

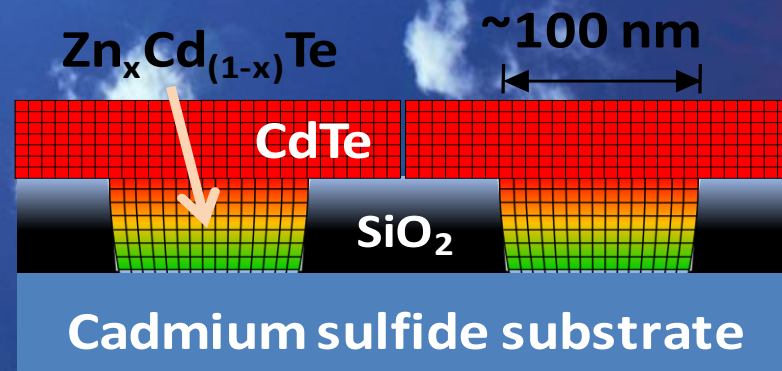


SAND2012-3620 C

SAND2012-3620C

Path to increase efficiency in thin film CdTe solar cells

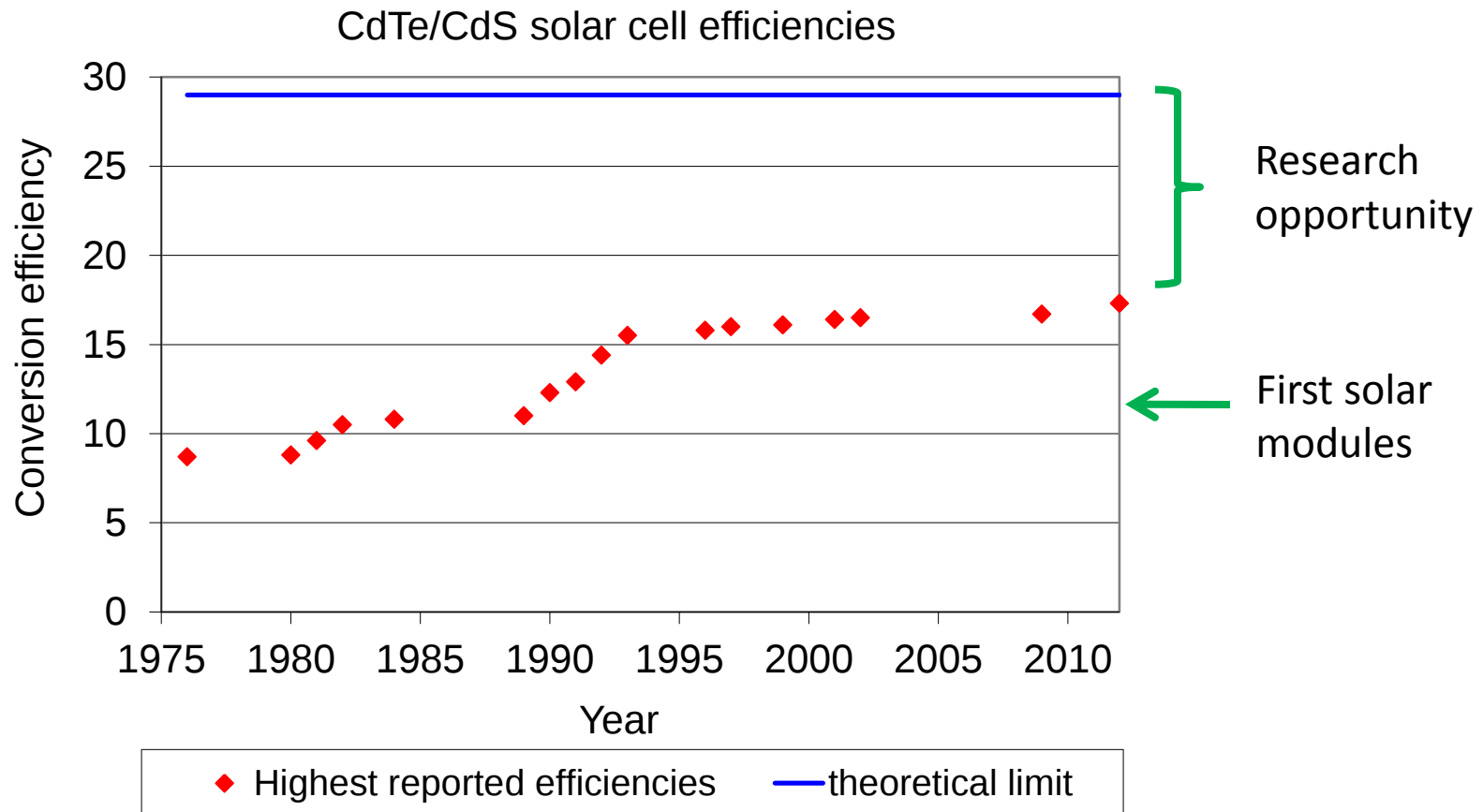
Jose L. Cruz-Campa, David Zubia, Xiaowang Zhou, Donald Ward, Carlos A. Sanchez, Jose J. Chavez, Brandon A. Aguirre, Farhana Anwar, Damian Marrufo, Erik D. Spoerke, Calvin Chan, Ping Lu, Joe Michael, Michael J. Rye, Heber Prieto, John C. McClure, and Gregory N. Nielson



New Mexico Chapter of AVS
May 22, 2012- Albuquerque, NM

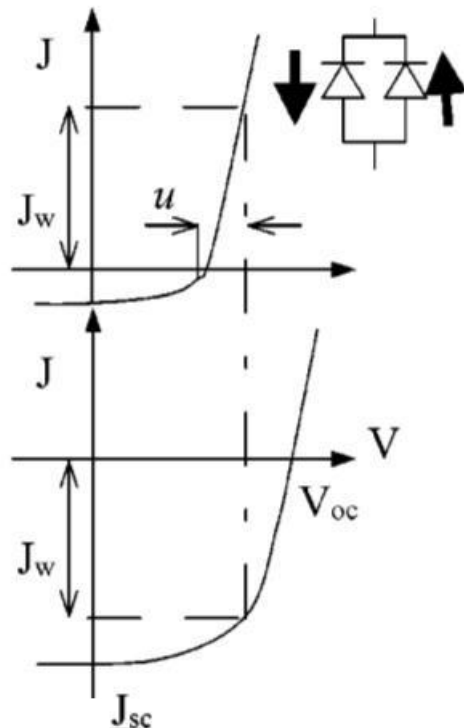
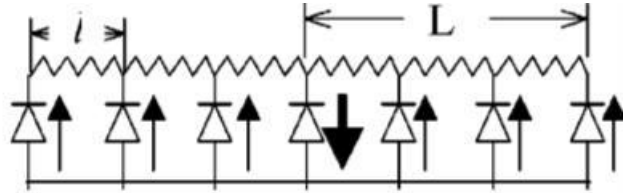
"Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000"

CdTe cells have kept almost the same efficiency for 18 years

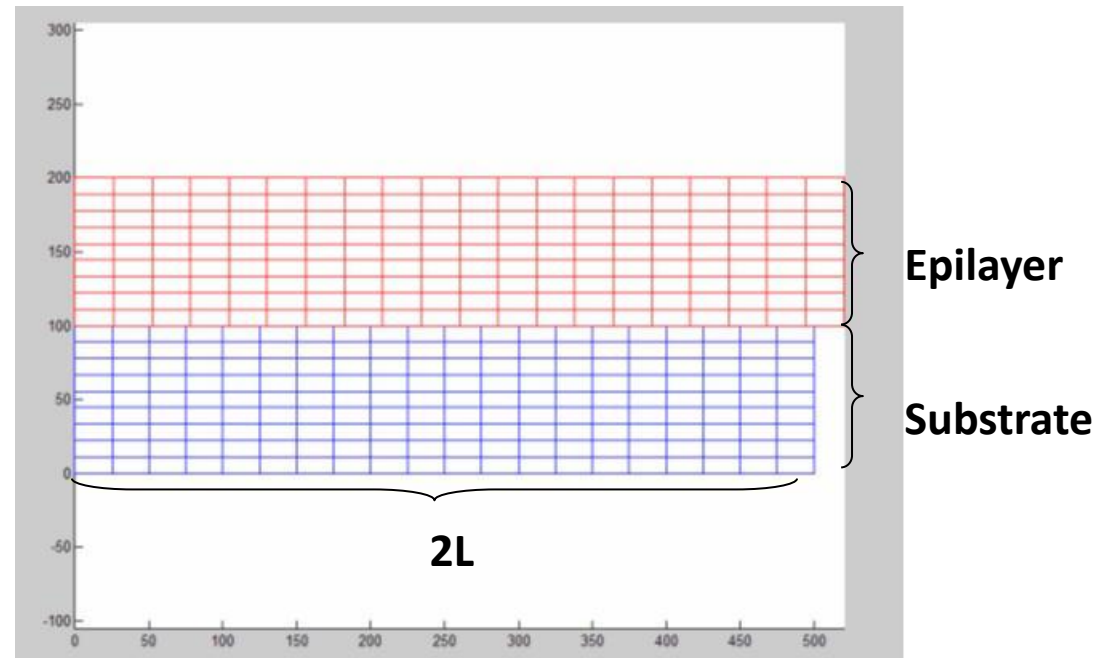


Non-uniformity and Lattice-mismatch lead to low efficiencies

*Non-uniformity → Loading losses

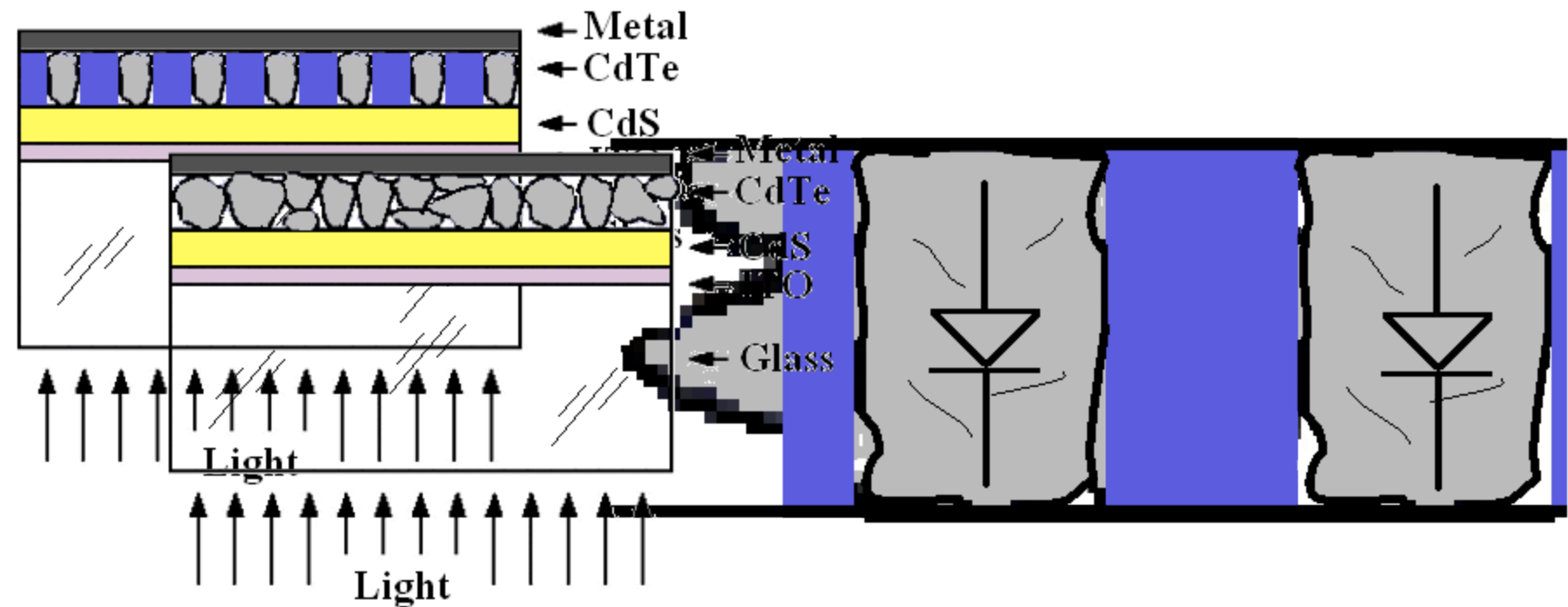


Lattice-Mismatch → Defects → Low V_{oc}



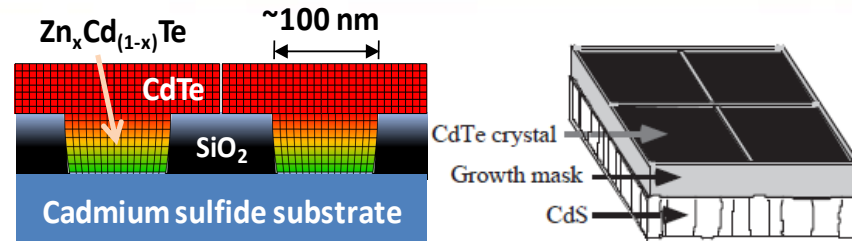
A patterned substrate could enhance uniformity

- ✗ Non-uniform growth on polycrystalline CdTe → efficiency losses.
- ✓ Improve uniformity by isolating grains.

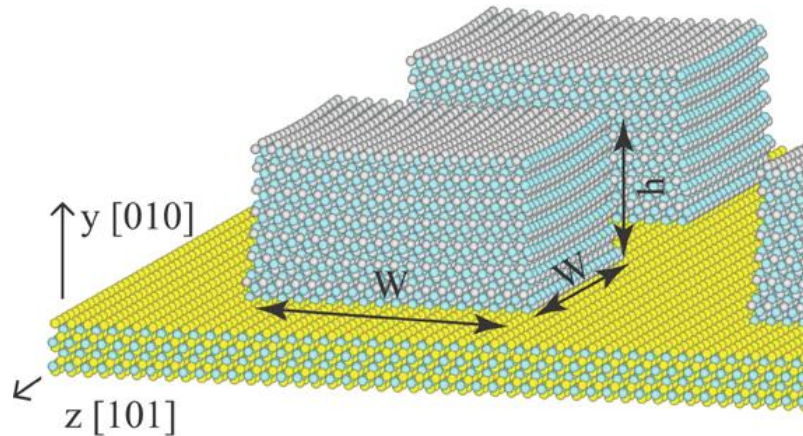


Outline

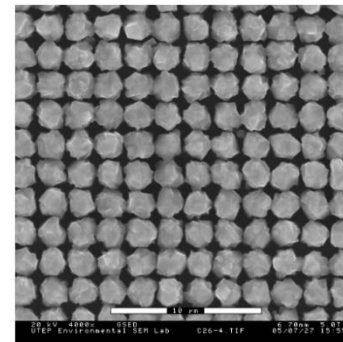
1. Proposed concept



2. Simulations

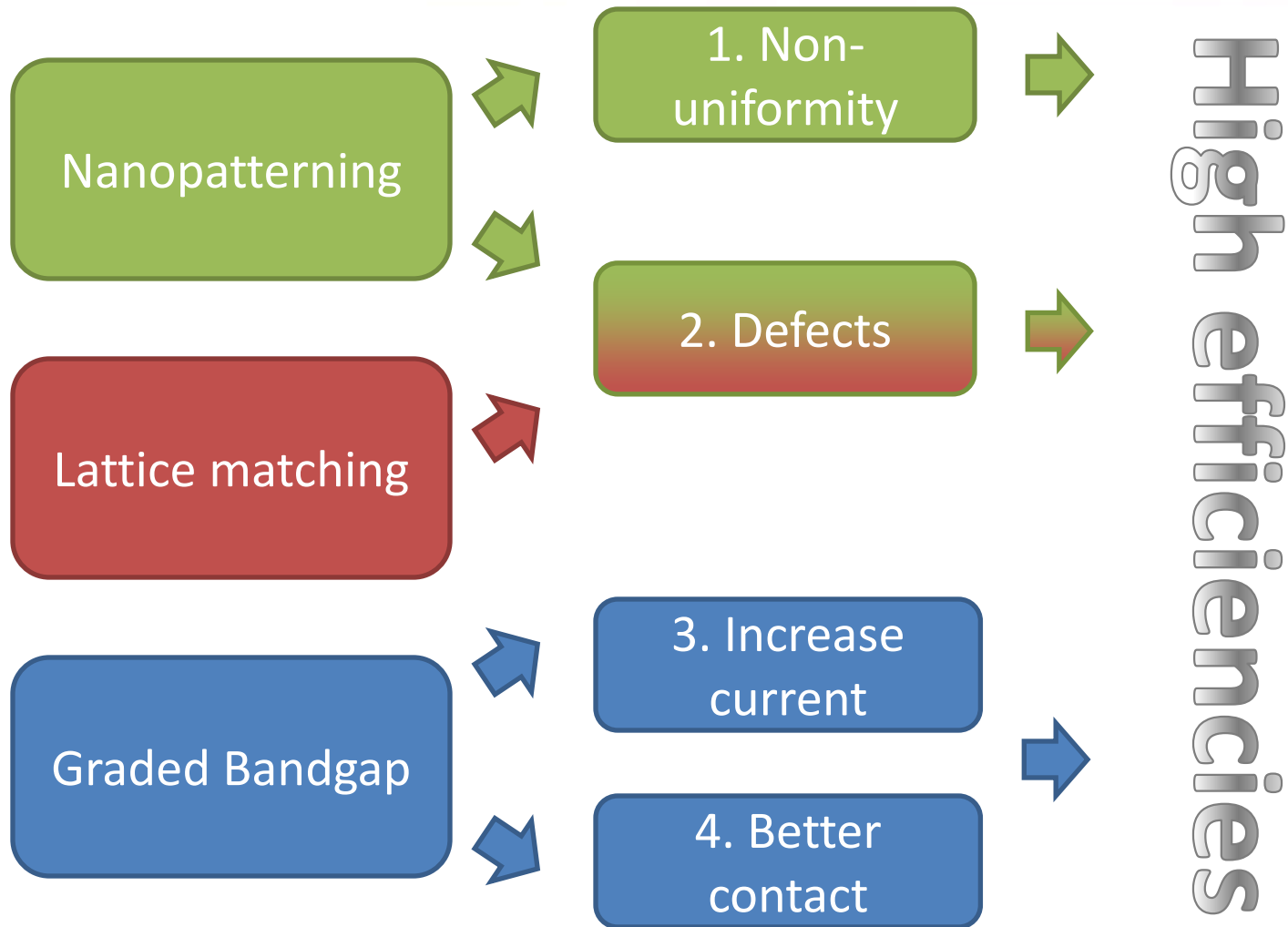


3. Initial Results

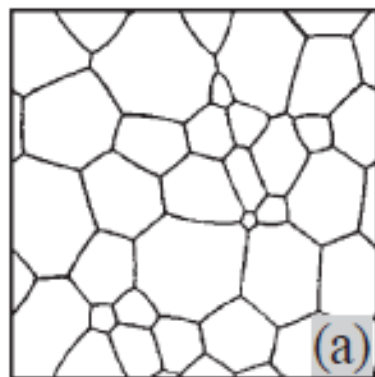


1. Proposed concept

We propose nanopatterning and lattice matching to enhance cell performance

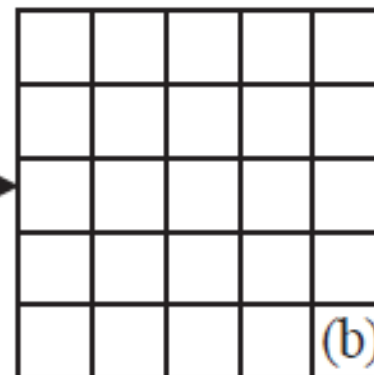


Nanopatterning can improve uniformity

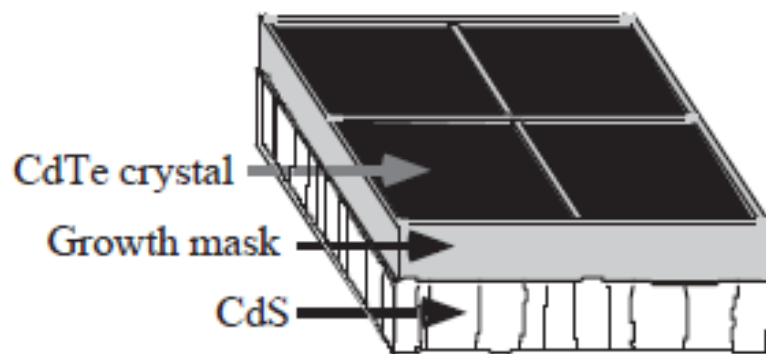


Non uniform

Patterning and
selective-area
deposition

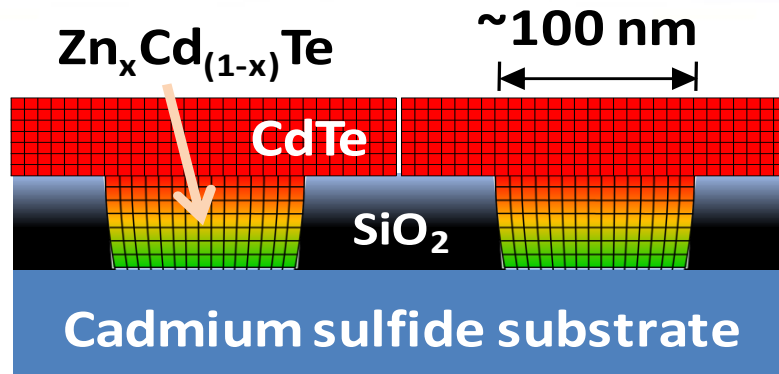


Uniform



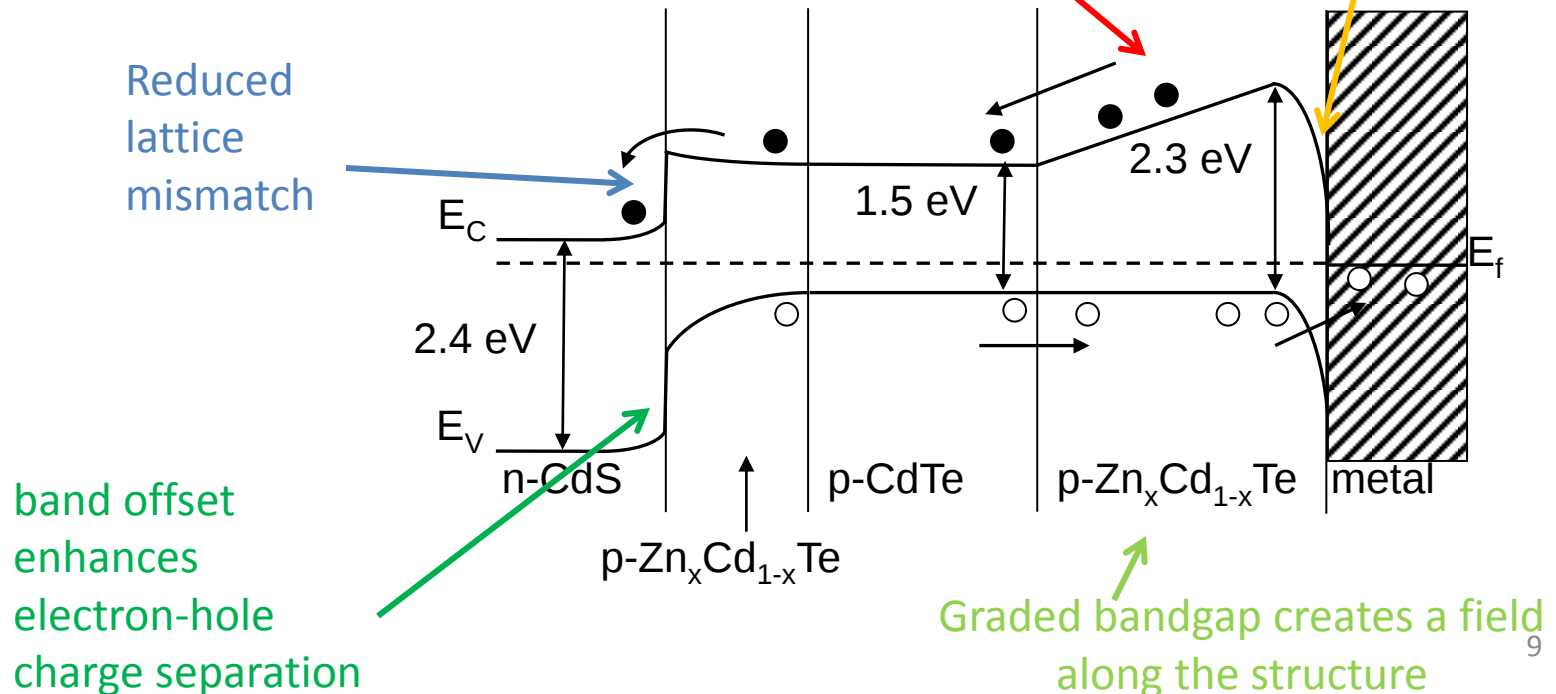
Controlled
nucleation

A graded bandgap can reduce lattice mismatch and enhance contacts



Spatial variation of the band-gap can increase both J_{sc}

high level doping (10^{18} cm⁻³) thus creating a tunneling junction with the metal electrode

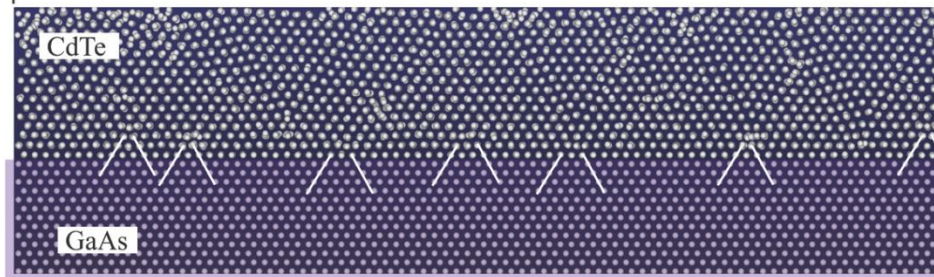


2. Simulations

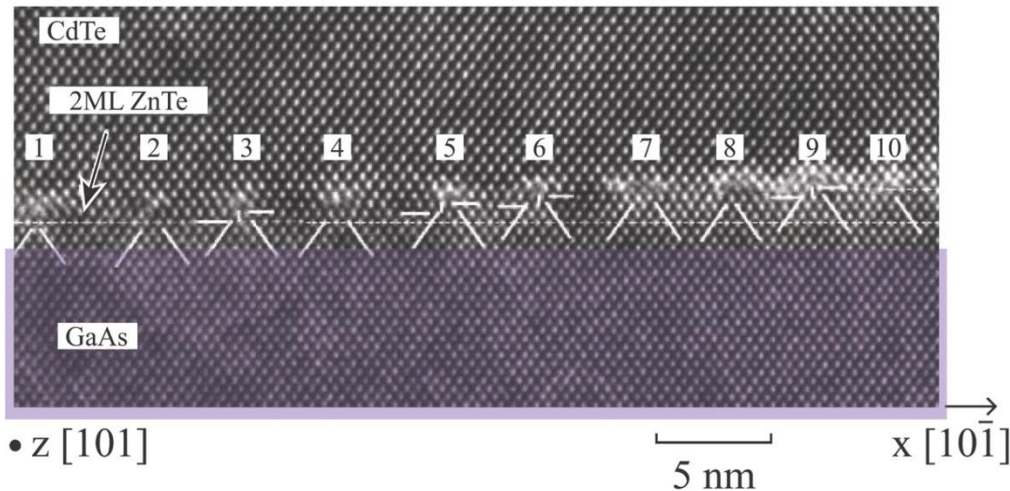
MD Simulations of misfit dislocations are validated with experimental data

(a) BOP simulation (only Cd and the approximate “Ga” atoms are shown)

↑ y [010]

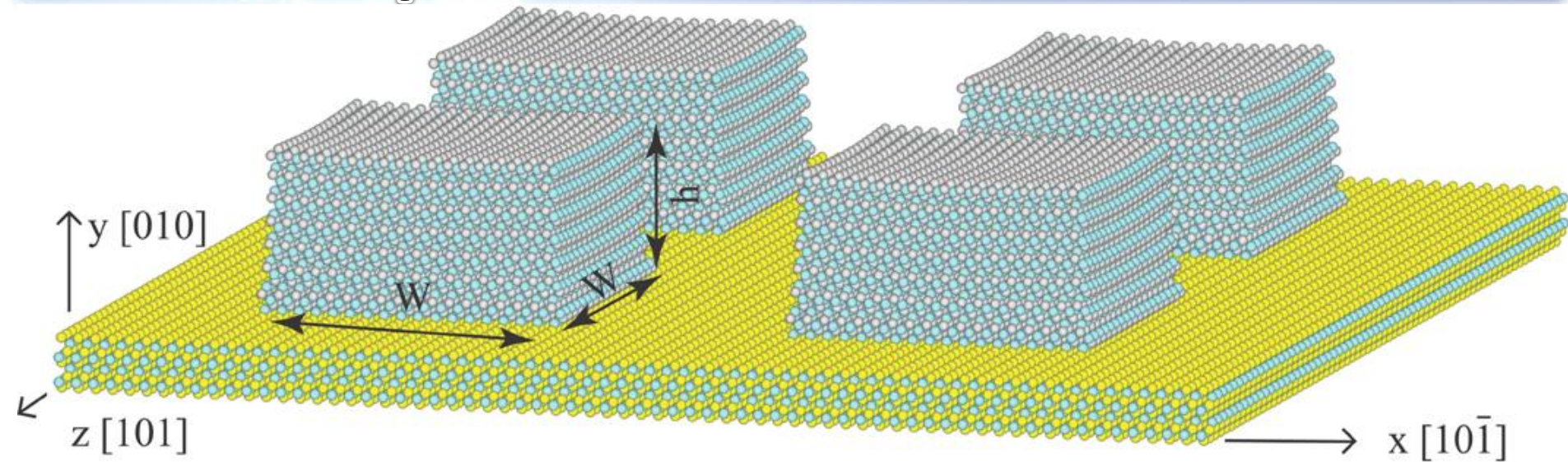


(b) HRTEM experiment from S. Kret et al, Phil. Mag., 83, 231 (2003).



- BOP allows system energy as a function of dislocation spacing to be derived
- Minimization of system energy with respect to dislocation spacing leads to an equilibrium spacing around 3.8 nm, matching remarkably well with experiments

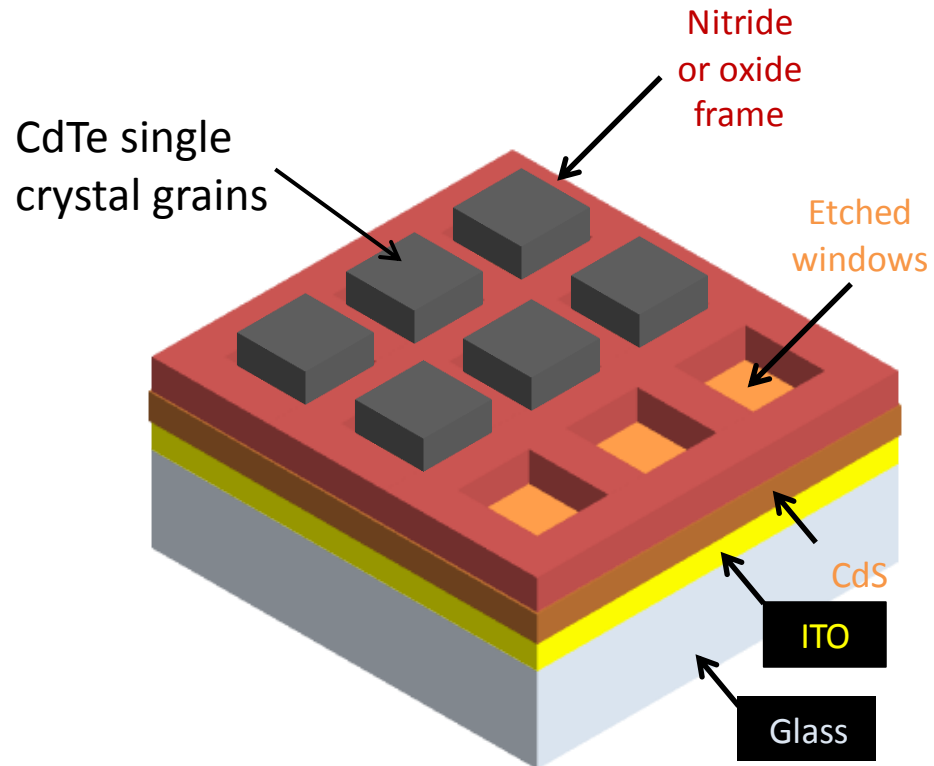
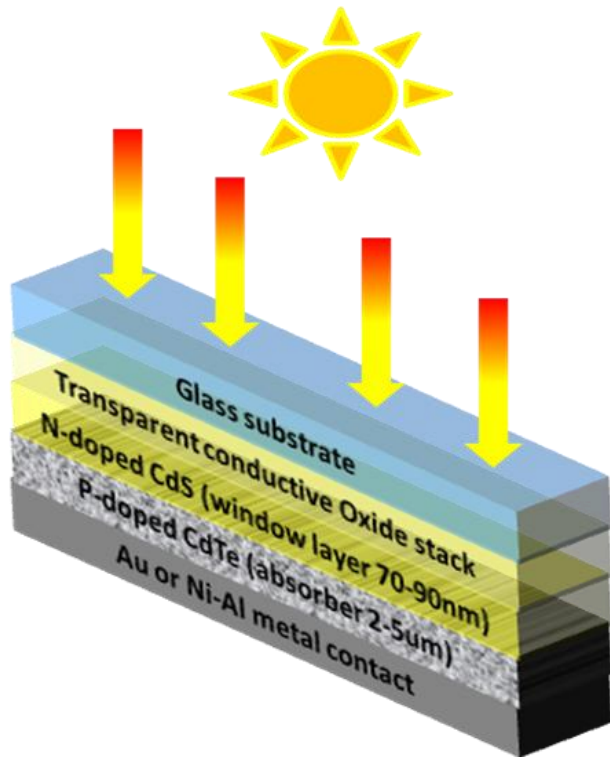
BOP has calculated $\text{Cd}_x\text{Zn}_{1-x}\text{Te}/\text{CdS}$ critical diameter



- Critical Island Width, W (fixed substrate)
 - CdTe-CdS: 4 nm
 - ZnTe-CdS: 40 nm
 - ZnTe-CdS: 100 nm (only 5 dislocations)

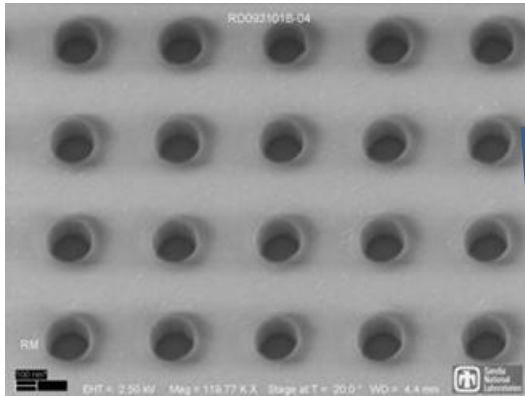
3. Initial Results

We are focusing a on the nanopatterning and the growth of grains



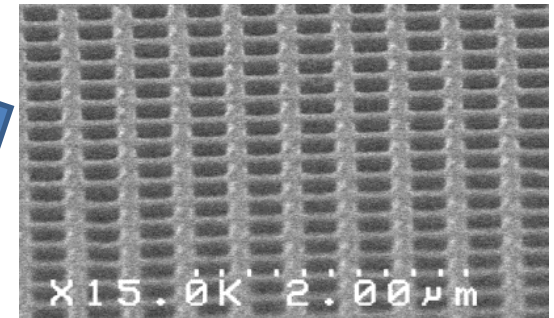
We have tried 4 different lithography techniques to achieve a nanopattern

Standard



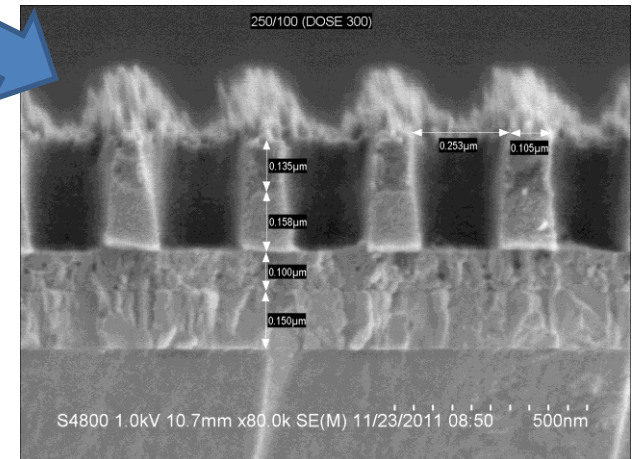
Feature size **200-500nm**

Nano Imprint



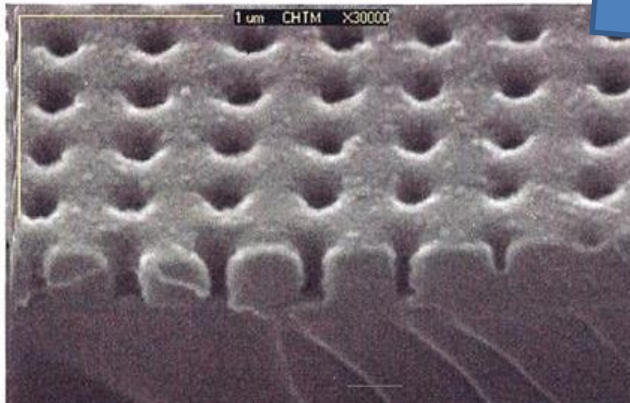
Feature size **125-275nm**

eBeam

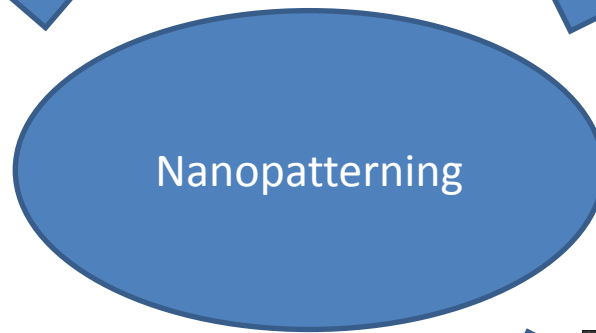


Feature size **50-150nm**

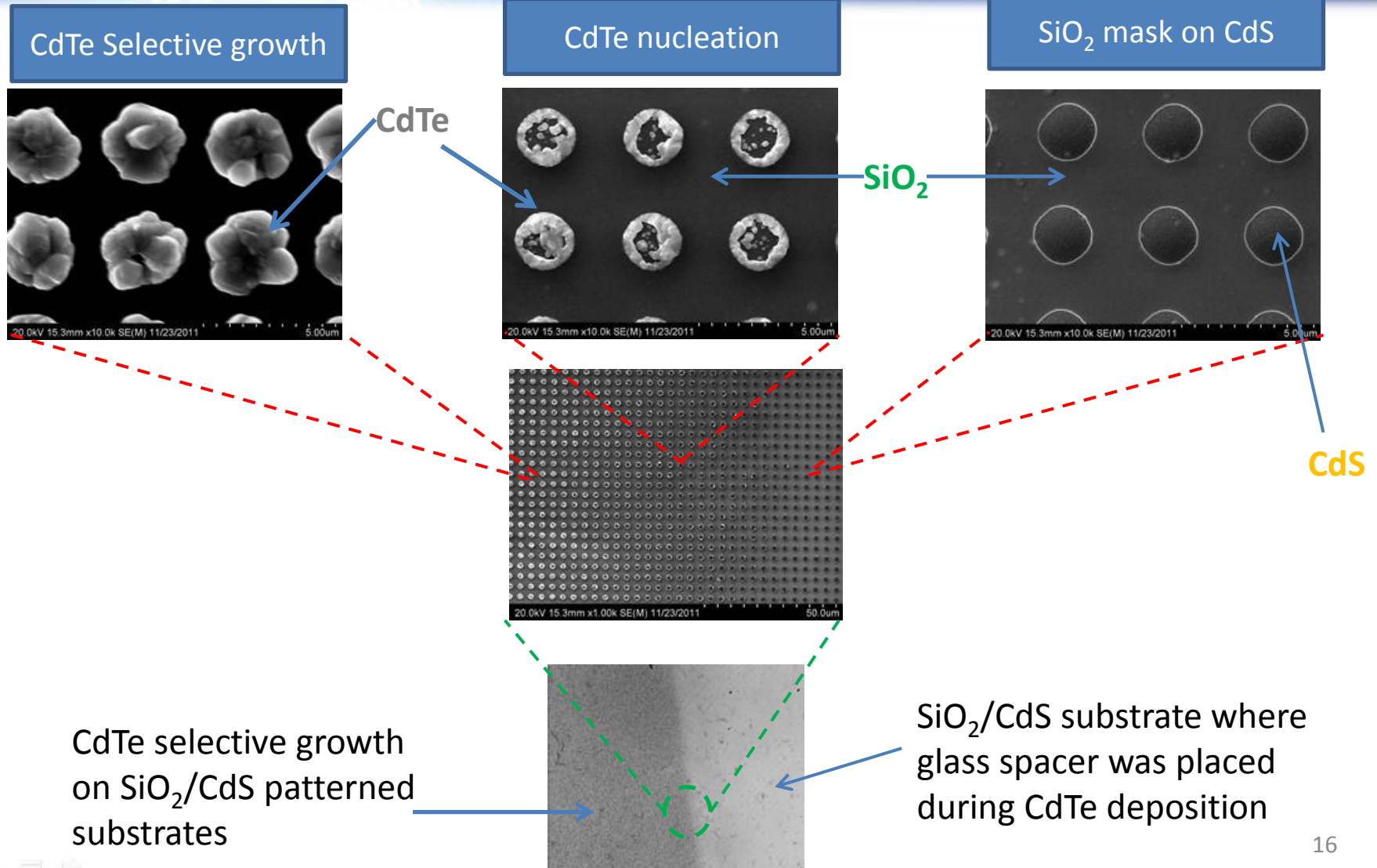
Interferometry



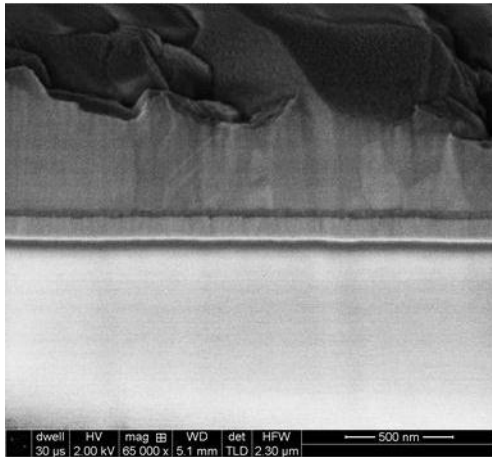
Feature size **150-250nm**



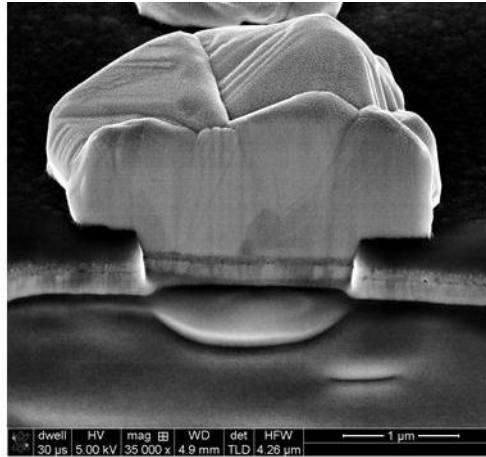
Grain size appears to be 100nm in CdTe/SiO₂/CdS (2μm window) depositions



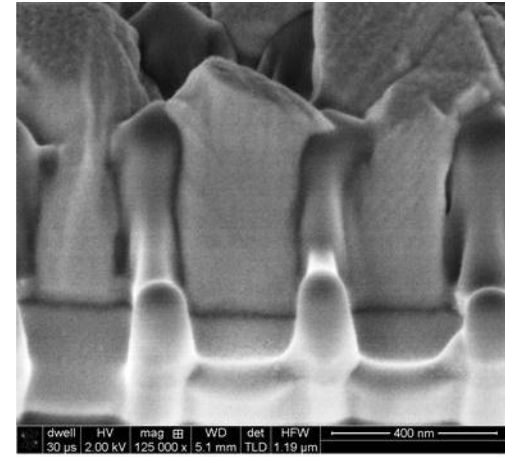
Fewer crystal domains are observed when using the nanopattern and ZnTe



Planar

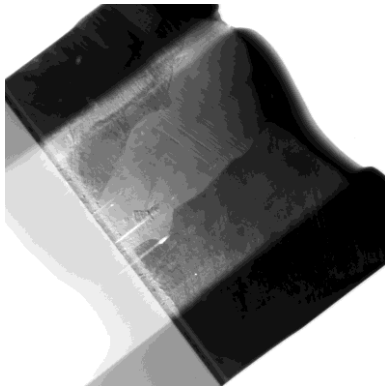


Micropattern

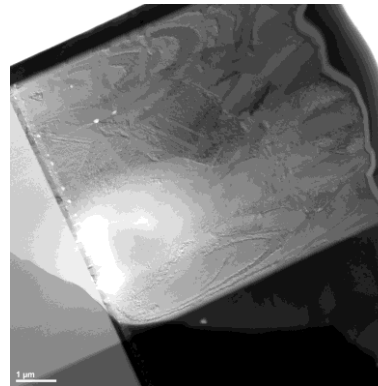


Nanopattern

ZnTe



CdTe



Acknowledgements

•PI's

- David Zubia, Ph.D.
- Jose Cruz-Campa , Ph.D.
- Gregory Nielson, Ph.D.

•Collaborators

- Xiaowang Zhou , Ph.D.
- Jennifer Granata , Ph.D.
- Erik Spoerke, Ph.D.
- Bruce Burckel, Ph.D.
- Calvin Chan, Ph.D.
- John McClure, Ph.D.
- Carlos Sanchez

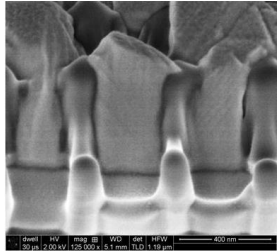
•Students:

- Christian Tapia
- Jose Chavez
- Brandon Aguirre
- Heber Prieto
- Felipe de Alva
- Farhana Anwar
- Damian Marrufo

•Administrative:

- Reagan Stinnett, Ph.D.
- Michael Kress
- Alyssa Christy

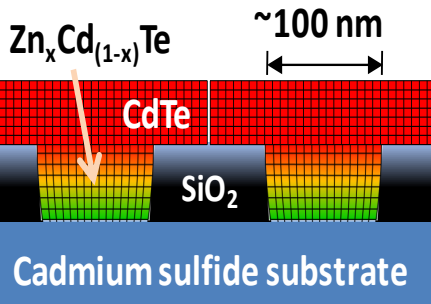
In conclusion we have presented an approach to increase efficiency of CdTe cells



Nanopatterning

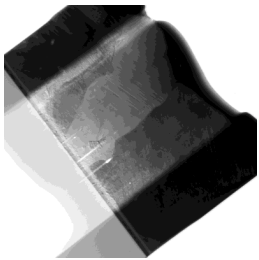
1. Non-uniformity

2. Defects



Lattice matching

2. Defects



Graded Bandgap

3. Increase current

4. Better contact

Questions?

High efficiencies