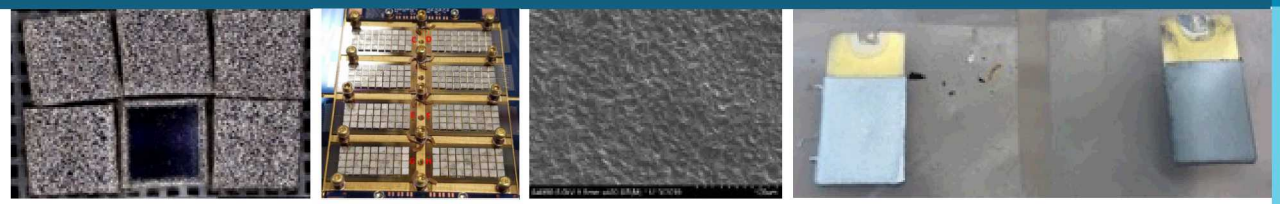
SAND2020-6557C

Investigation of Microcalorimeter Absorber Performance



Christian Arrington[1], Jamin Pillars[1], Jesse Bland[1], Steve Carr[1], Rupert Lewis[1], Dan Schmidt[2], Joel Ullom[2], Mark Croce[3], Michael Hamel[1]

[1]Sandia National Laboratories
[2]National Institute of Standards and Technology
[3]Los Alamos National Laboratory

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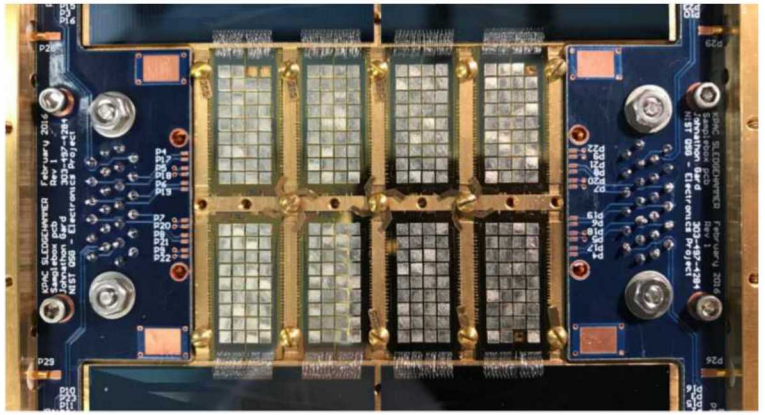
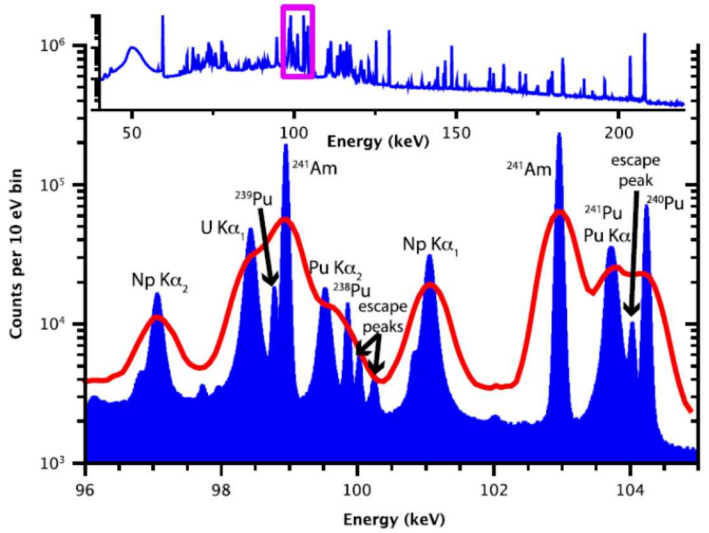
Background Information

NIST/LANL Microcalorimeter

- Excellent resolution near 100 keV
  - About 50× improvement compared to HPGe at 97 keV
- Hand assembly process creates distribution of pixel performance
- Pixel reliability limits potential application space and fieldability
- Pixels with poor performance degrade overall resolution and efficiency



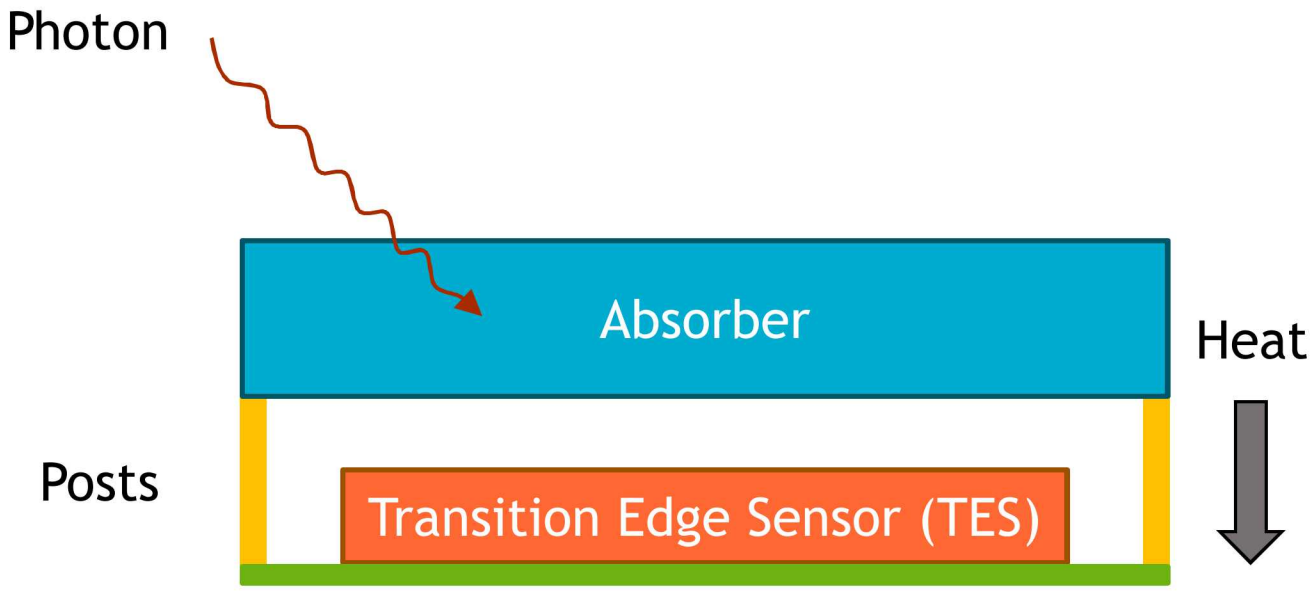
NIST/LANL 256-pixel detector



Result from NIST/LANL microcalorimeter:
22 eV at 97 keV

Background Information

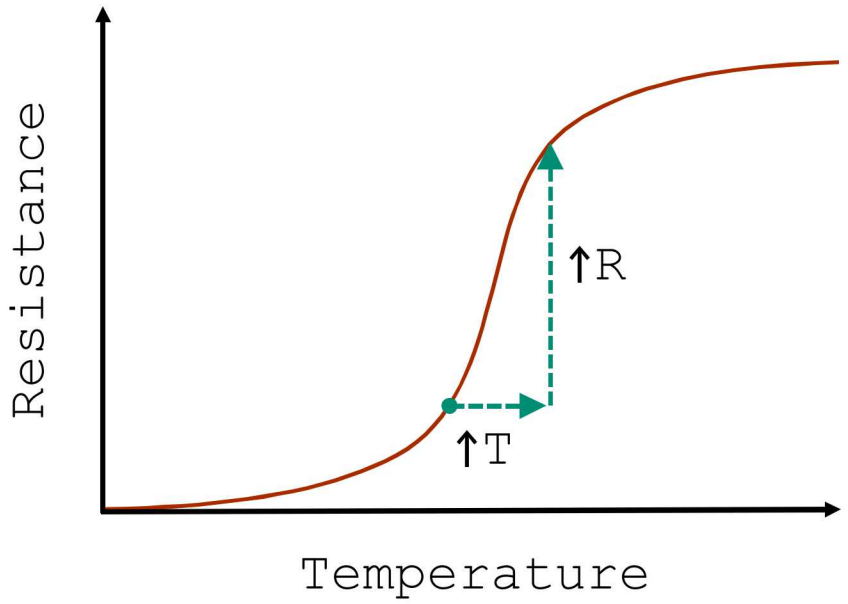
TES Microcalorimeter Principles of Operation



1. Photon interacts in the absorber
2. Temperature of the absorber increases proportionally to the photon energy deposited
3. Heat is transferred from the absorber to the TES through the posts
4. The response of the TES is read out

Background Information

TES Microcalorimeter Principles of Operation



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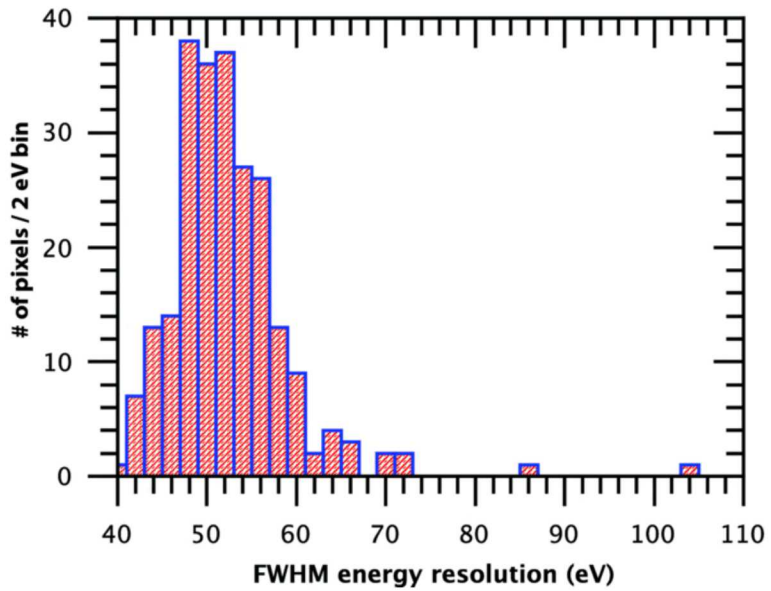
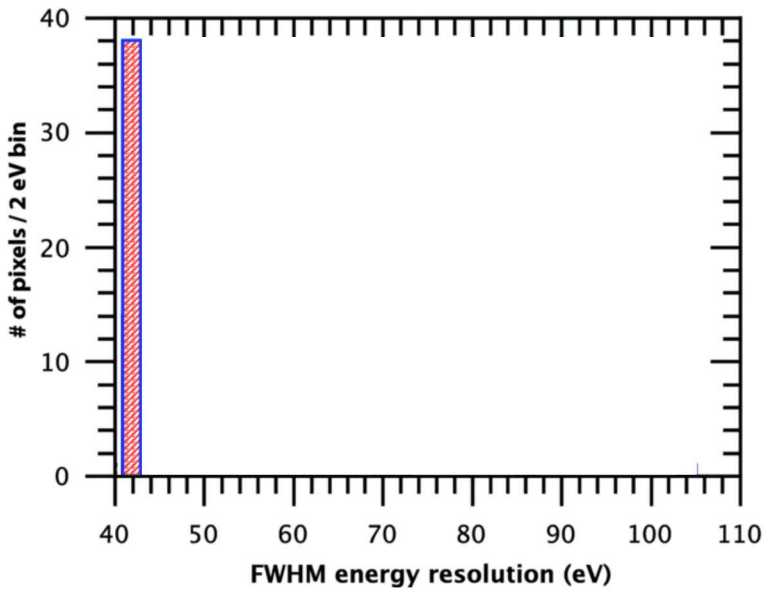
Objective

Improve single pixel performance

Reality

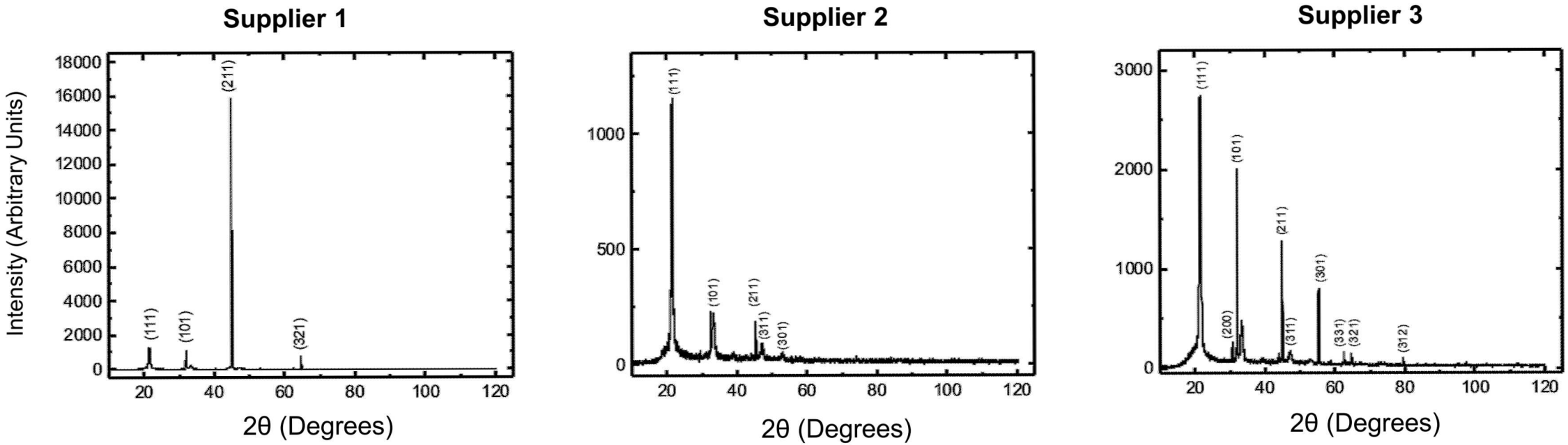


Goal



Bulk Tin Analysis

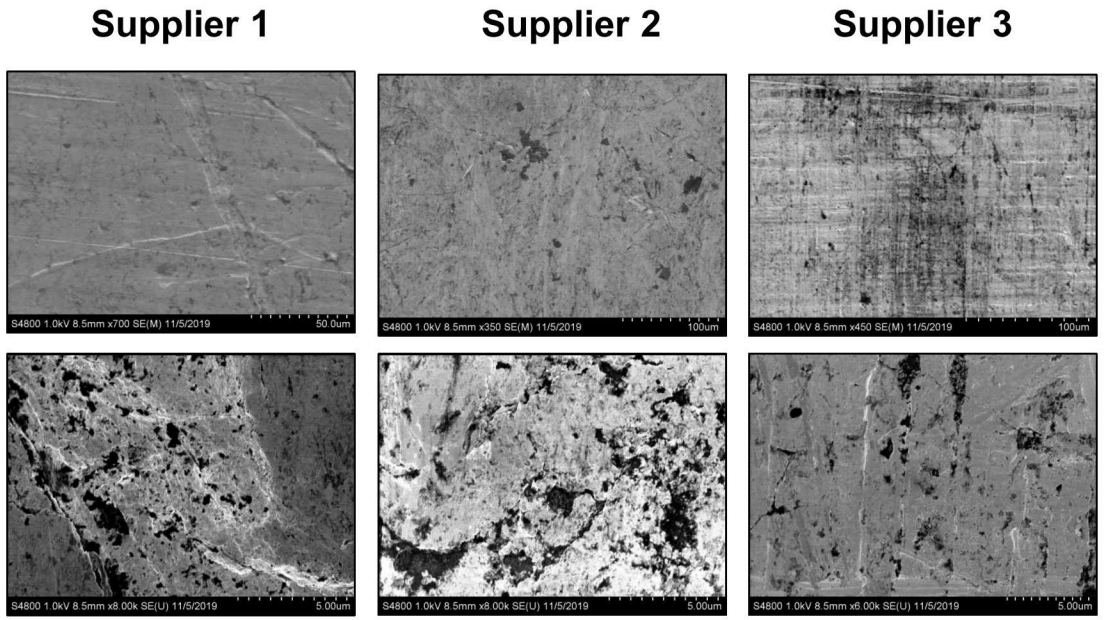
- Determine microstructure of tin that produced absorbers with good performance
- Analyzed bulk tin samples provided by NIST from three suppliers
  - Tin from Supplier 1 produced the best energy resolution, followed by Supplier 2, with Supplier 3 producing poor resolution
  - Tin with worse energy resolution showed signs of higher heat capacity which translates directly to worse energy resolution
- **Hypothesis:** We hypothesize that the crystal orientation for the Supplier 1 tin provides better heat transfer properties, more thermal conductance across the absorber/post interface, and may be a factor in performance differences.



Bulk Tin Analysis

- Images taken with scanning electron microscope (SEM) show rough irregular surfaces in all samples
  - Irregularities could produce variability in results from different absorbers using the same supply of tin
- Both the Supplier 2 and Supplier 3 tin samples are nanocrystalline with crystallite sizes in the 15-20 nm for most orientations. The better performing Supplier 1 tin had a crystallite size over 100 nm for the (211) orientation.
  - More experimentation needed to correlate grain size with thermal transport and interface thermal conductance for this material system
- Research has shown the preferred crystal orientation of the metal in a metal/nonmetal interface varies the thermal conductance across the interface*

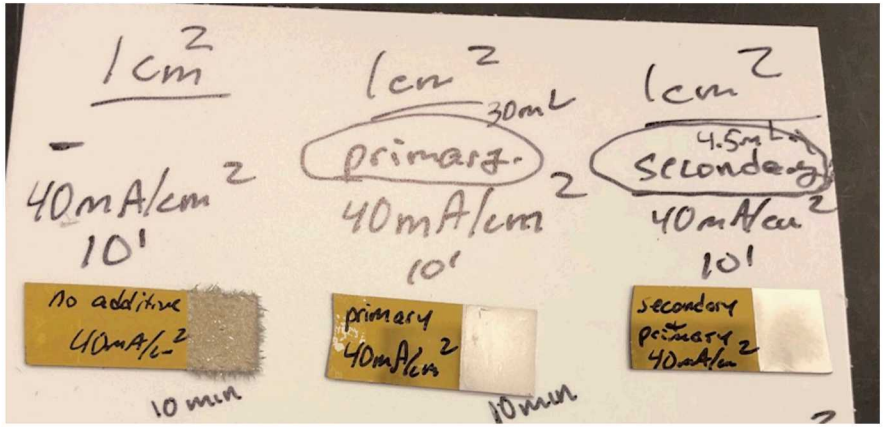
SEM Images



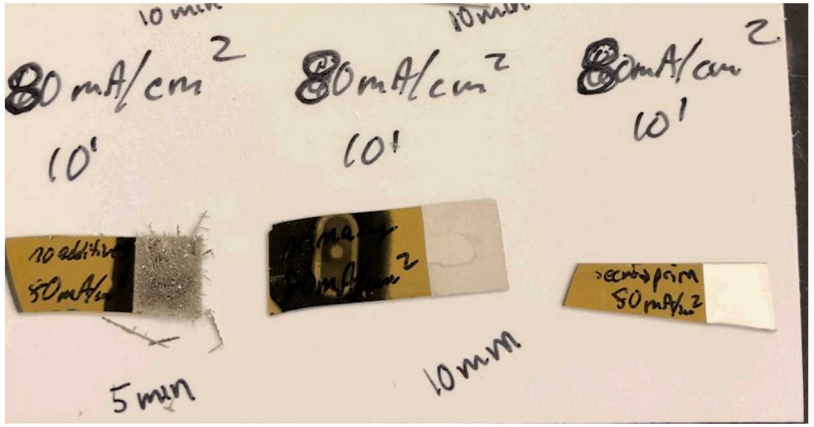
* R. Varghese et al., "Effect of crystallinity on Thermal Transport in Textured Lead Zirconate Titanate Thin Films," Applied Materials and Interfaces, vol. 6, pp. 6748-6756, (2014).

Absorber Fabrication

- Tin electroplating using Dow Solderon Tin/Silver (97%/3%)
  - Silver not added
- Tin was electroplated using various currents and additives onto an E-beam seed layer of Ti/Au 100/500 A°
  - 40 and 80 mA/cm^2 currents
  - No additive, primary additive, primary and secondary additives
- Pulsed plating was tested by varying the duty cycle (DC) from 50% to 90%
  - DC = ("on" time)/ (total pulse time)



Electroplated tin with
40 mA/cm^2 current

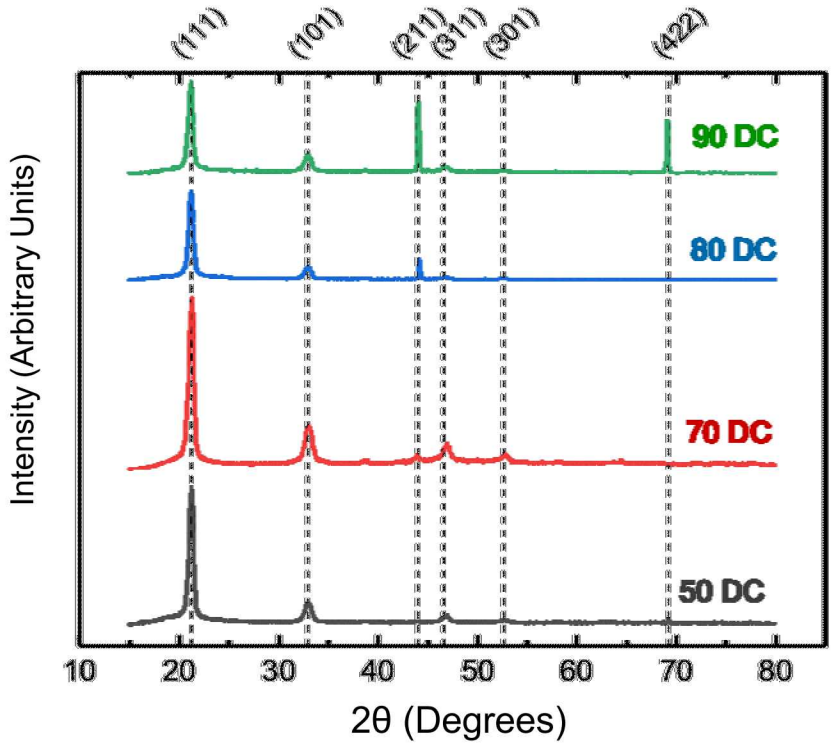


Electroplated tin with
80 mA/cm^2 current

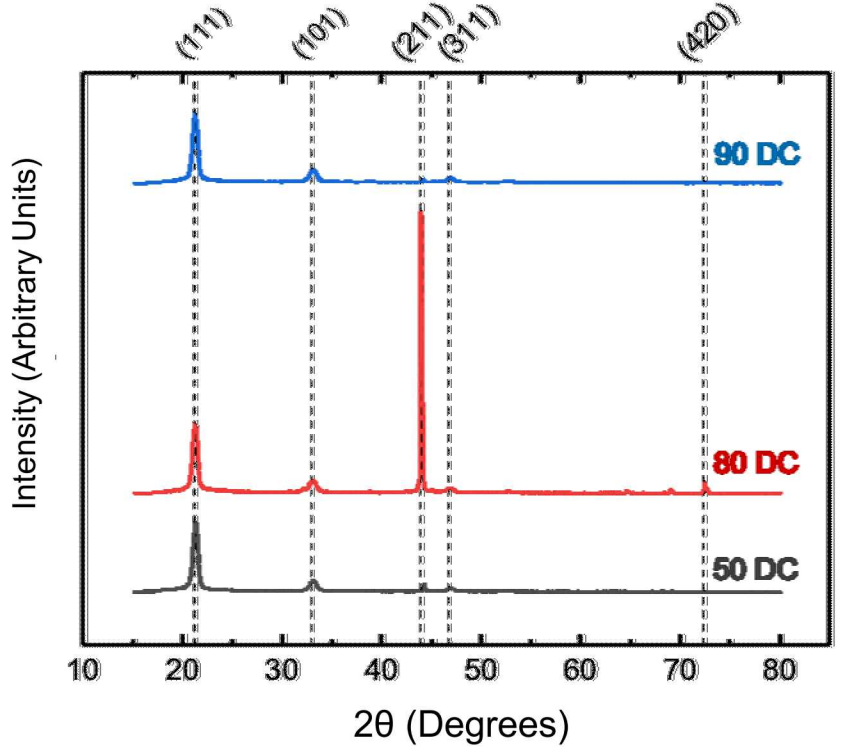
Absorber Fabrication

- XRD Analysis of samples plated across two current densities and a range of pulsed duty cycles (DC) from 50%-90%
- A decrease in the duty cycle for samples plated at 40mA/cm^2 resulted in less (211) orientation and an increase in the (111) – indicators of poor performance
- At 80mA/cm^2 and a duty cycle of 80%, the tin film has a preferred (211) orientation with a crystallite size >100nm
  - Consistent with good performing tin absorbers from Supplier 1

Samples Plated at 40 mA/cm^2 at Varying Duty Cycles



Samples Plated at 80 mA/cm^2 at Varying Duty Cycles



Absorber Fabrication

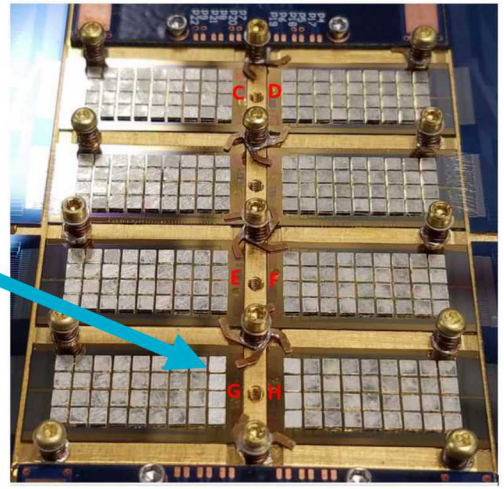
Diced SNL tin absorbers

Absorbers were electroplated with a constant current of 40 mA/cm^2

1.5 mm

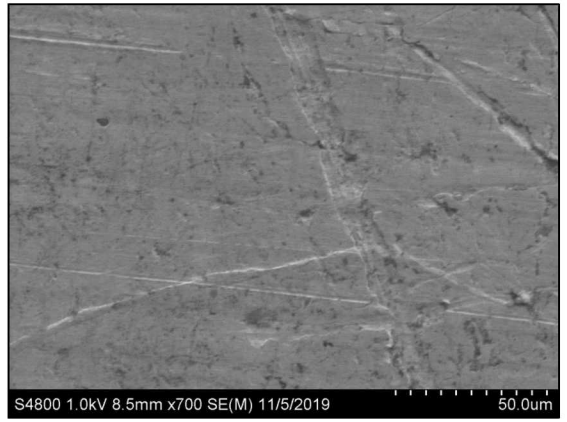
Thickness: 400 µm

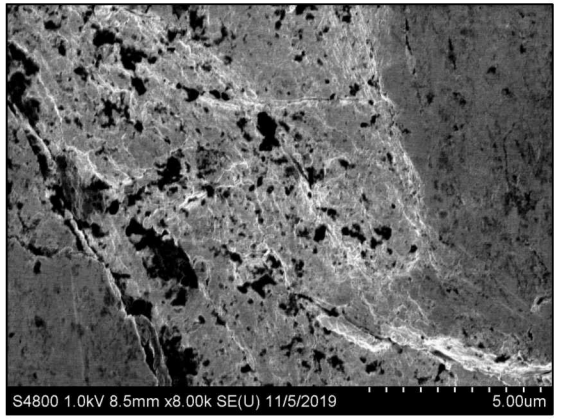
Bottom-row middle absorber shows back side of tin



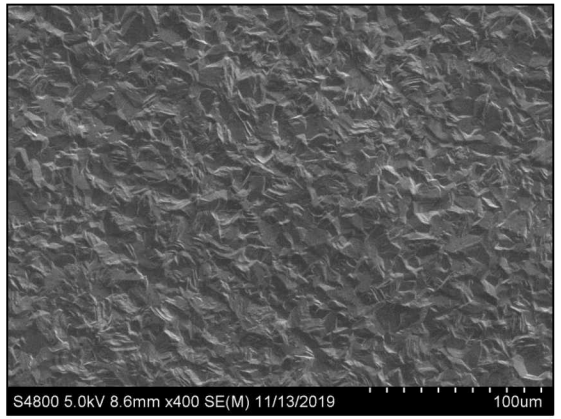
Installed SNL absorbers (8 total adjacent to G and H labels). Photo from NIST.

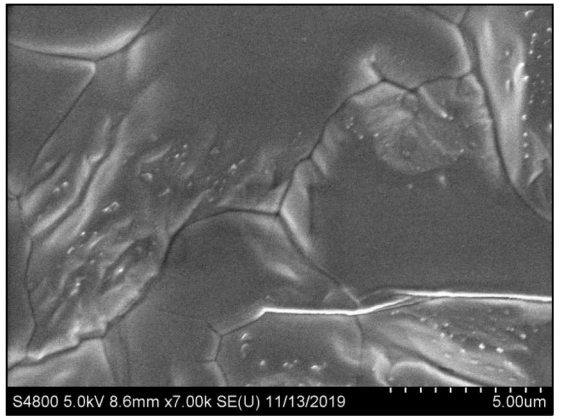
Supplier 1





SNL Tin





Future Work

- Evaluate performance of SNL absorbers using NIST/LANL microcalorimeter
- Adjust fabrication process to create a new microstructure if needed
- Work to fabricate absorbers directly to TES
  - Eliminate hand assembly using epoxy