Enhanced optical absorption in ultrathin PV absorbers via embedded metal nanopatterns

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Introduction

Compared to conventional crystalline solar cells, thin film cells use less material and can be made on flexible substrates, allowing for potential cost savings, among other benefits. However, they typically suffer from poorer performance than crystalline cells. A key limiting factor of conventional thin films is that the optical absorption length is typically much greater than the minority carrier diffusion lengths — the thick-thin compromise.

Conventional thin films
- High absorption of light
- Reduced charge extraction

Ultrathin films
- Poor absorption
- High charge carrier extraction
- Lower material use
- Potential for hot carrier enhanced solar cells

Method

Fabrication: CdTe device
- 50 nm x 2 CdTe depositions by RF magnetron sputtering (U. Toledo)
- 30 nm thick Ag hole pattern (500 nm pitch) via nanosphere lithography with e-beam evaporation
- 200 nm Ag back reflector via e-beam evaporation

Fabrication: a-Si device
- 20 nm + 80 nm a-Si by PECVD
- 20 nm Ag hole pattern
- 250 nm Ag back reflector

Results

CdTe

Experiment
- 8% enhancement (300-825 nm)
- 16% enhancement at band edge
- 93% average absorbance vs. 86% for control
- 20x less material than conventional cell

a-Si

Experiment
- 11% enhancement (300-689 nm), assuming band gap of 1.8 eV
- 3% enhancement over conventional control (500 nm)

Other Techniques
- Integrating sphere for reflection measurements
- AFM to characterize surface morphology of films
- Ellipsometry to calculate dielectric functions and thicknesses of a-Si device films

References

3. Kong, Rose, Naughton, Kempa, et al., Optics Express, accepted.

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www.bc.edu/cleanroom

Simulation

Performed with COMSOL
- Literature values of complex dielectric functions
- Most loss occurs in CdTe, not Ag
- Rough agreement w/ exp. due to textured FTO and defects

Simulation is used to show that the absorbance enhancement seen in experimental samples likely occurs to the macroscopic not the metal, and thus should be an issue even in rigid or an active solar cell.