

Plasmonic absorption enhancement in organic photovoltaics

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ABSTRACT

Organic solar cells have a strong potential for the near future, because their material and fabrication costs can be much smaller than for traditional technologies. However, in order to become commercially viable their efficiency needs to increase. One of the novel, interesting techniques to increase the light absorption is by including plasmonic enhancements [1]. These metallic features instigate strong, local resonances which trap the light in the very thin layers. In this work we report rigorous numerical investigations of organic cells with embedded metallic nanoparticles and with patterned metallic electrodes. The state-of-the-art material P3HT:PCBM is employed as the active layer. We show that in both cases, with particles or with patterned electrodes, a strong enhancement is achievable, with roughly an increase of up to 50% in the solar light absorption. Such enhancements could prove crucial for more efficient energy devices.

Keywords: organic photovoltaics, plasmonics.

DESCRIPTION

Subwavelength-scale metallic structures exhibit intricate enhancement and scattering effects. We rigorously model these effects in thin-film cells using the frequency domain finite element software COMSOL. For nanoscale metallic particles incorporated inside the active layer the main physical enhancement effect is due to a local increase of the fields [2]. On the other hand, for the metallic electrode structures (Fig. 1) the diffraction and enhancement is more intricate and depends strongly on the period and the triangle height. We can extend the absorption edge (around 600nm for P3HT:PCBM) to significantly higher wavelengths by judiciously choosing these parameters, see Fig. 1(b). This leads to strong resonances with a significant overlap of the mode field and the active layer (Fig. 1(c)).

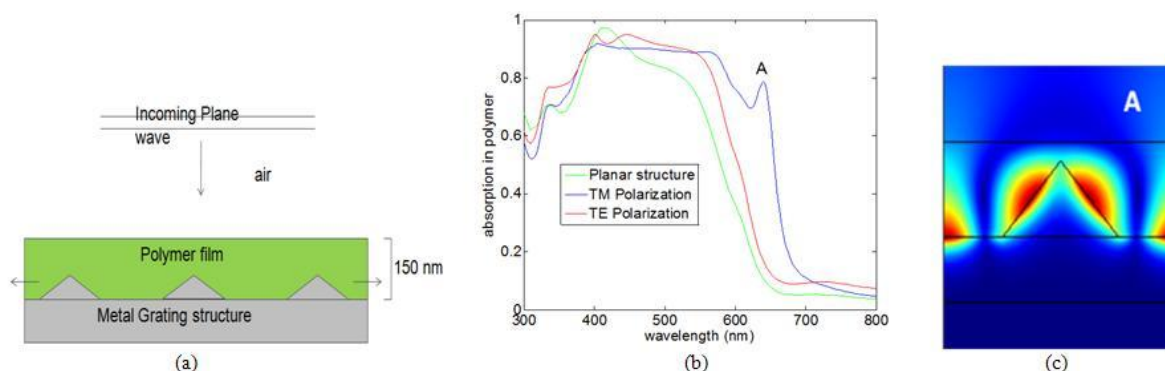


Figure 1: (a) Schematic of the electrode system. (b) Example of an absorption spectrum for the planar and patterned device (period=400nm, fill factor=0.5, triangle height=120nm). (c) Plot of the norm of the magnetic field profile for TM polarization at 640nm wavelength (peak indicated by A in (b)).

CONCLUSION

Plasmonic elements can increase the absorption efficiency of thin-film organic structures. Both metallic nanoparticles and patterned electrodes are studied with rigorous numerical methods. With silver nanoparticles (24nm diameter) we observe an enhancement with a factor of around 1.56 in a 33nm thick active layer, bringing the structure to the absorption level of much thicker active layers without nanoparticles [2]. For the patterned electrode we determine an integrated absorption efficiency increase of 15.6% throughout the 300-800nm spectral region, for a 150nm thick active layer.

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