Nanopatterning And Bandgap Grading To Reduce Defects In CdTe Solar Cells

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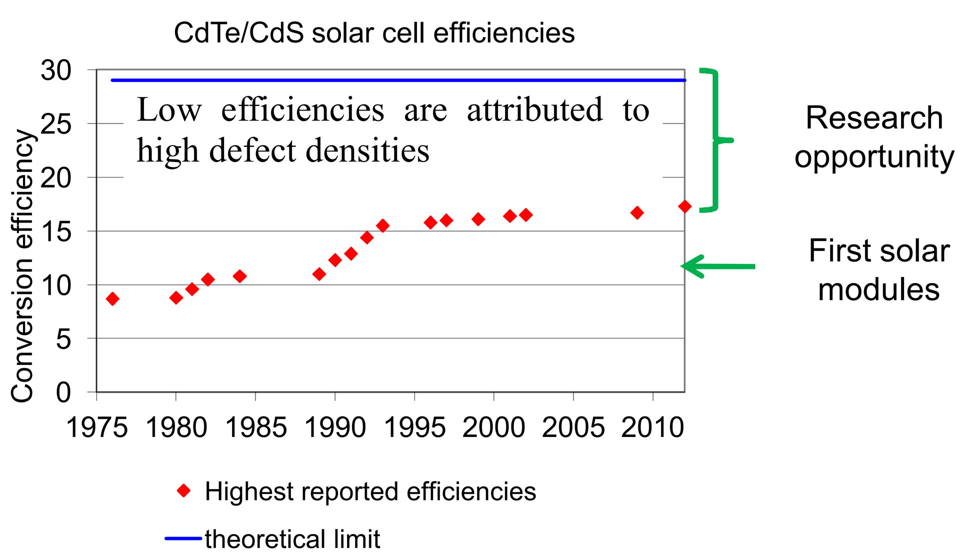
Motivation

CdTe thin film photovoltaic technology has the lowest module cost in the market (~75 ¢), making it the most desirable thin film technology.

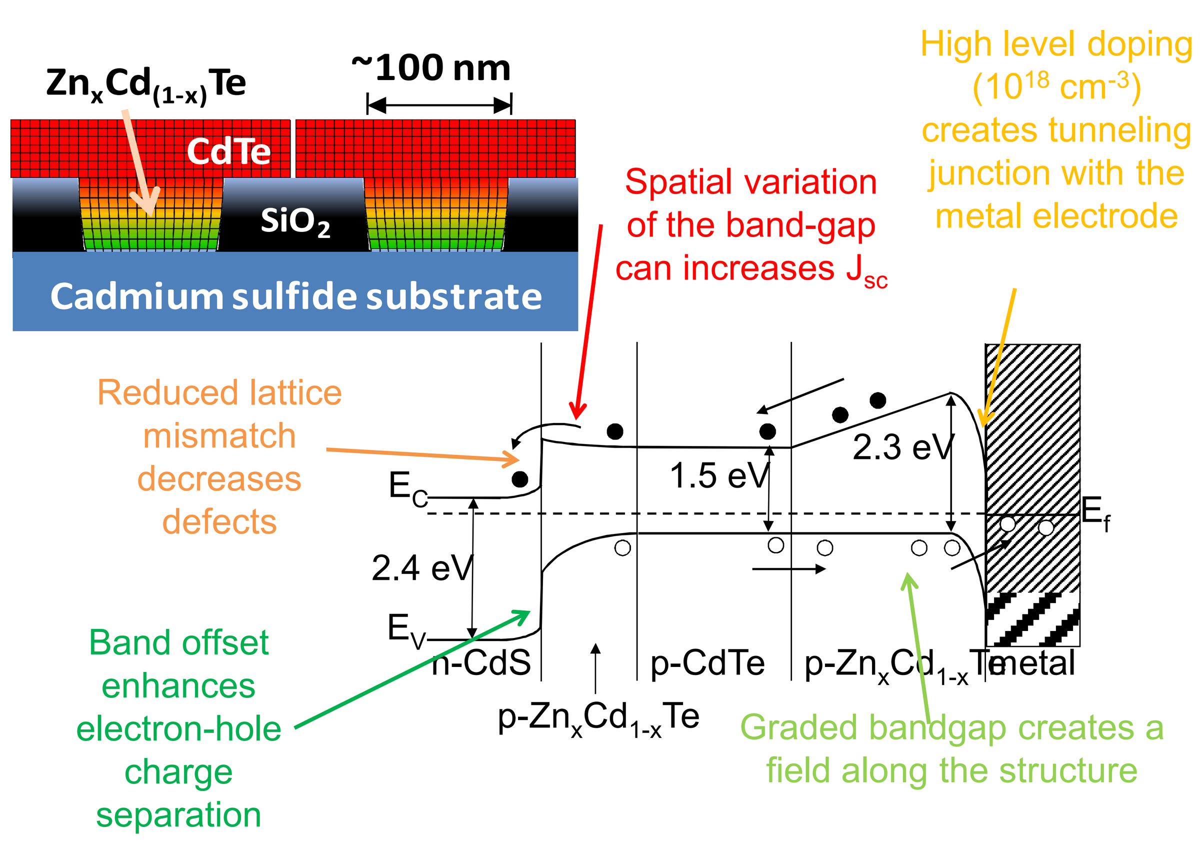


In the past defect passivation has been used to mitigate defects rather than eliminating them directly.

In this work, nanopatterning and bandgap grading are proposed to eliminate defects, reduce recombination, enhance carrier collection and increase efficiency of CdTe/CdS solar cells.

Objective

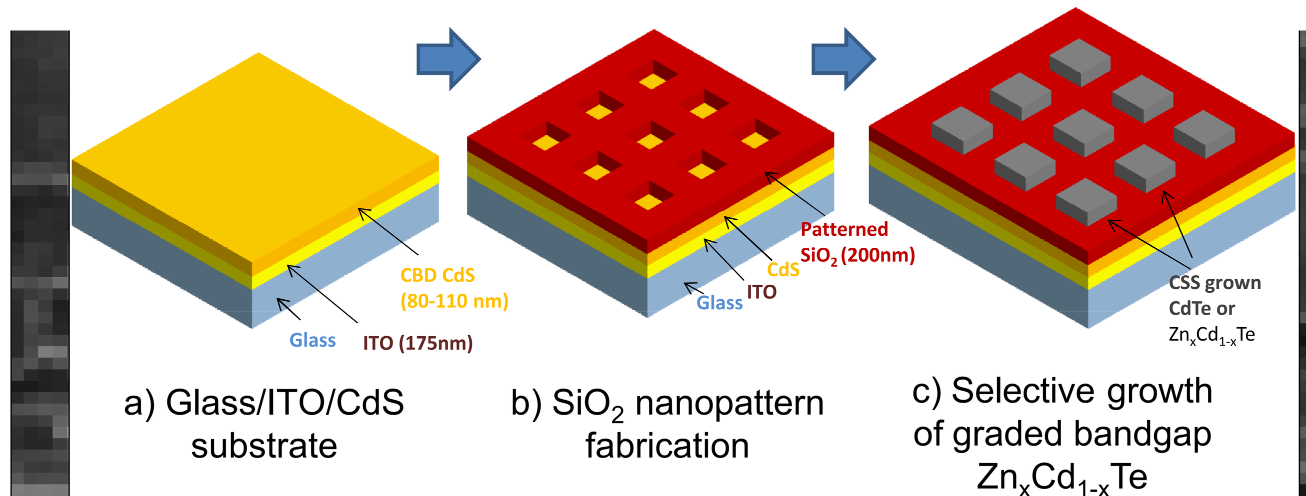
To reduce stress and misfit defects in CdTe/CdS solar cells to increase lifetime and conversion efficiency using nanopatterning and bandgap grading.



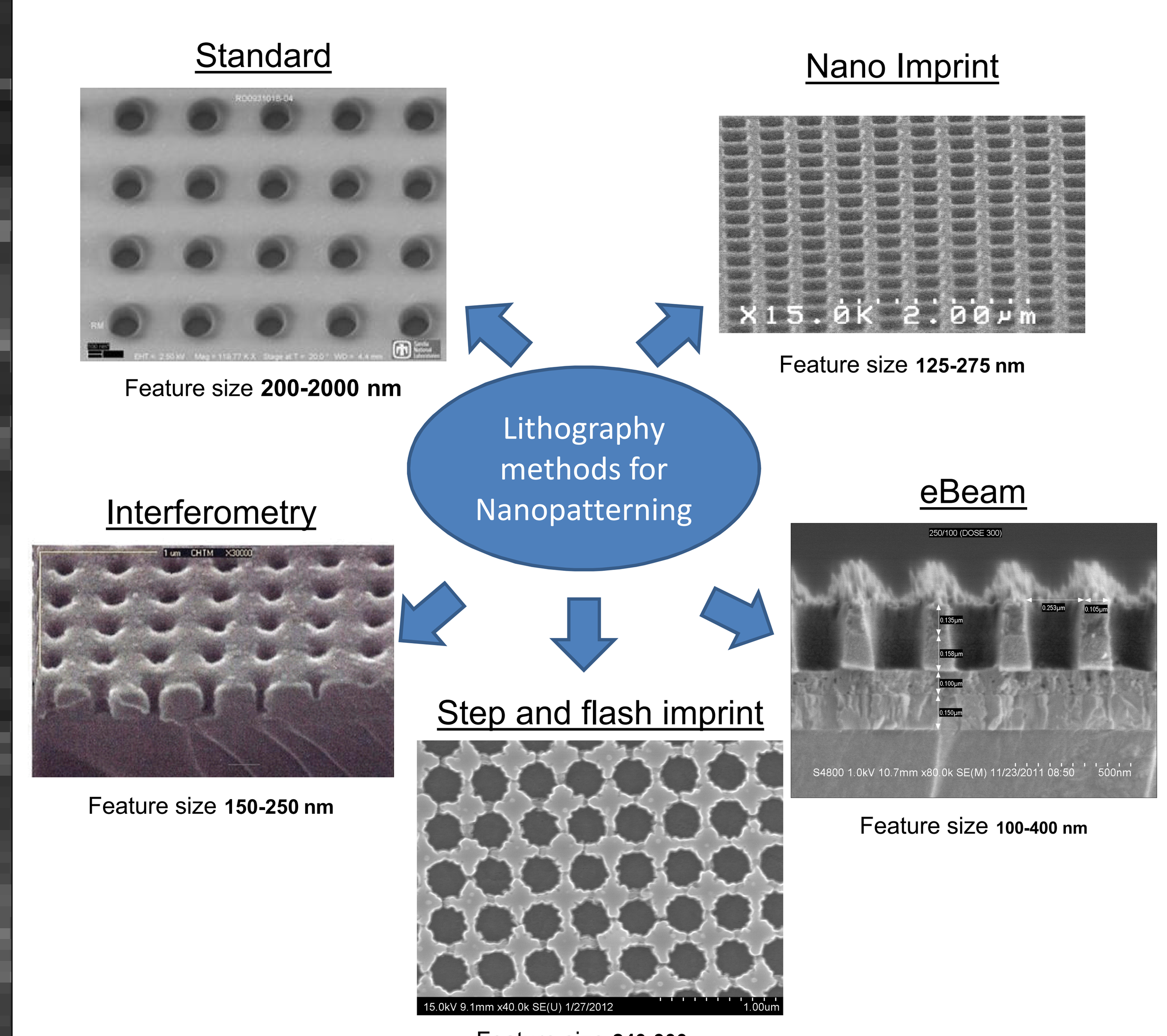
Cross-section schematic of a $Zn_xCd_{1-x}Te$ graded bandgap nano island and its corresponding energy band diagram

Methods

The overall method is shown in the figure below. First we grow CdS in glass/ITO substrates using chemical bath deposition, then we fabricate a SiO_2 nano-pattern and finally a CdTe or $Zn_xCd_{1-x}Te$ band gap graded semiconductor is selectively grown inside the nano-patterned template using Close Space Sublimation.



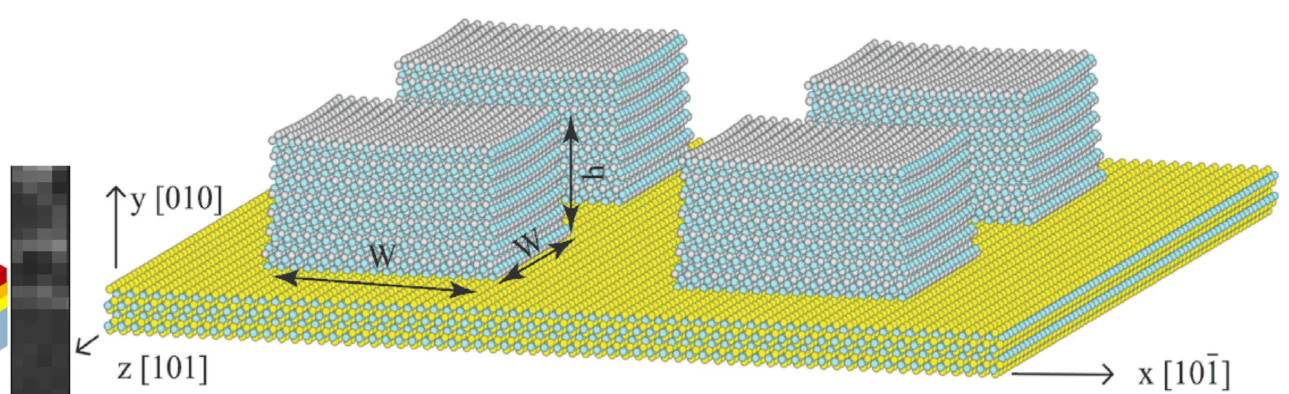
Five methods were successfully tried to create the nanopattern. Standard lithography (2 µm) and step and flash imprint lithography (280 nm) were used for CdTe growths. The pattern was transferred on the PECVD grown SiO_2 with a CHF_3 etch.



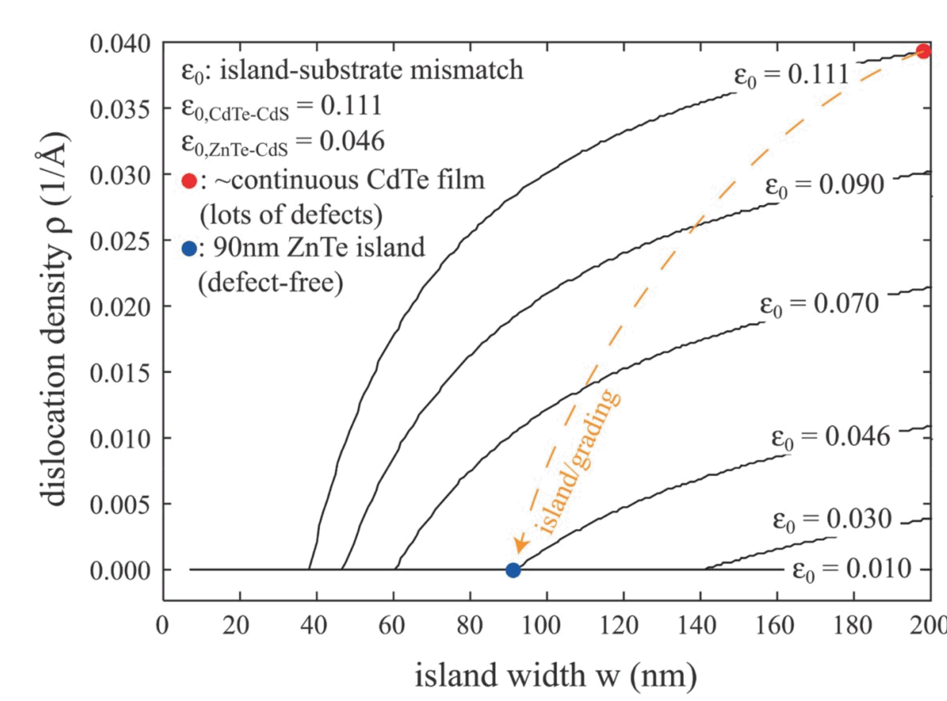
SEM pictures of nanopatterned substrates obtained by different techniques to be used as templates for selective growth

Simulations

Molecular dynamics simulations using novel Bond Order Potentials (BOP) were performed to predict the dislocation density as a function of the nano-CdTe islands size for different CdTe-island to CdS substrate mismatch.

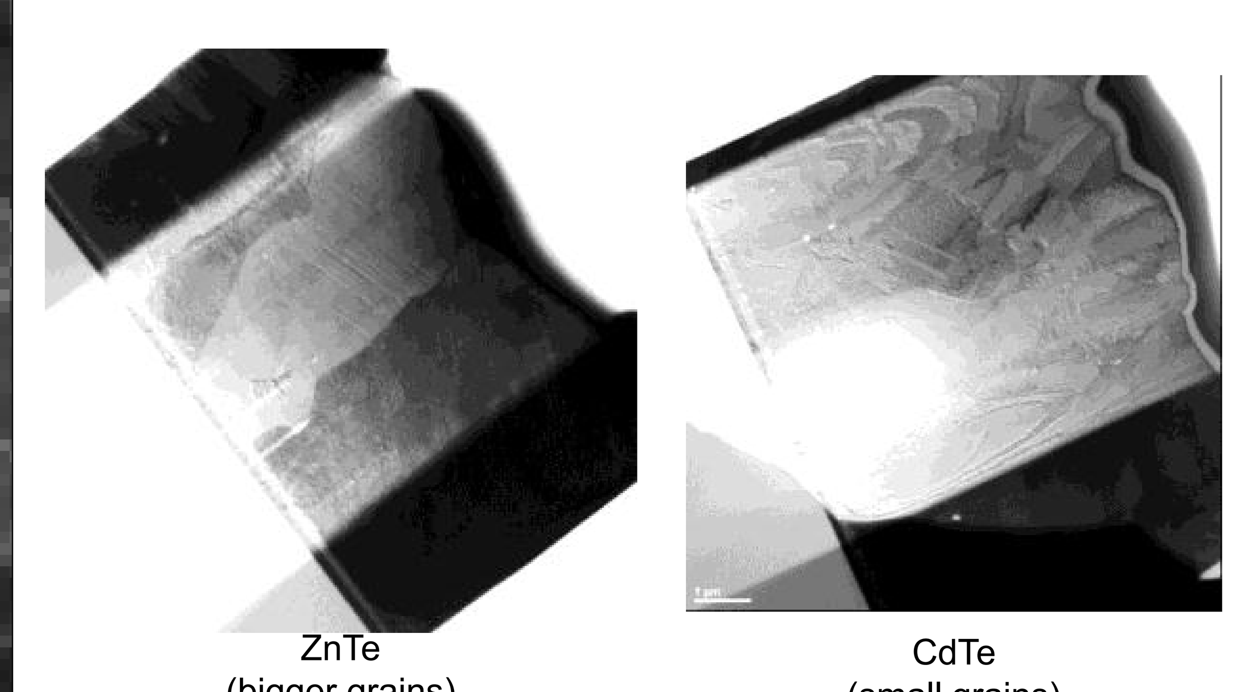


Simulated growth of nanoislands of CdTe on CdS. The stress due to lattice mismatch relaxes as the structure grows.



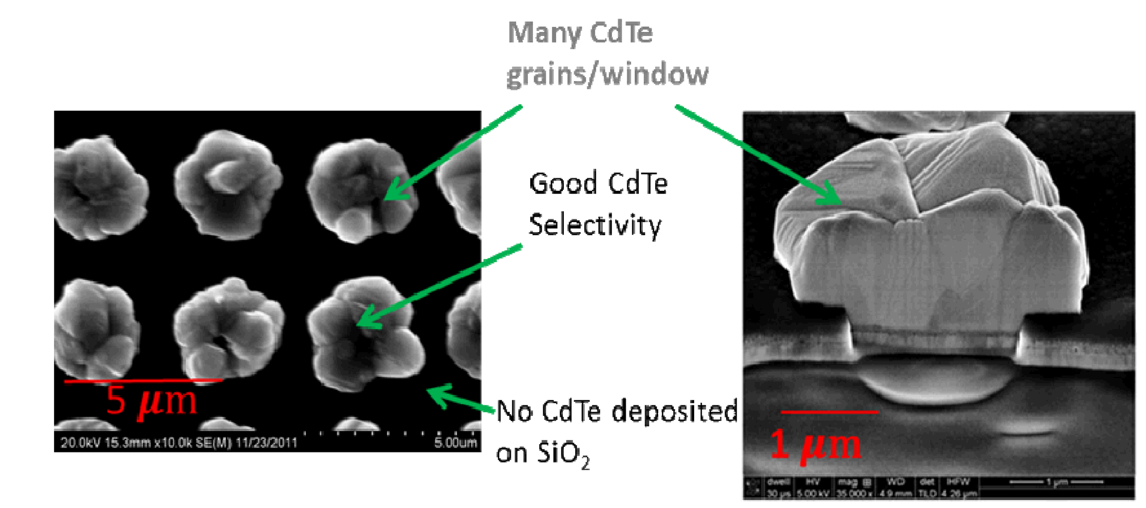
Dislocation density as a function of window size for different CdTe-CdS and ZnTe-CdS island-substrate mismatch. Dislocation density is predicted to be reduced substantially by using the island growth with graded material.

Results I

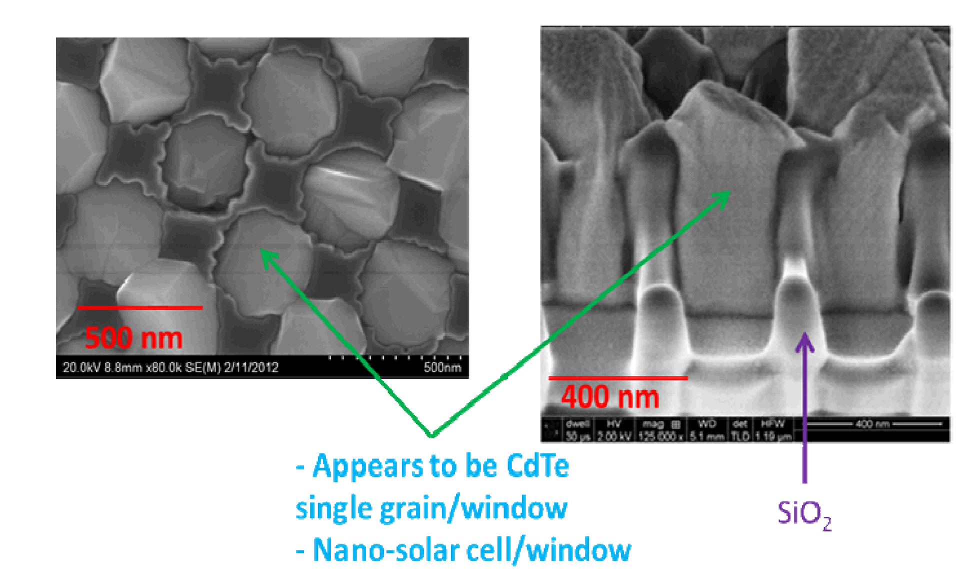


TEM cross-section image of CdTe/ZnTe deposited on CdS and CdTe deposited on Cds. The TEM shows that introducing ZnTe yields larger grains

Results II



Top and cross-section SEM images of CdTe selective growth on 2 µm-window size glass/ITO/CdS patterned substrates



Top and cross-section SEM images of CdTe selective growth on 285 nm window size glass/ITO/CdS patterned substrates. In comparison with the micro pattern, the nanopattern seems to generate single grains per window.

Conclusions

Selective growth of graded bandgap nano-ZnCdTe islands was proposed to increase the efficiency of CdTe solar cells. Molecular dynamic simulations showed dislocation-free CdTe and ZnTe films for window sizes of 90 nm and below. Preliminary experimental results showed fewer defects on ZnTe/CdS interfaces compared to CdTe/CdS interfaces. Also, single, uniform and ordered CdTe grains were grown as feature sizes were reduced towards to defect-free dimension predicted by simulations

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