Plasmon-Enhanced Light-Trapping for Thin-Film Solar Cells

Sponsor: ACS Petroleum Research Fund (Award No. ACS PRF# 50277-DNI10)

Zhaolin Lu, Microsystems Engineering, Kate Gleason College of Engineering,
Rochester Institute of Technology (Email: zhaolin.lu@rit.edu)

Objective

This program is focused on increasing light harvesting in thin film solar cells by exploiting the light trapping effects of surface plasmons and photonic crystals. Most of the research results have been or will be published in journal or conference papers. Accordingly, this report only contains milestone data of research.

Multilayer Metal-Insulator Stacks for Light Trapping

In this project, we investigated the multilayered metal-insulator (MMI) stack system by solving its fundamental super surface mode, and demonstrated the tuning of effective surface plasmon frequency (ESPF). By tuning the filling ratio and especially the coating material’s refractive index, surface modes with arbitrary wave vectors and absorption coefficients are achieved. The design rules drawn in this project would bring important insights into applications such as solar cells, optical lithography, nano-sensing and imaging.

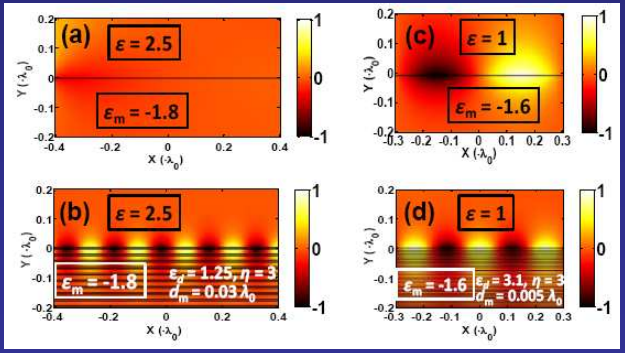

Figure 1. H field distribution for:
(a) No propagation of bounded surface modes above surface plasmon frequency.
(b) Bounded surface wave with subwavelength mode profile beyond the conventional cutoff frequency.
(c) Bounded surface wave propagated on a single metal-insulator interface.
(d) Bounded surface wave on a MMI-insulator boundary with shorter wavelength and manageable mode size compared to (c).

Other Engaged Projects

- **Arbitrary Scattering Element for Light Trapping**

We designed surface features to scatter and trap the random, broad-band sunlight.

- **Super Talbot Effect in Indefinite Metamaterial**

We re-visited one classical optical phenomenon, named Talbot effect, and investigated this effect in an indefinite metamaterial without the paraxial approximation. For solar cell applications, the indefinite materials enable a “power pulling” effect, which converts evanescent waves into propagating waves.

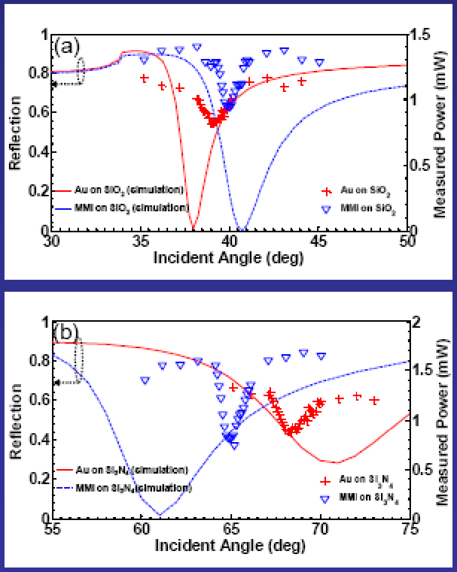

Figure 2. Numerical and experimental results of reflection vs incident angle for (a) increased ESPF and (b) decreased ESPF.

Designer Surface Plasmons

We performed the experimental demonstration of using the designer surface plasmons (or spoof surface plasmons) to achieve deep subwavelength power squeezing. Simple metal gratings can function as designer surface plasmonic waveguides with suitable geometrical parameters. We show that there is no difficulty to scale the structure into higher frequency regime. This will provide us a new means to squeeze and trap light power in thin film solar cells.

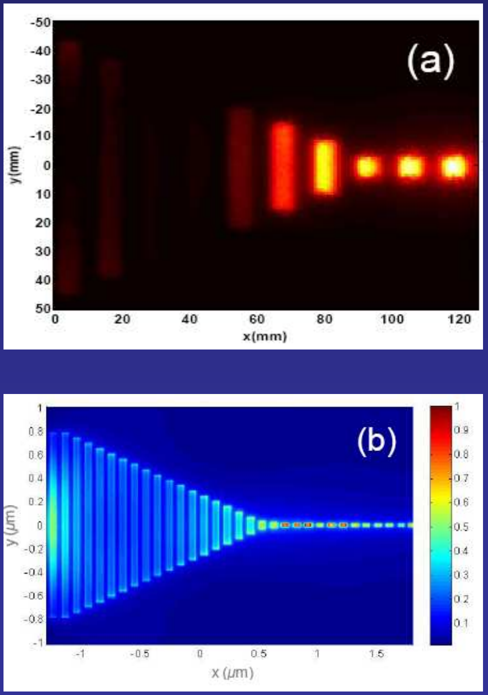

Figure 3. (a) Experimental demonstration light power squeezing in the microwave regime. (b) Numerical modeling of the technique in the visible light regime.