Self assembled dimers of metallic nano-particles for enhanced light harvesting in organic solar cells

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Organic based photovoltaics (OPVs) is one of the solar technologies that has the potential to become cost effective while providing added functionality such as transparency and flexibily. However, for an efficient charge collection in materials with a rather low charge mobility, one must fabricate devices with very thin active layers. Such thin layers imply that an efficient light harvesting is difficult to achieve. One approach to enhance light harvesting has been to consider the inclusion of metallic nano-particles (NPs) to enhance the scattering of sunlight within the active material [1-2].

In the current work we consider the inclusion, in between the transparent electrode and the active material, of single 40 nm gold nano-particles (NPs) and groups of the same NPs forming a dimer nano-structure. To obtain the dimers we used a simple self-assembly based method which lead to the controlled formation of strongly coupled particles. The two NPs in the dimer remain linked to a fix distance by Dithiothreitol (DTT) molecules, as shown in the SEM image from Figure 1.

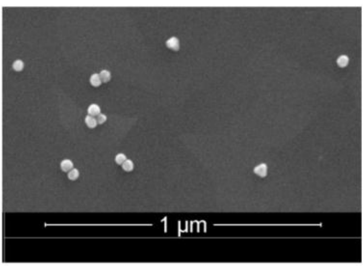

Figure 1: SEM image of Self-assebmled gold Nanoparticles on an ITO substrate showing dimers NPs.

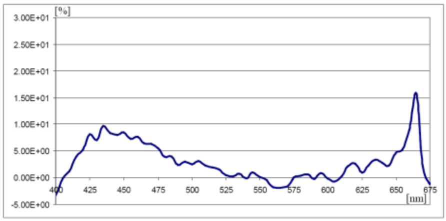

Figure 2: Plot of the percentage change in the EQE function of a plasmonic solar cell with monomer and dimer 40 nm in diameter Au NPs inclusions relative to a plasmonic solar cell with single 40 nm in diameter Au NPs inclusions.

We fabricated three types of OPV devices, a standard inverted OPV planar device with the following architecture ITO/TiO_2/P_3HT:PCBM/MoO_3/Ag. A similar type of device where single nano-particles were dispersed at the ITO/TiO_2 interface and, one last type of device including the dimer nano-structures at the same interface. The latter one exhibited a photoconversion of 3.2% and a short circuit current that we measured to be 11% times larger than the efficiency of the standard one, while for the single NPs device the increase in short circuit current was only 8%. Such enhanced performance of the dimer device can be understood when considering that the scattering cross section is almost twice at short wavelengths below 540 nm, it has a comparable behavior in the middle wavelengths range (540-650nm), while it exhibits a resonance peak at around 665nm. These wavelength dependent enhancements are clearly visible in the external quantum efficiency (EQE) percentage change measurements shown in Figure 2. The increase in EQE at the short wavelengths range (from 420 nm to 510 nm) is about 18%, while at the long wavelength range (from 630 nm to 670 nm) is about 23% relative to the standard cell without NPs.

In conclusion, we showed that dimers of gold nano-particles have a larger capability than monomers to lead to an effective photon absorption at those wavelengths where the optical absorption constant of the majority of photovoltaic polymers is smaller.

References

[1] J. Wu, F. Chen, Y. Hsiao, F. Chien, P. Chen,C. Kuo, M. H. Huang, C. Hsu, "Surface Plasmonic Effects of Metallic Nanoparticles on the Performance of Polymer Bulk Heterojunction". ACSnano, vol. 5(2), (2011), 959-967.

[2] Wang, D. H., Park, K. H., Seo, J. H., Seifter, J., Jeon, J. H., Kim, J. K., Park, J. H., et al., "Enhanced Power Conversion Efficiency in PCDTBT/PC70BM Bulk Heterojunction Photovoltaic Devices with Embedded Silver Nanoparticle Clusters", Advanced Energy Materials, 1(5), (2011), 766-770.