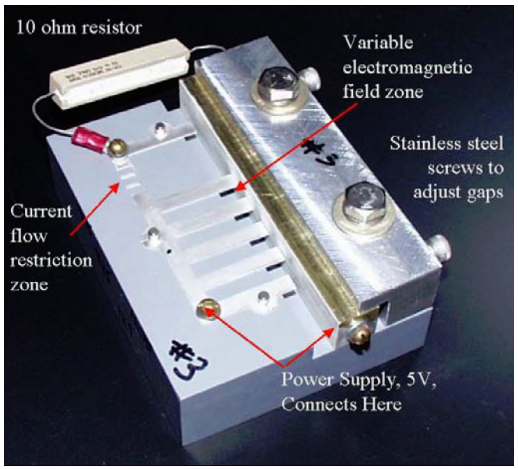
A. Vasko V. Karpov

The University of Toledo

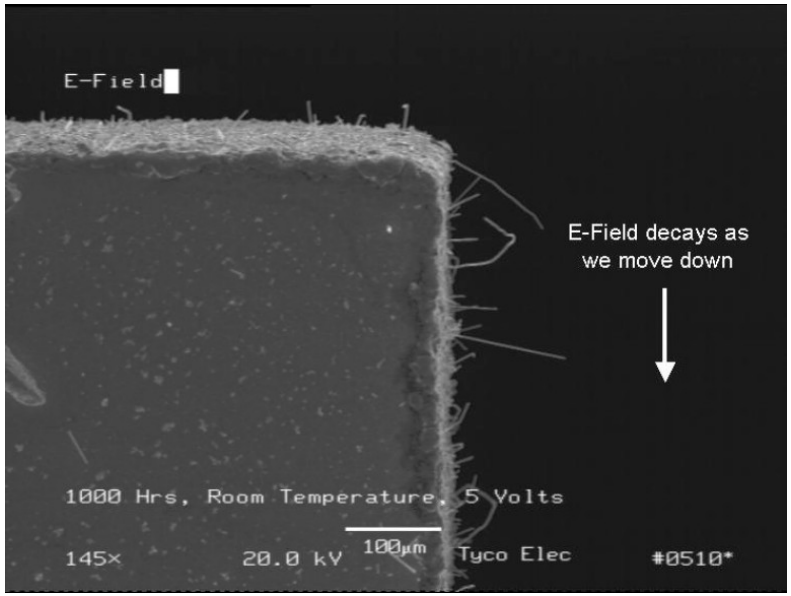
September 25, 2014

Prior Art Review

"Electrostatic Fields and Current Flow Impact on Whisker Growth"
Robert D. Hilty, Ned Corman, Hank Herrmann
IEEE Transactions on Electronics Packaging Manufacturing (2004)



Prior Art, Continued



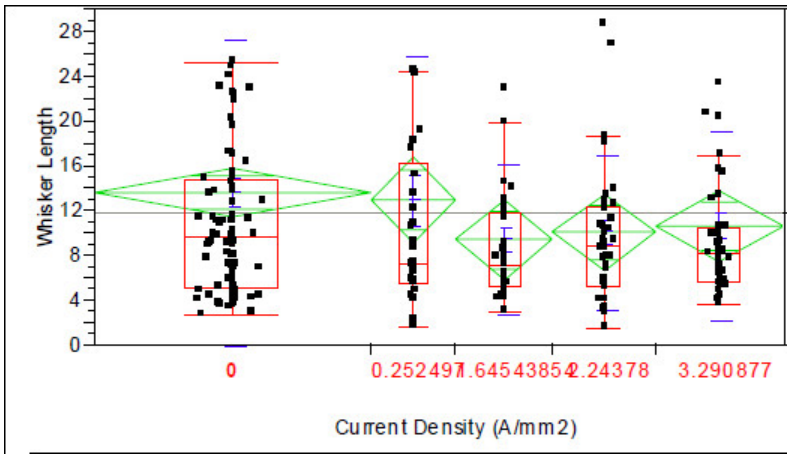


Figure: Left: SEM image of whiskers in "electric region". Right: Statistics of whiskers in "current region".

Prior Art, Continued

Their conclusion: "Electrical bias does not effect whisker growth for room temperature exposures on this plating"
This is due to qualitative (no statistics collected) similarities in regions of different field strength

BUT! Whiskers in "E field region" up to 100 μm long, compared to $<$ 30 μm in "current region"

My conclusion: Evidence of electric bias effect, though not of linear nature.

Current Effect

The previous paper also found statistically meaningful differences in whisker length and densities in regions of different current densities, but no simple (e.g., monotonic) relationship. It is speculated that the stochastic components of whisker growth dominate the effects of current density in this experiment.

Other work studied the current effect:
"Tin whisker growth driven by electrical currents" S. H. Liu, Chih Chena, P. C. Liu and T. Chou Journal of Applied Physics, 2004

1. Used two current densities; the highest always produced more whiskers, and whisker densities increased with time under stress

Factors Governing Tin Whisker Growth
Erika R. Crandall
Disseration, 2012

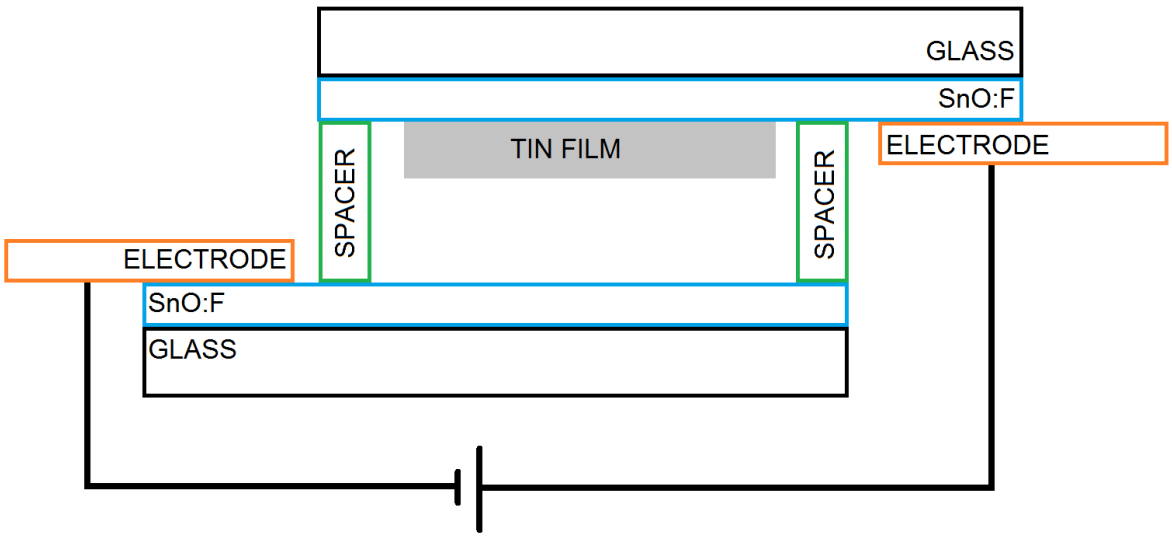
1. "In conclusion, exposing a 1 μm Sn film pattern to 0.2 A of current produced whiskers in hours instead of weeks or months. "

However, our work presented here considers only field, at zero current

Deposition Setup

1. Films deposited through thermal evaporation
2. The evaporator allows multiple samples per deposition
3. Therefore, the control and experimental sample were deposited at once and are identical
4. Samples were deposited on TEC (fluorine doped tin oxide) glass substrates, for ease of attaching electrodes
5. Sn thickness = 150nm
6. Control sample was stored in a box; experimental sample was exposed to electric field

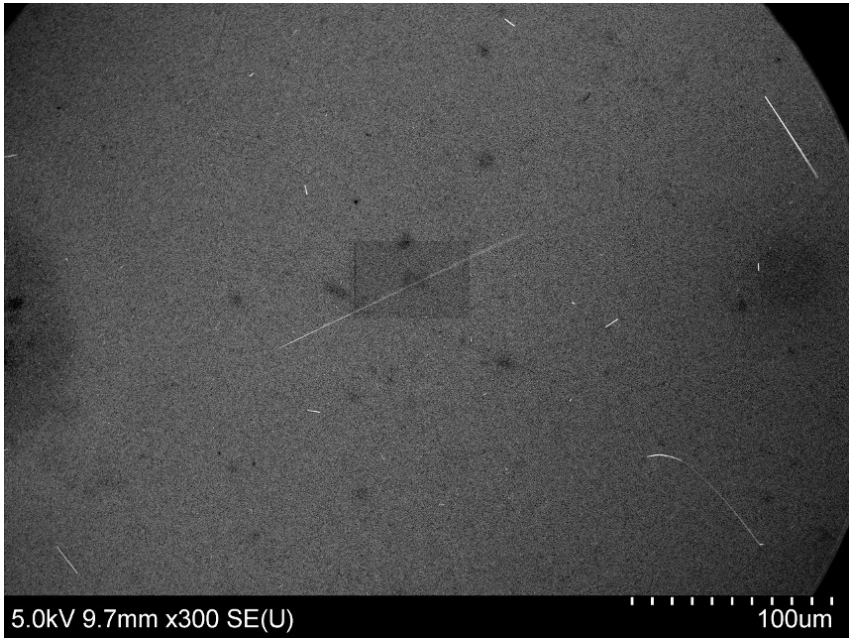
Capacitive Setup



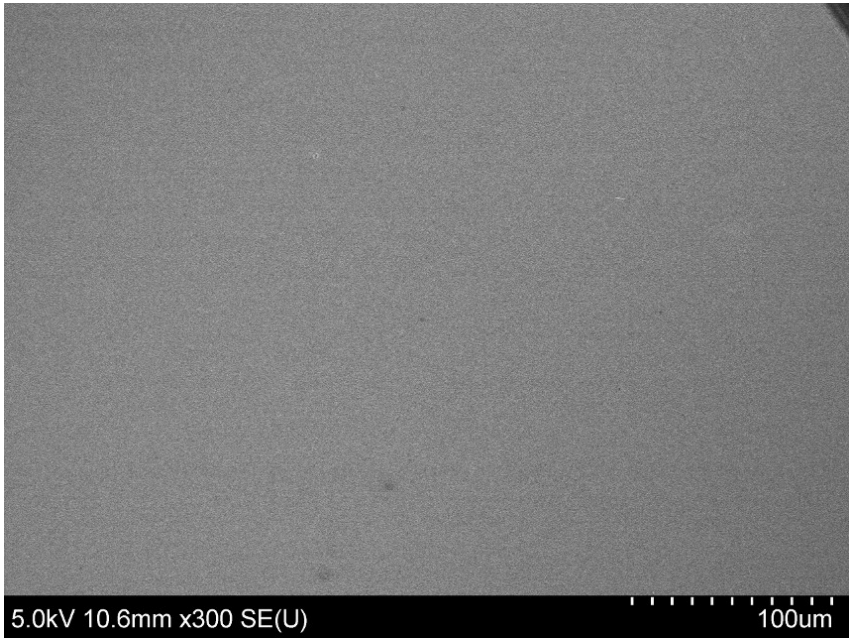
1. Spacers $\approx 50\mu m$
2. Voltage = 14.5V
3. Field $\approx 3000\,V/cm$
4. Field applied parallel to direction of grain growth
5. Field applied for 7 days

SEM Images

Experimental Sample:



Control Sample:



1. Experimental sample has $\sim$ 30 whiskers in area 0.4mm x 0.3mm
2. Control sample has 0 $\sim$ 1 whiskers in same area
3. Whisker length on experimental sample up to $\sim 100\mu m$
4. Control sample whisker $\sim 5\mu m$
5. *Order of magnitude* differences in whisker densities and lengths

Higher Magnification

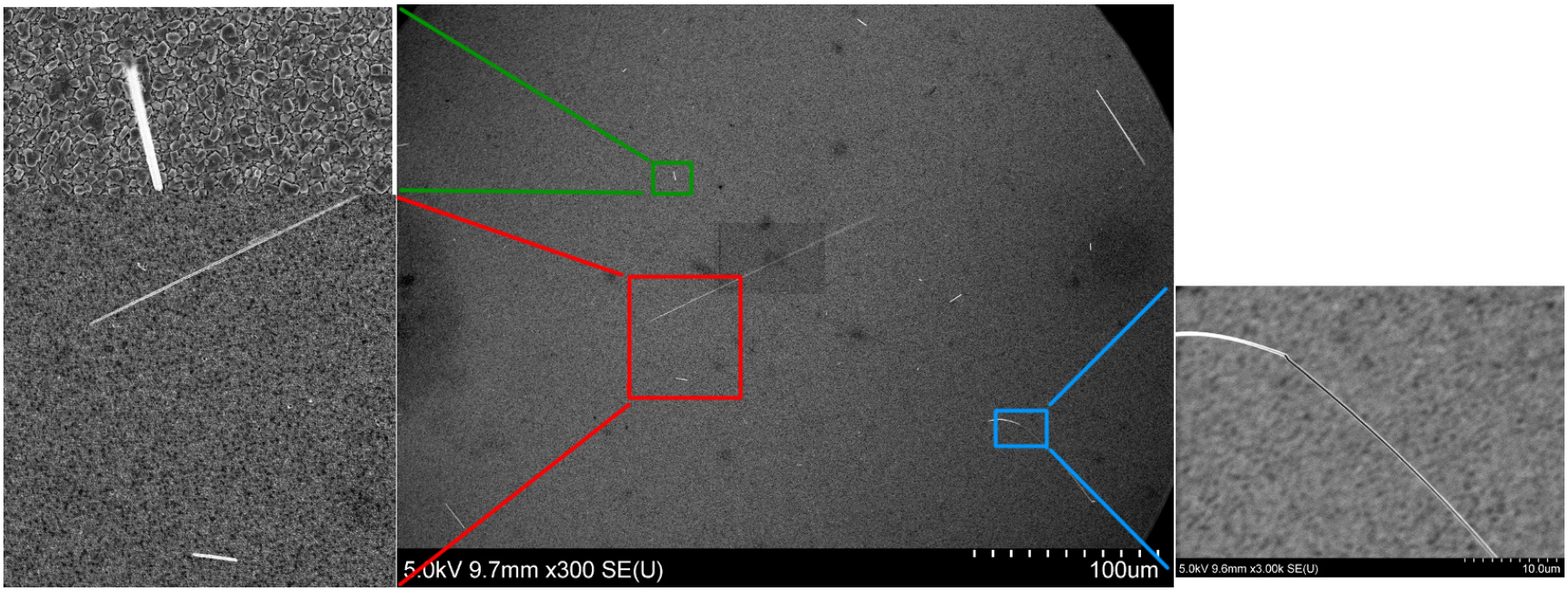


Figure: Higher magnification confirms normal whisker morphology and presence of additional, smaller whiskers

Previous Whisker Lengths and Density Representative

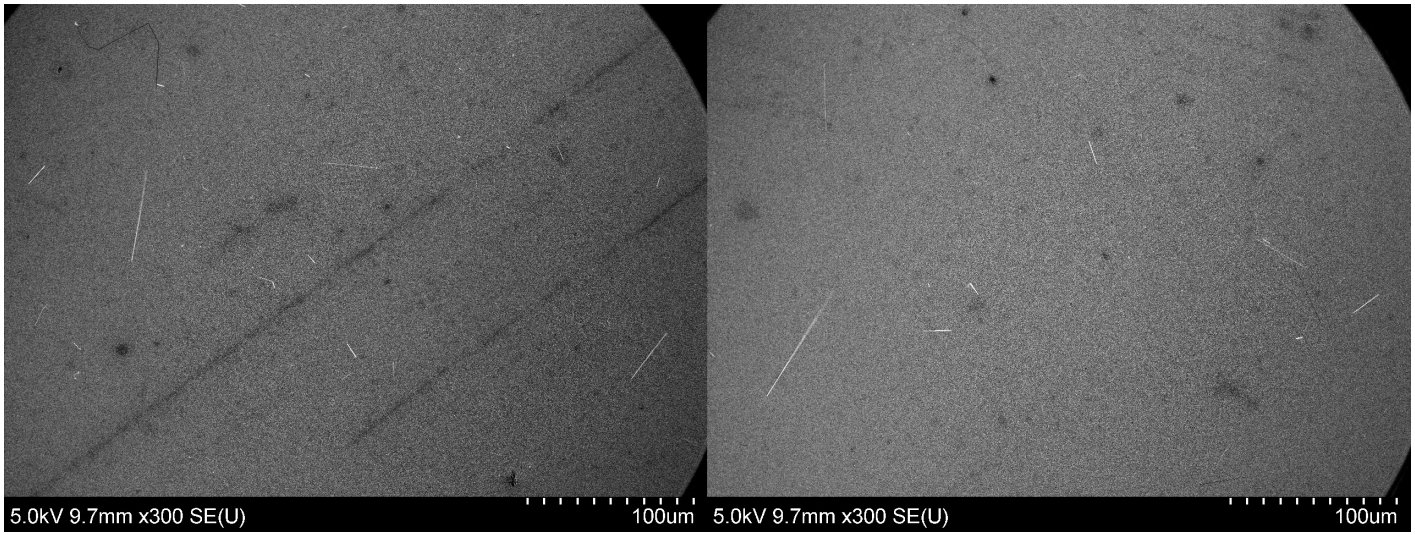


Figure: Previous Whisker Lengths and Density Representative of Sample Exposed to E Field

Higher Magnification

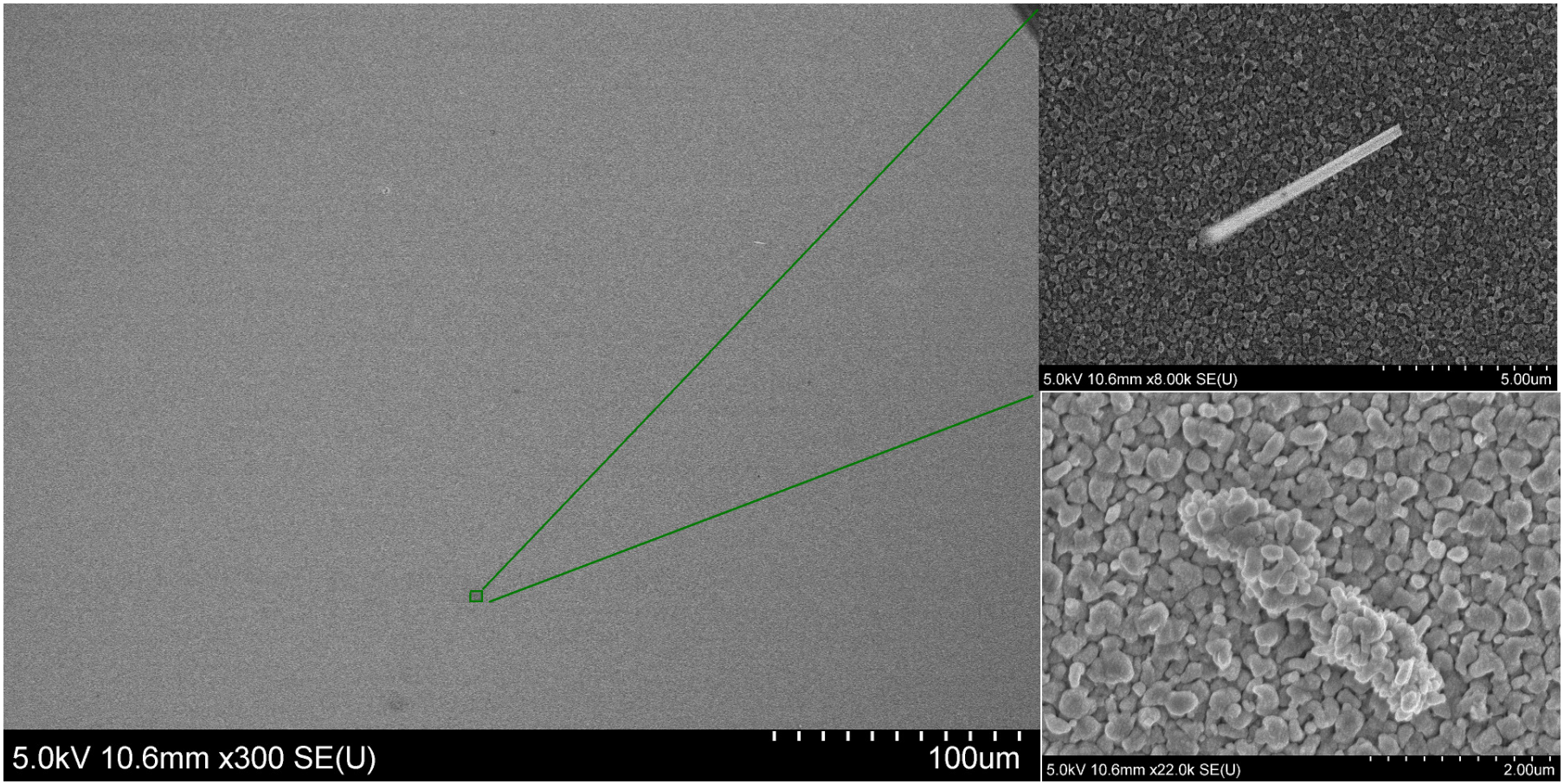
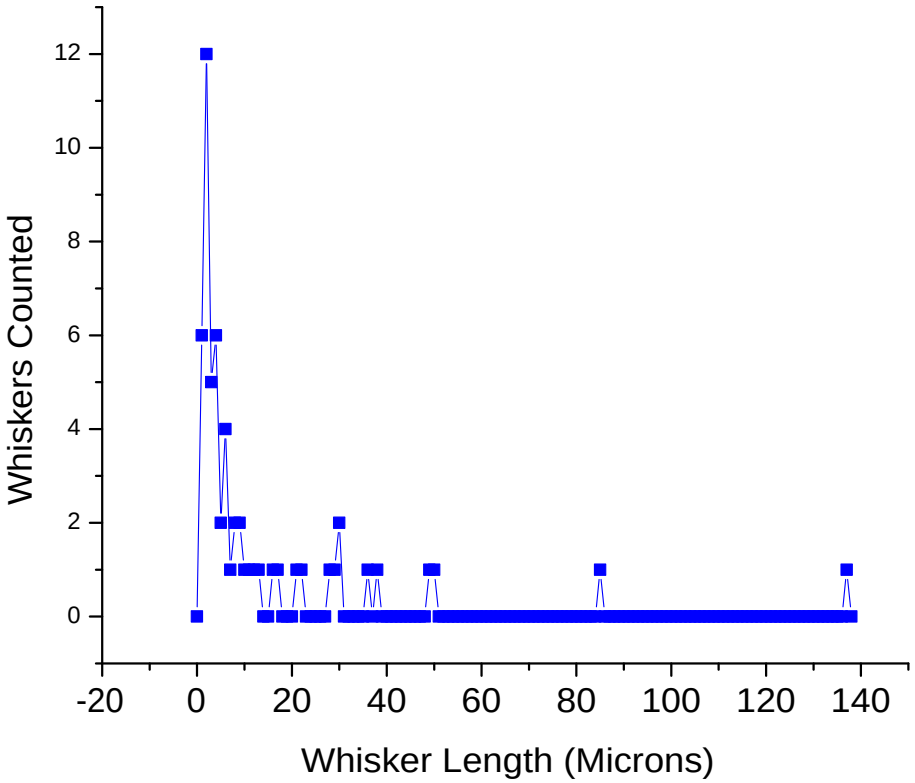


Figure: There is one whisker in this region on the control sample! (And one feature that looks like a whisker but is revealed to not be one under higher magnification, lower right inset)

Whisker Statistics
For Experimental Sample



1. Mean length = 14 μm
2. Standard Dev. = 23 μm
3. Skew = 3.2

Future Work

1. Reproduce results
2. Statistics as function of time under field
3. Other deposition conditions – sputtering as well as thermal evaporation, possible stress control