

Plasmonic and Back-Reflector Enhanced Light Trapping in a P3HT Photovoltaic

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ABSTRACT

2 MODELS

We numerically simulate the performance enhancement of an organic (P3HT) photovoltaic produced from a variety of light traps. An additional improvement factor of over 4 is obtained in a plasmonic ITO architecture via the use of a textured (rather than flat) back-reflector. An improvement factor of over 5 is demonstrated within a silver nanowire architecture and examples of the underlying resonances are briefly discussed.

Keywords: solar energy, photovoltaics, light trapping, nanoparticle scattering

1 OVERVIEW

Organic photovoltaics (OPVs) hold promise over inorganic PVs due to their low-cost of large-scale manufacturability, etc., but suffer from relatively low quantum efficiency (or equivalently, low responsivity). Many researchers have proposed to circumvent the low efficiency of OPVs via the use of light trapping. Light trapping refers to any means by which light not converted into electricity on one pass through the PN junction of the PV is reflected back through the PN junction to give it another chance to be converted. We numerically simulate the enhancement of an organic, Poly[3-hexylthiophene] a.k.a. P3HT, photovoltaic with conductive electrodes as a top-reflector; used in conjunction with a (perfectly conducting) back-reflector of either a flat, or textured shape. We utilized two basic architectures as illustrated in Figs. 1 and 2. In the architecture of Fig. 1 the rectangular electrodes are made of ITO and the geometry in the case of the flat back-reflector is the same as in [1]. In that case [1] an improvement factor in the optical absorption in P3HT of over 3 had been achieved through the use of plasmonic effects within the ITO alone (with a flat, i.e., not textured back-reflector). We obtain similar results in that case and demonstrate that an *additional* improvement factor of over 4 can be achieved by also incorporating a textured (herein a periodic and triangularly shaped) back-reflector. A trapping enhanced absorption factor of over 5 is also demonstrated in the architecture of Fig. 2, wherein the top-reflector electrodes are elliptical in shape and made of silver nanowires embedded in a glass cover which lies on top of the P3HT slab.

The real and imaginary parts of the index of refraction for the P3HT were curve-fitted from measured data [2], [3] – as were also those of ITO for the case of the architecture of Fig. 1. Within the architecture of Fig. 2, the silver nanowires were simulated via a Drude model with plasma frequency = $2.224455 (10^{15})$ Hz and damping frequency = $0.0050778 (10^{15})$ Hz. The performance metric for calculating improvement factors, denoted P_{abs} , is taken to be the integral with respect to frequency of the power absorbed in the P3HT layer times the input spectral density (herein taken to be solar AM 0). The dimensions in the ITO architecture (labeled in Fig. 1) were set to be those deemed optimal in [1] for the flat back-reflector case.

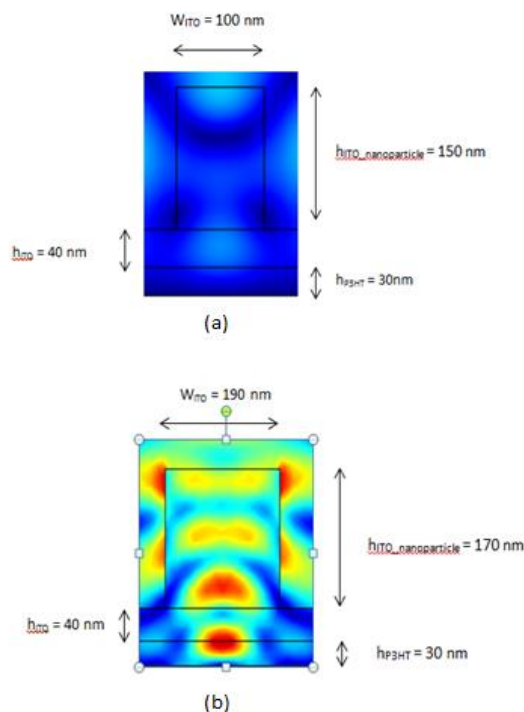


Figure 1: Optimal dimensions from [1] used for (a) TE and (b) TM polarizations in the ITO architecture.

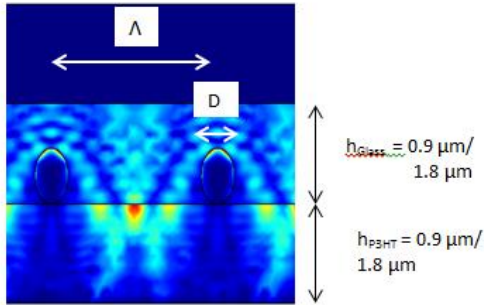


Figure 2: Architecture of silver nanowires embedded in a glass cover on a P3HT slab (the top layer is air)

3 RESULTS

In the rectangular ITO architecture we find that the incorporation of a textured back-reflector sets up a resonant enhancement yielding (relative to a flat back-reflector) an *additional* improvement factor, in Pabs, of over 4. As exemplified in Fig. 3 the absorbed power is indeed primarily in the P3HT. Careful comparison of the electric field magnitudes in Fig. 4 (for a flat back-reflecting electrode) versus those in Fig. 5 (for the periodically textured back-reflecting electrode) illustrates a diminished reflection into the air above the rectangular ITO. This translates into an increased field magnitude at the ITO/P3HT interface beneath the rectangles.

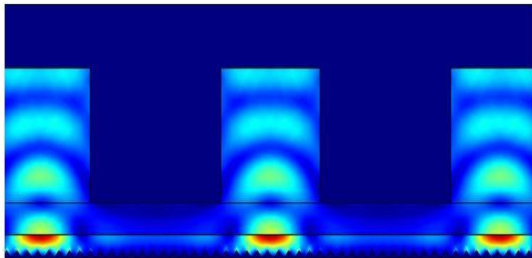


Figure 3: Absorbed power at 700nm with a textured back-reflector, TM polarization.

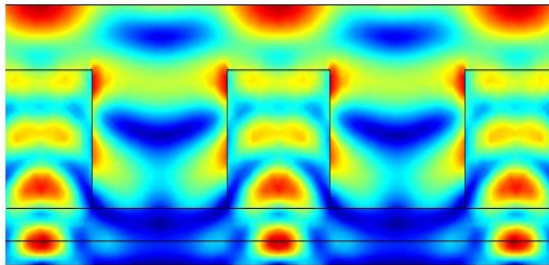


Figure 4: Electric field magnitude at 700nm with a flat back-reflector, TM polarization.

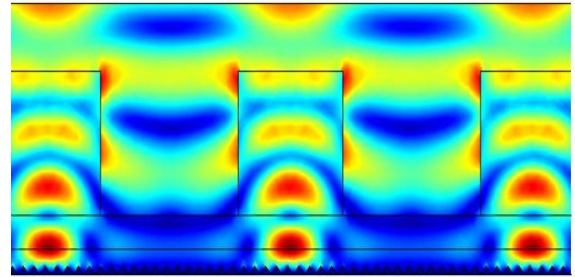


Figure 5: Electric field magnitude at 700nm with a periodic back-reflector, TM polarization.

Fig. 6 displays an example of the polarization magnitude in the silver nanowire architecture. The polarization at the glass/P3HT interface is clearly enhanced by the resonant interaction between the ellipses and triangles. Pabs was increased by a factor of over 6 (relative to the non-trapped case) for $D = 0.6$ microns at a spacing of 6 microns for TE polarized light. This was the optimal improvement factor over the small parameter space we explored – but a more thorough attempt at optimization is a work in progress.

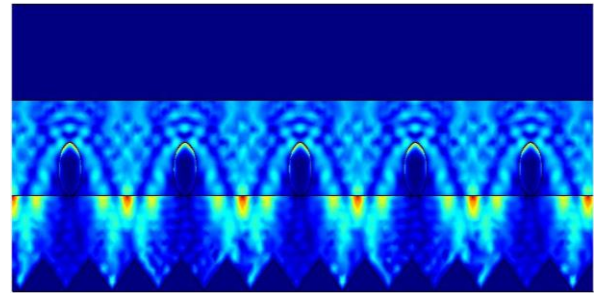


Figure 6: Polarization magnitude at 350nm with a periodic back-reflector, TE polarization.

REFERENCES

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