SAND2014-2312C

Indexing and TEM Sample Preparation of Isolated CdTe/CdS Nano-Islands

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Southwest Energy Science and Engineering Symposium

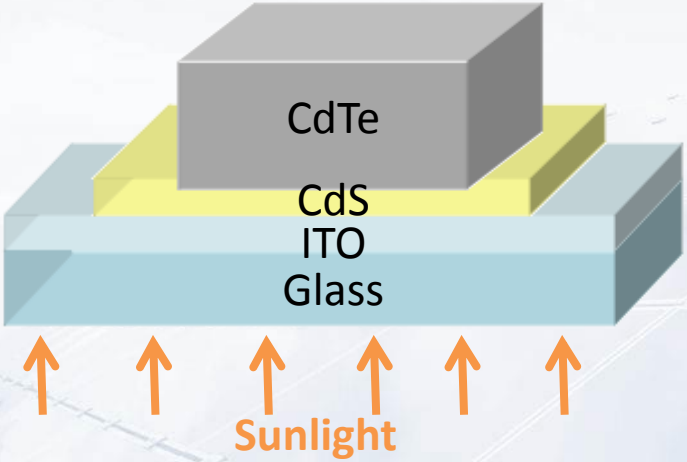
March 22nd, 2014, El Paso, TX

Outline

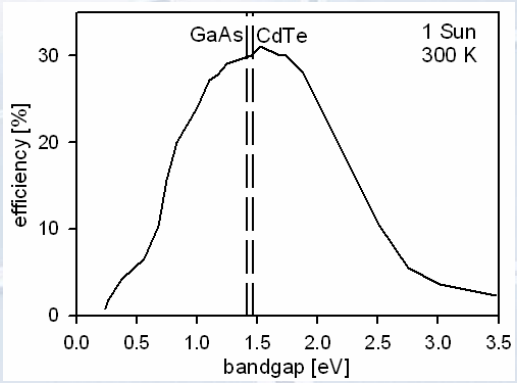
- Introduction
  - Efficiency of CdTe solar cells over time
- Impact of CdTe quality on V_{oc}
  - Defects
- Proposed characterization path
  - Selective area growth
- Results
  - Sample preparation
- Future work
  - Electrical micro-structure correlation

Introduction

Maximum theoretical efficiency of 30%



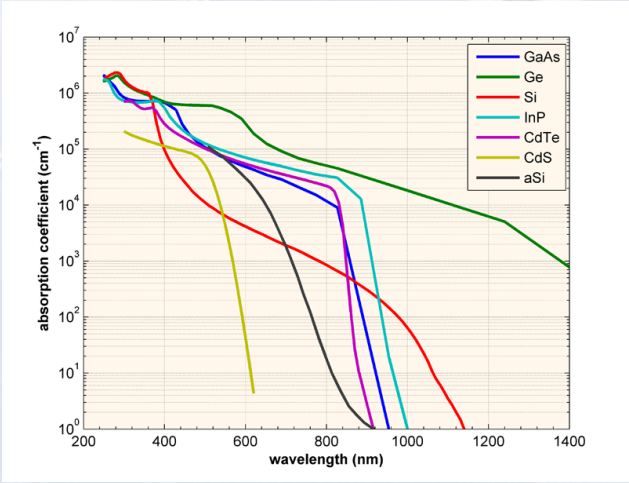
Ideal bandgap (1.5eV)



[1] J. Pan, 2007 Dissertation work, Colorado State University

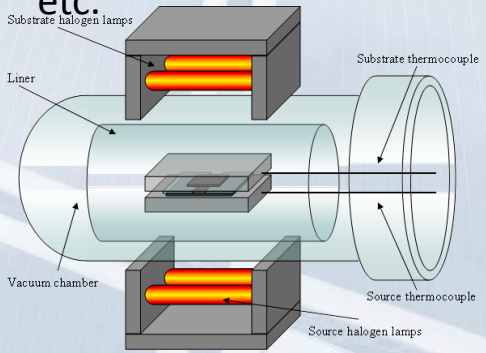
Good Absorption

95% of the incident light is absorbed by 0.7um



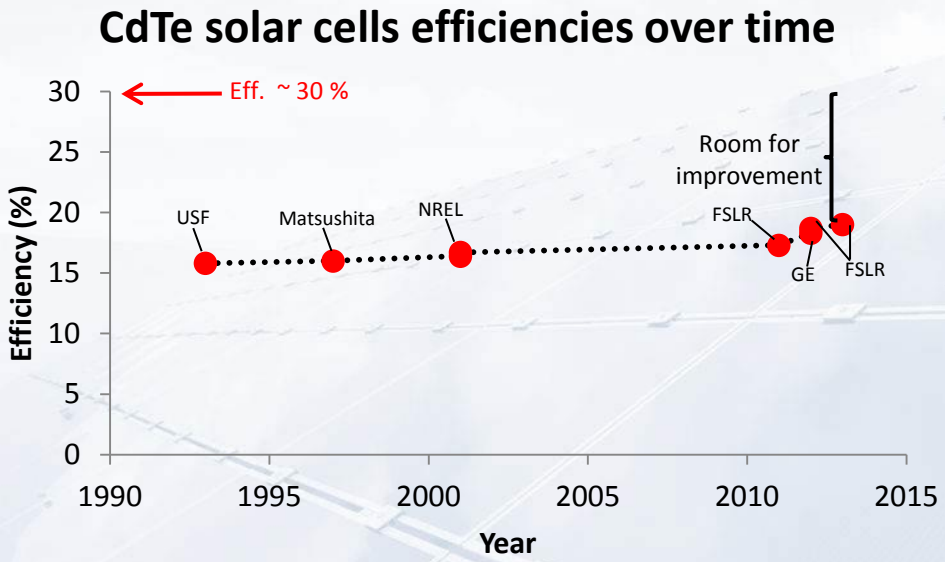
[2] http://pveducation.org/pvcdrom/pn-junction/absorption-coefficient

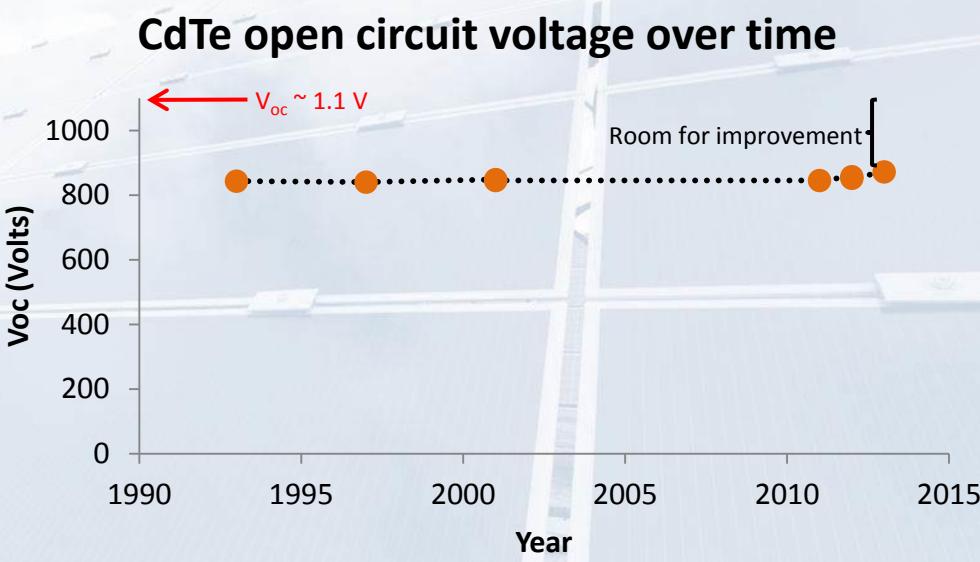
Low cost: CSS, spray, etc.



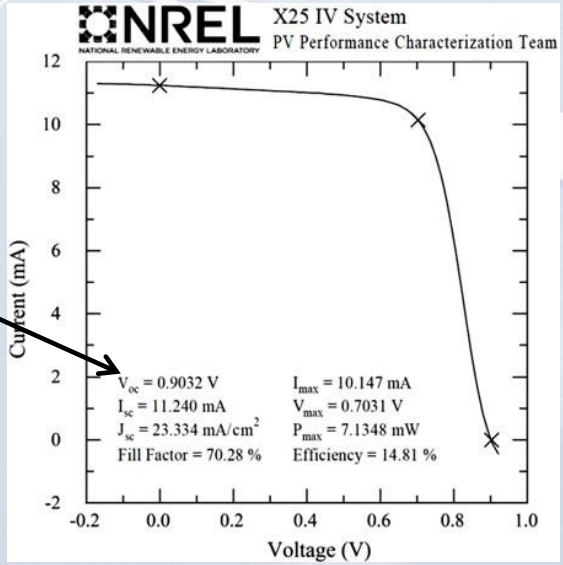
[3] A. Escobedo, 2008, M.S. thesis work, UTEP

History of CdTe solar cells (V_{oc})





IV curve for new world record V_{oc} = 903 mV (2013)

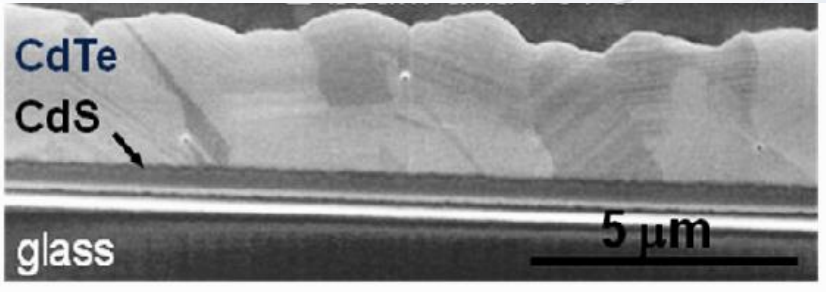


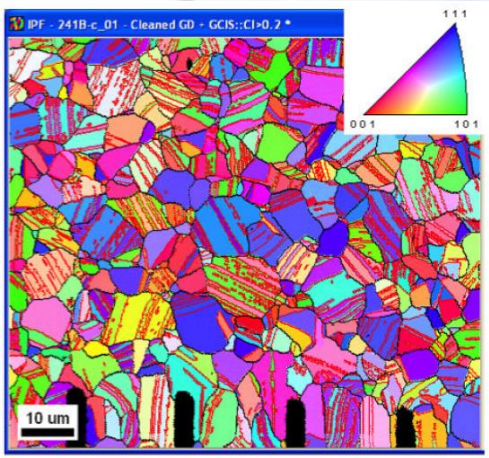
- V_{oc} has been between 840 – 860 mV for 20 years
- V_{oc} reached 872 mV for a record cell of 19%
- V_{oc} = 903 mV has been demonstrated

[4] M. Gloeckler, 2013 IEEE Journal of Photovoltaics

CdTe material characteristics

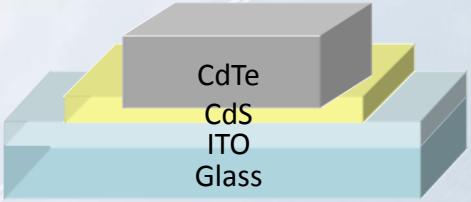
Grain Boundaries

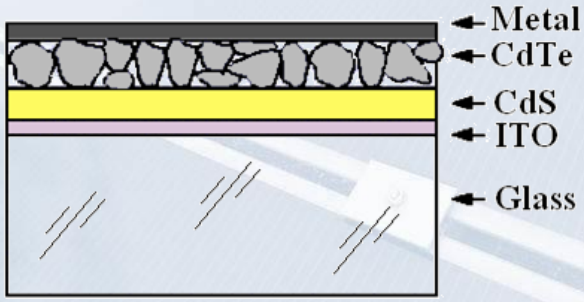


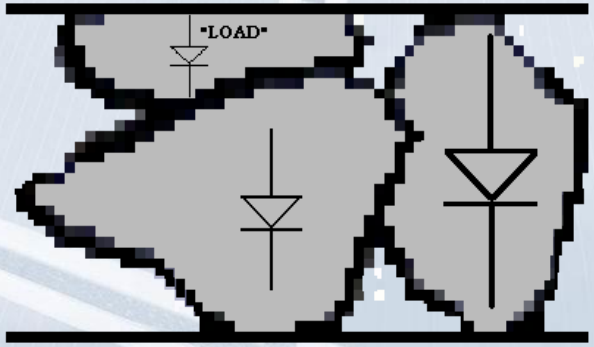


Typical grain boundaries formed in CdTe films. Cross-section (SEM) and plane view (EBSD)

Inhomogeneity





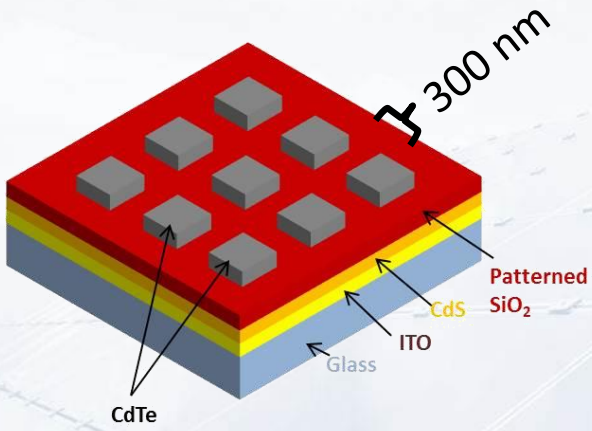


Inhomogeneity in CdTe solar cells cause low efficiencies [5]

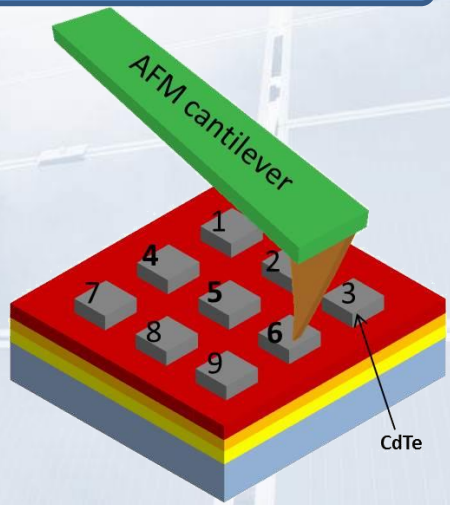
[6] B. Lita, 2010, IEEE
[7] H.R. Moutinho, 2013, PVSC
[8] V. G. Karpov, 2004, The American Physical Society

Proposed characterization path

CdTe Selective Area Growth

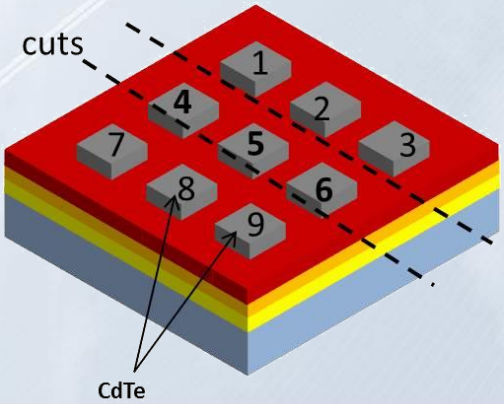


Electrical Characterization

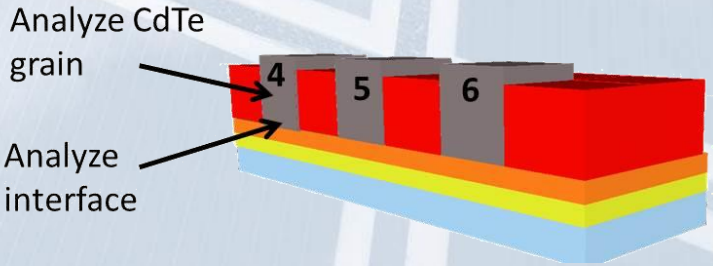


Correlation

Sample Preparation



Microstructure characterization



CdTe nano-island Indexing using SEM and focus ion beam (FIB)

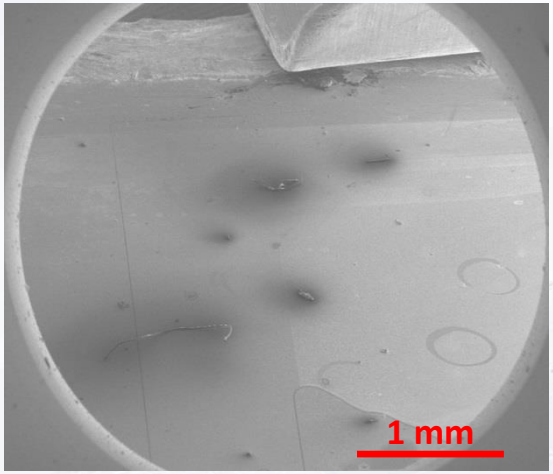


Fig. 1 SEM surface view of nanopaterned sample

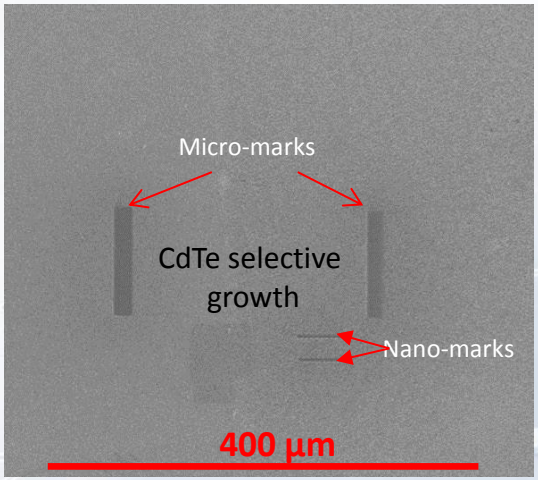


Fig. 2 micro and nano-FIB marks made on surface of sample

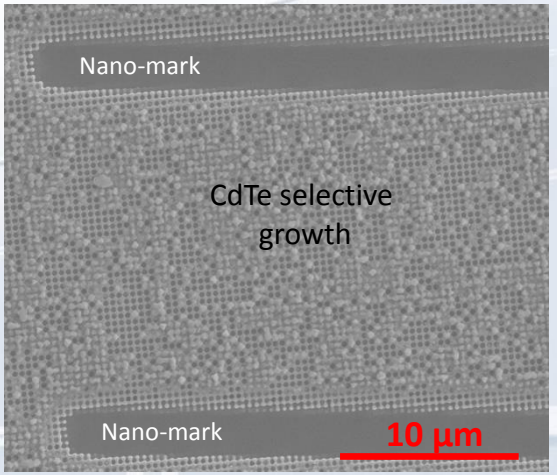


Fig. 3 Zoom-in to nano-marks and CdTe nano-islands

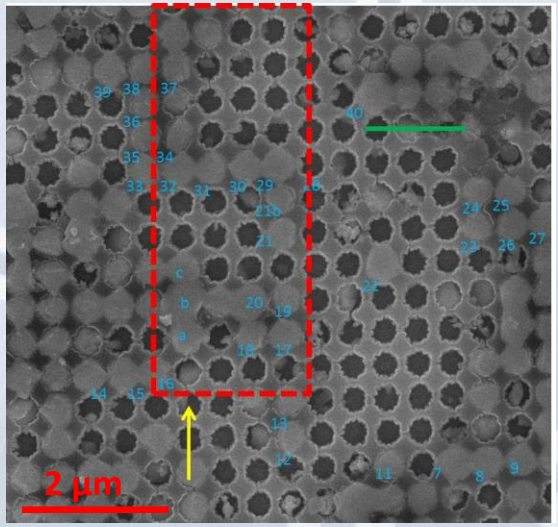


Fig. 4 Indexed nano-islands in area of interest

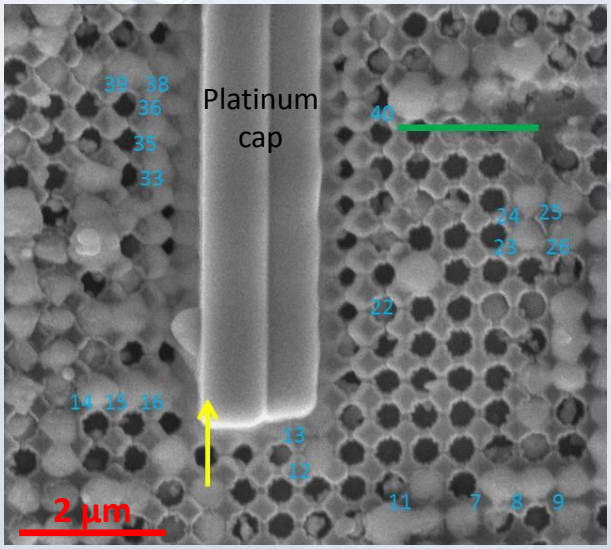


Fig. 5 Protective layer covering islands of interest

Indexed CdTe nano-islands were prepared for TEM using FIB

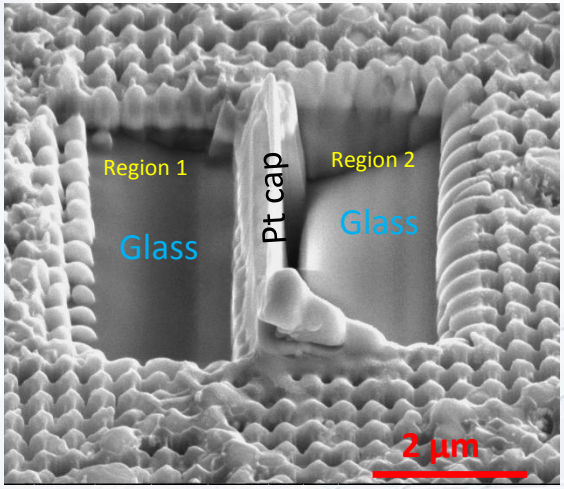


Fig. 1 Rough milling for sample prep
- Ga ion beam used for milling
- Regular cross-section option used to make Regions 1 and 2

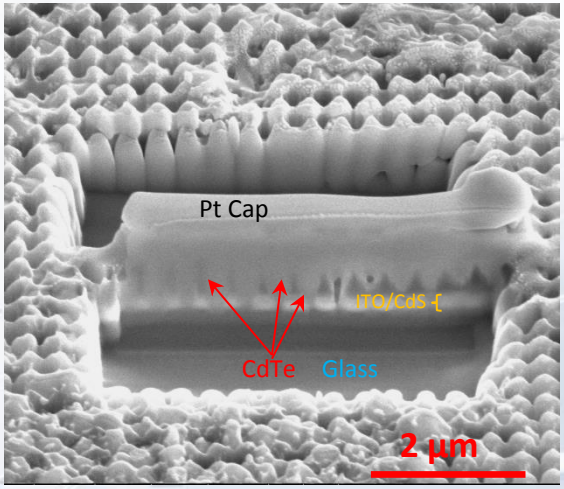


Fig. 2 1st fine milling for cleaning sample
- Ga ion beam used for milling
- Rectangle option used for milling

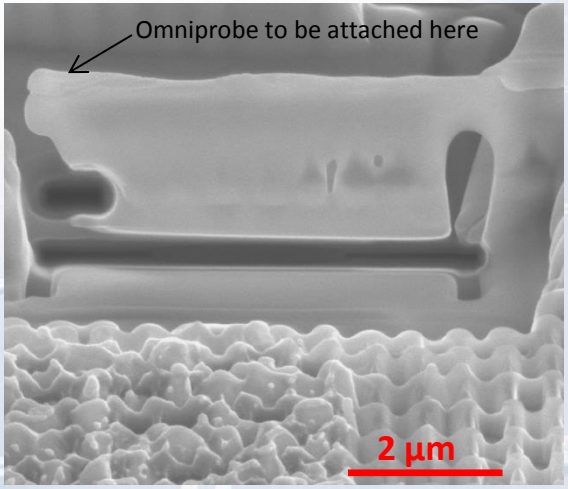


Fig. 3 "U" cut made from region 1
- Ga ion beam used for cutting
- Rectangle option used for cutting

Fig. 4 Copper lift-out grid
- 3 posts
- 30 um thick
- 3 mm diameter

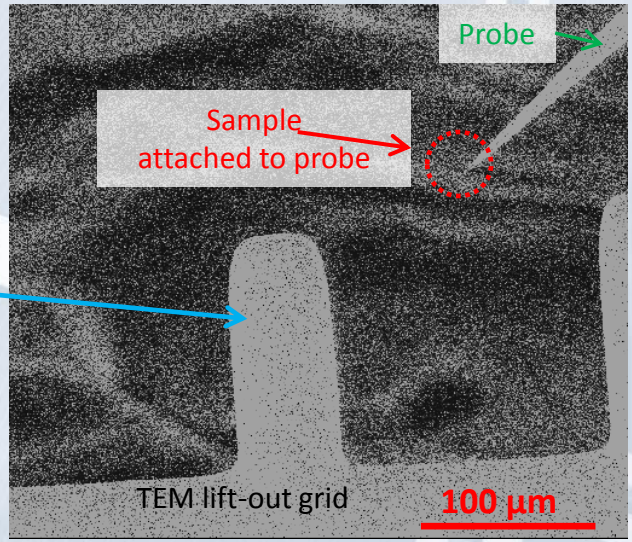


Fig. 5 Ga ion picture showing TEM grid and sample attached to onmiprobe

CdTe nano-islands thinning for electron transparency using FIB

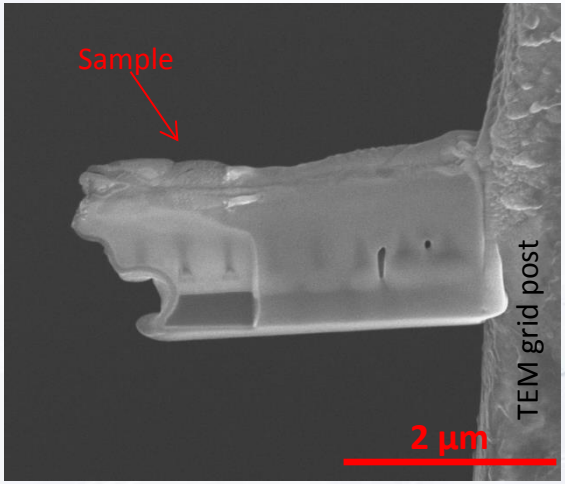


Fig. 1 SEM x-section view before thinning
- Sample mounted on TEM grid
- Sample was thinned on TEM grid (2nd fine milling)

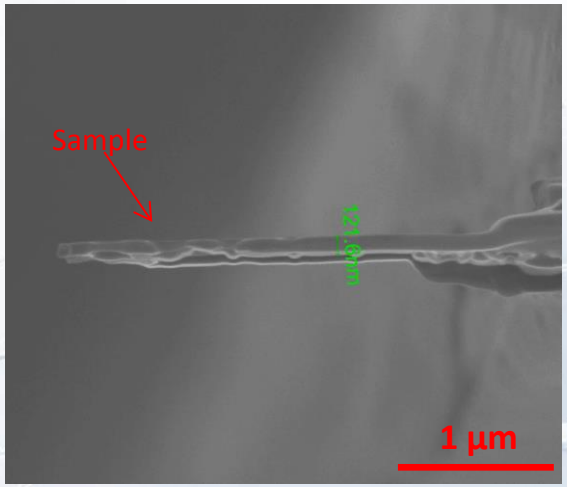


Fig. 2 SEM plane view
- Sample was thinned to ~ 121 nm

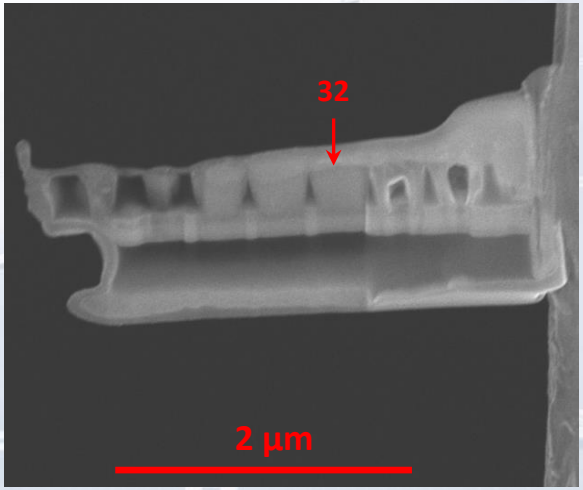


Fig. 3 SEM x-section view after thinning
- Islands 32 is marked on the image

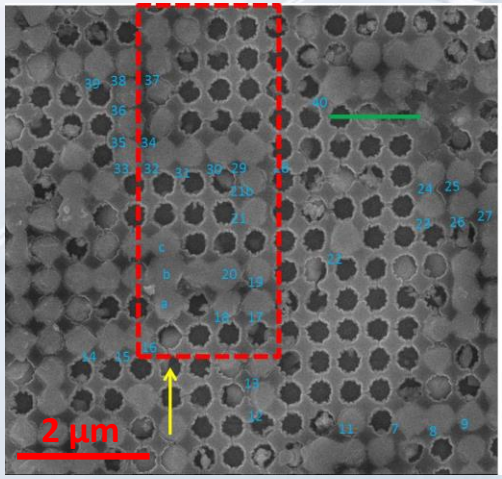


Fig. 4 SEM plane view before sample prep.

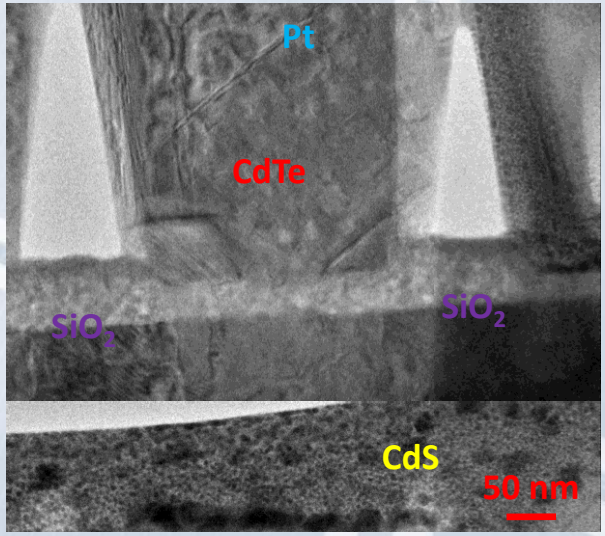


Fig. 5 Low mag. TEM image

Future work

- CdTe atomic structure
- Zinc blend, wurtzite

- Check for Epitaxial growth
- FFT analysis, analyze strain

Compare atomic structure to MD simulations

TEM

Dislocations, stacking faults per unit length

- Analyze atomic interface
- Defective vs. non-defective interface

Thank you

This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000