Nanoscale Structure and Charge Transport in Nanocrystalline Silicon for Advanced Solar Cell Applications

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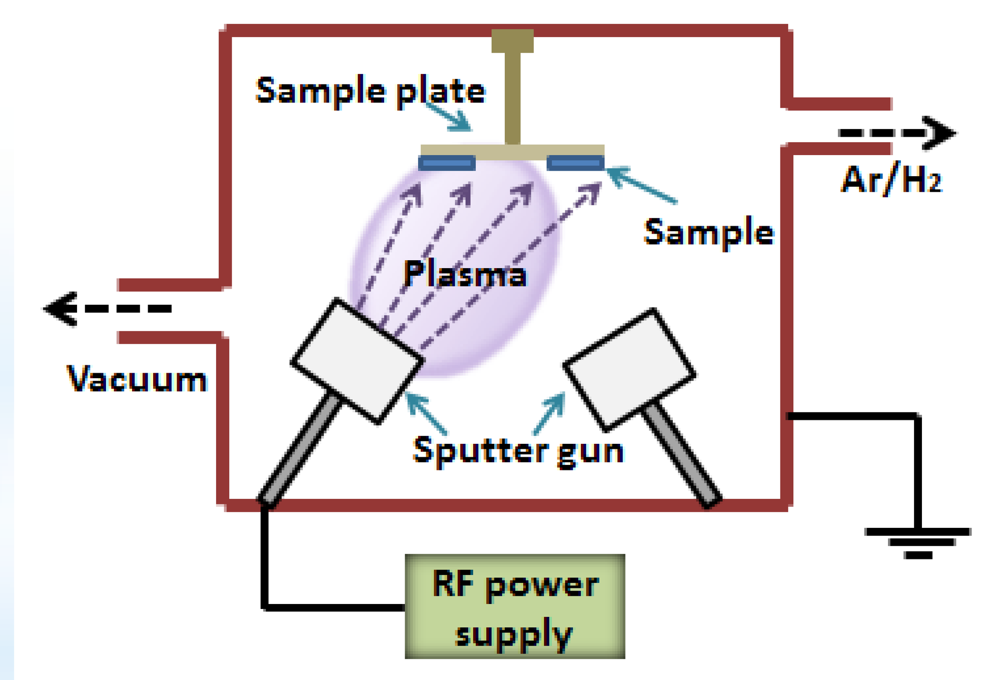
Abstract

Hydrogenated nanocrystalline silicon (nc-Si:H) is a promising absorber for advanced solar cell devices. However nc-Si:H is a heterogeneous material with spatially varying optoelectronic properties at nanometer length scales due to presence of crystallites, disordered regions and grain boundaries. The structural disorder results in poor carrier transport and also causes light induced degradation (LID), which adversely affects the device performance. This work reports the local charge distribution at grain/grain-boundary (GB) interfaces of nc-Si:H studied by Current-sensing atomic force microscopy (CS-AFM), Electrostatic Force Microscopy (EFM), and Scanning Kelvin Force Microscopy (KFM).

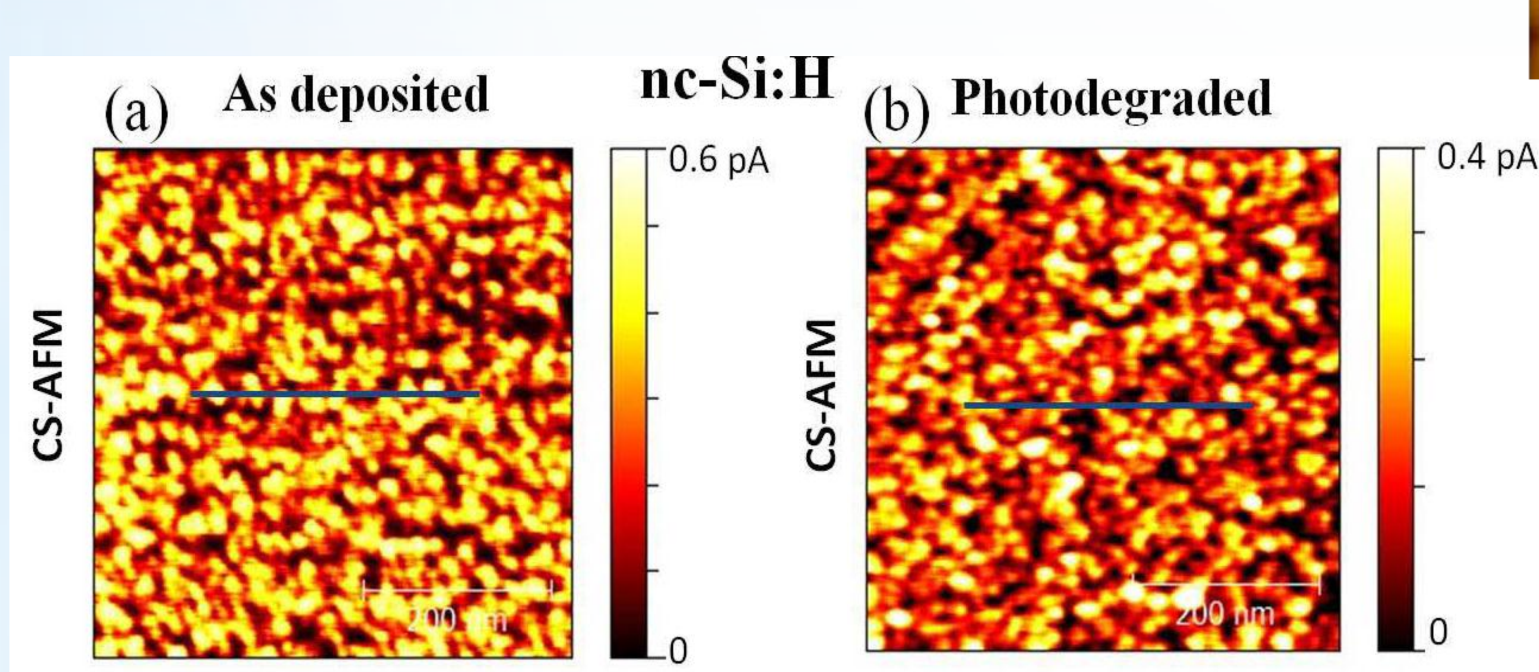
Experimental Procedures

- nc-Si:H thin films were deposited using reactive RF sputtering in hydrogen/argon atmosphere in a custom built deposition system at a base pressure of 10^{-7} torr.



Light Induced Degradation in nc-Si:H - Influence of Grain Boundaries

- Grain interiors provided paths for electrical conduction.
- Grain boundaries are highly resistive compared to grain interiors
- Light induced degradation (LID) resulted in significant decrease in average current and increase in highly resistive or defective regions
- LID's influence is prominent in GB regions



CS-AFM images of nc-Si:H before (a) and after LID (b)

Acknowledgement

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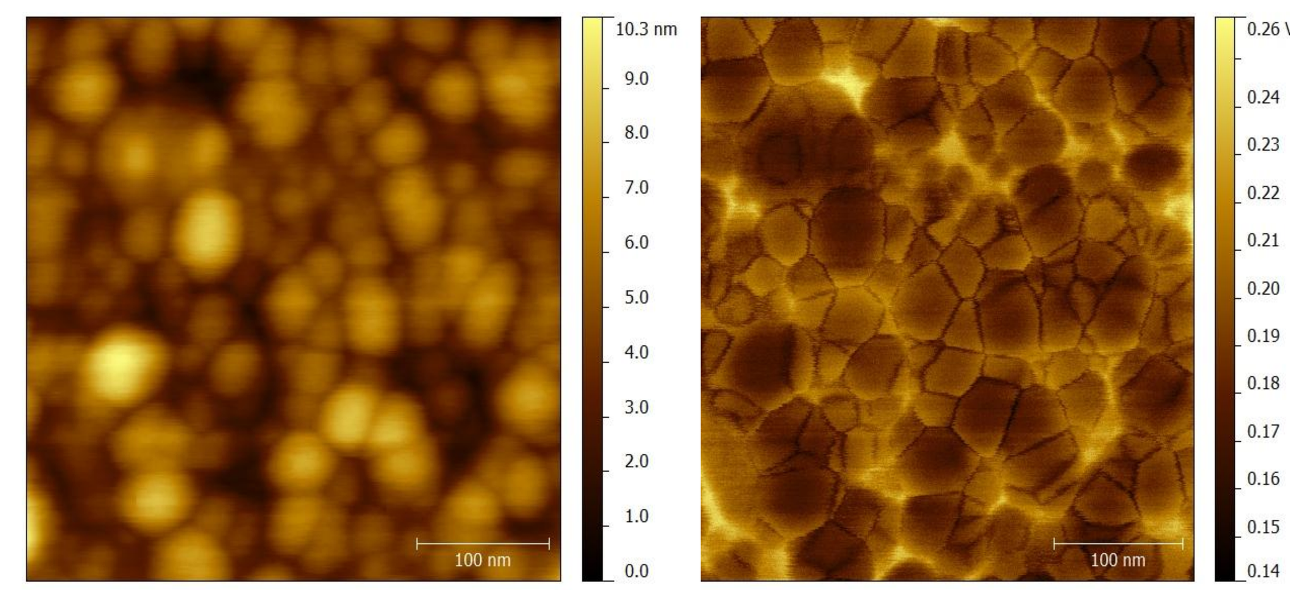
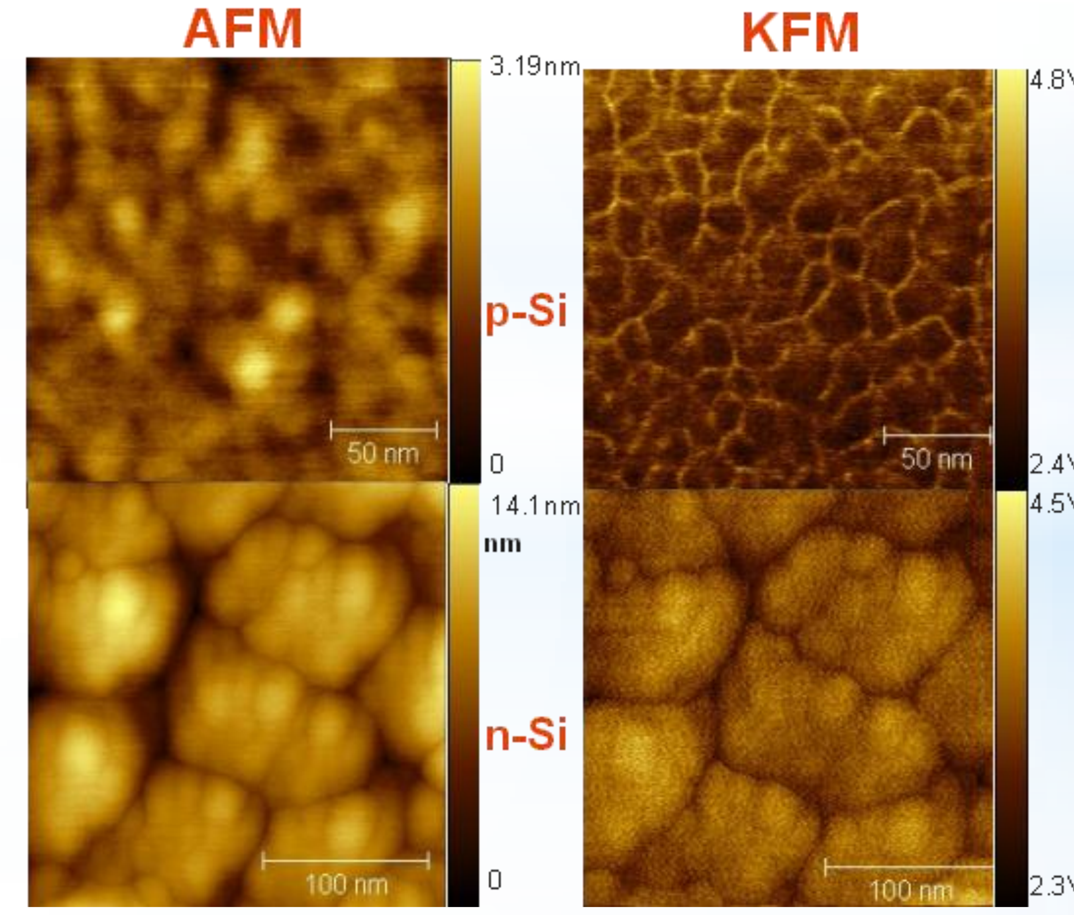
Local Charge Distribution in nc-Si:H across Grains and GB's



Topography and EFM images of nc-Si:H

- Nanocrystalline grain interiors were at lower potential and amorphous grain boundaries were at higher potential
- Potential drop varies in larger and smaller grains

Local Band Bending at Grain/GB interfaces in nc-Si:H



- Grain boundaries in p-type silicon (brighter regions) show an upward band bending
- Grain boundaries in n-type silicon are darker regions and show downward band bending

Conclusion

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

Future Work

- Quantitative analysis to correlate physical parameters (carrier diffusion length, local defect density) with local microstructural changes responsible for LID
- Synthesize highly stable and monodisperse intrinsic and doped silicon nanoparticles and develop corresponding silicon inks
- Study the opto-electronic properties of silicon nanoparticle and silicon ink

Si-ink