Effect of microstructure on local charge distribution in hydrogenated nanocrystalline silicon (nc-Si:H) thin film studied by Electrostatic Force Microscopy (EFM).

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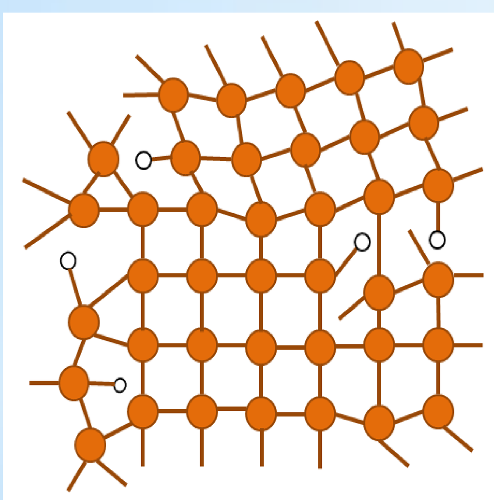
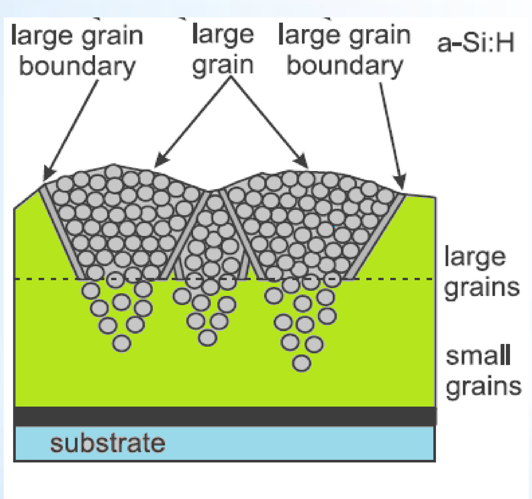
Abstract

Hydrogenated nanocrystalline silicon (nc-Si:H) is a promising absorber material for photovoltaic solar cells. Nanoscale electrical conductivity and overall electronic quality of this material is significantly affected by film microstructure, specifically the relative density and dimension of grains and grain-boundaries (GB). Local charge distribution at grains and grain/GB interfaces of nc-Si:H was studied by Electrostatic Force Microscopy (EFM) in constant force mode under dark condition. Bias voltage from -3 to +3 was applied in the tip and the sample was grounded. EFM analysis was combined with film topography to draw a correlation between surface morphology and nanoscale charge distribution in this material.

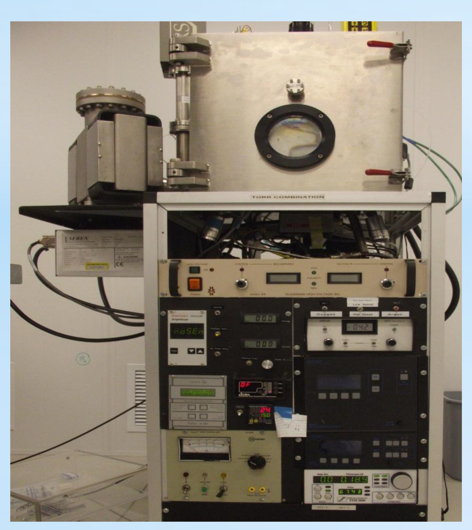
Introduction

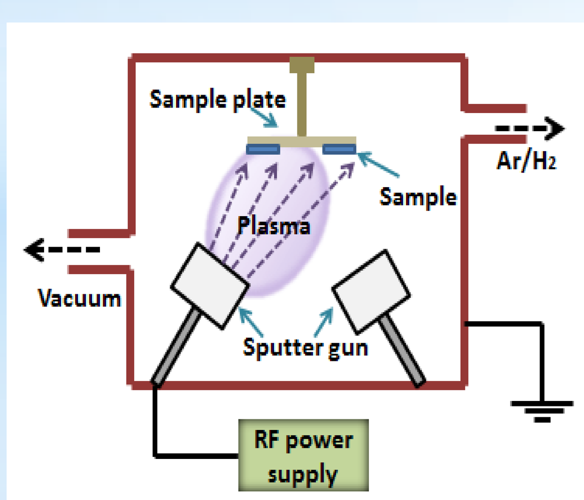




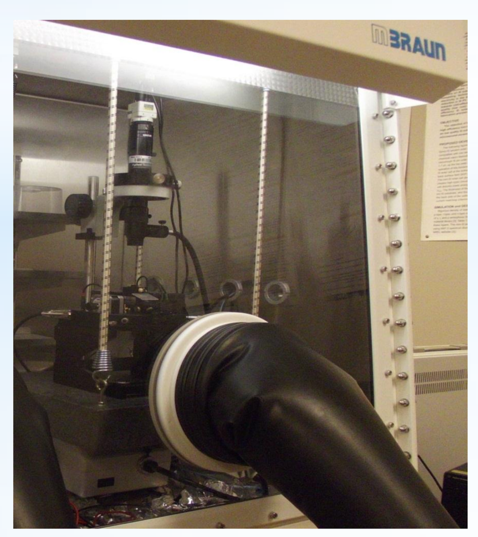
- nc-Si:H is a disordered semiconductor with Si nanocrystals embedded in amorphous matrix
- Nano-crystallite grains are separated from a-Si by highly defective grain boundaries (GBs)
- GBs capture excess free carriers resulting in depletion regions in grains and a potential barrier (V_{bi}) across GBs

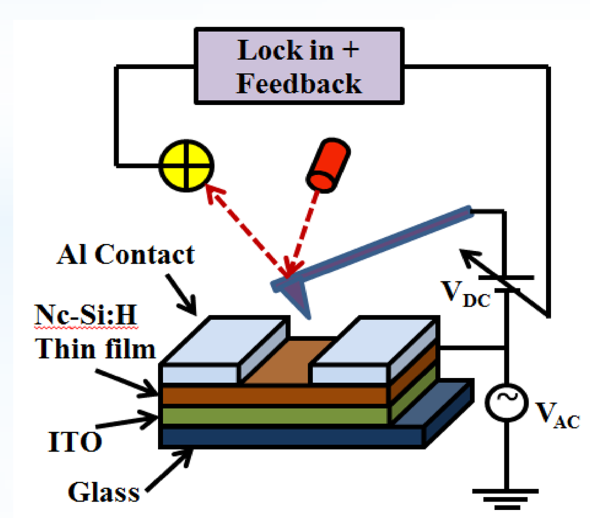
Experimental Procedures





A batch of 95 nm thick nc-Si:H thin films were deposited on ITO coated glass using reactive RF sputtering in hydrogen/argon atmosphere in a customized combination system by Torr International Inc.at a base pressure of 10^{-7} torr.





EFM was done by Agilent 5500 SPM in a nitrogen filled glove-box in dark condition. Pt/Ir coated silicon tip of 25 nm diameter and 40 N/m force constant was used. Tip bias was varied from -3 to +3 volts.

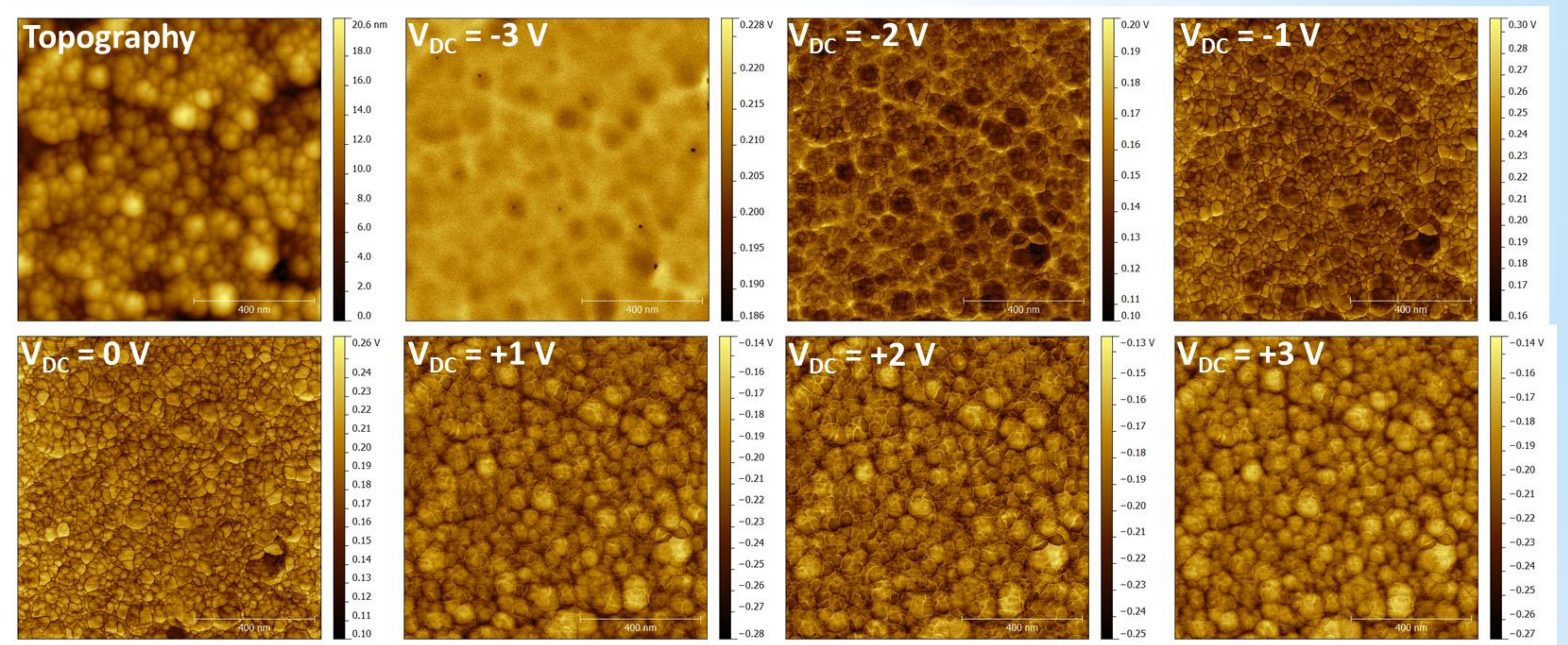
Future Work

- Quantitative analysis to correlate physical parameters (carrier diffusion length, local defect density) with local microstructural change
- Study EFM and KFM imaging with irradiation and elevated temperature
- Perform similar study on n-doped and p-doped sample

Acknowledgement

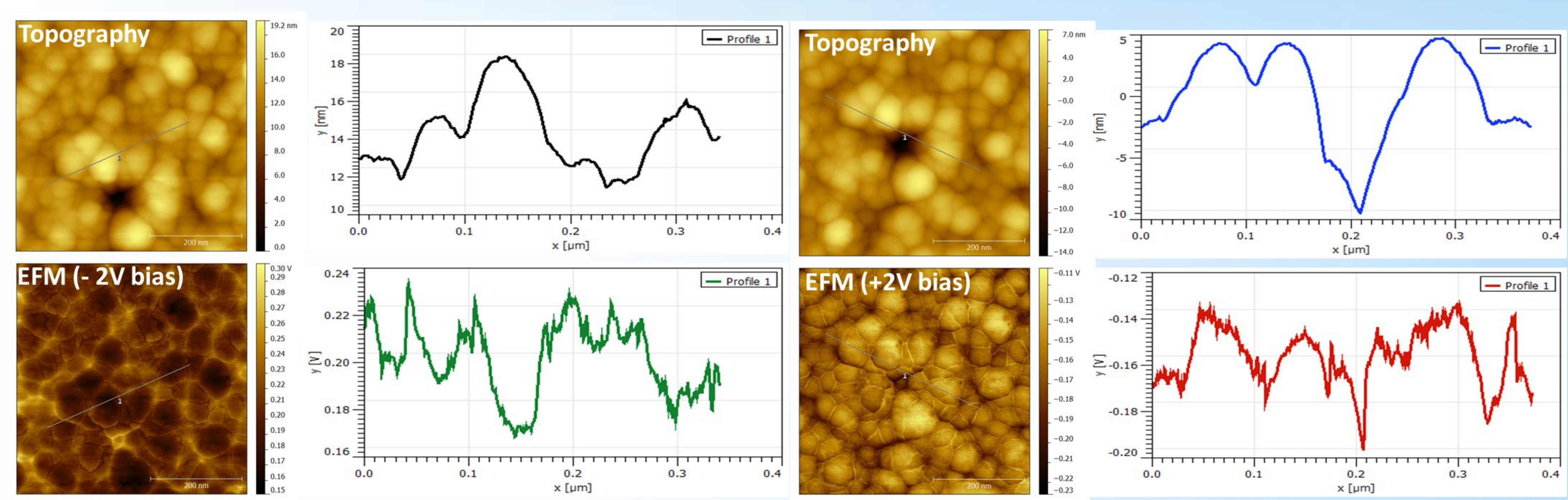
Results and analysis

Effect of bias voltage on local charge distribution



- Nanocrystalline grain interiors are at lower potential and amorphous grain boundaries are at higher potential for negative bias and vice versa for positive bias.
- Potential drop varies in larger and smaller grains
- Change in polarity in bias voltage reverses the polarity of the surface potential indicating the dominance of only one – presumably negative – type of defects

Line profile of topography and EFM images



- Height variation in large grain clusters (upper images) has very less effect on EFM images; while height variation in individual grains (lower images) has significant effect on EFM images indicating grain-size modulation of surface charges
- Variation in grain size affects the surface potential in an irregular manner; there is no direct correlation between each other

Conclusion

- Local charge distribution in nc-Si:H varies in grains and grain-boundary regions
- Grains are more conductive than grain boundaries