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Enhancement of the performance in organic solar cells through incorporation of gold nanoparticles

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Abstract – The incorporation of gold nanoparticles in the poly(3-hexyl-thiophene)/fullerene system increased the photocurrent and the fill factor of the bulk heterojunction solar cells. X-Ray diffraction, High resolution transmission electron microscopy and Atomic force microscopy studies reveal that such increase can be related to the plasmonic effect and also to a change in the morphology, increasing polymer crystallinity after incorporation of the gold nanoparticles. High resolution transmission microscopy images showed that the nanoparticles are distributed between both polymer and fullerene phase.

Organic solar cells have attracted great attention due to their low cost of production and materials used, as well as the chemical versatility and good electronic and optical properties of the organic semiconductors. This work reports how the incorporation of gold nanoparticles in the system poly(3-hexyl-thiophene) (P3HT)/fullerene (PCBM) increase the photocurrent and the fill factor of the photovoltaic devices. The gold nanoparticles (Np-Au) were synthesized according to Araki e cols.[1].The organic devices were fabricated by spin-coating a solution of P3HT/PCBM or P3HT/PCBM/Np-Au into an ITO/Pedot-PSS substrate, followed by thermal deposition of aluminum. The nanocomposite was prepared by dissolving P3HT/fullerene/Np-Au in 1,2,4-trichlorobenzene in the proportion 62, 37,1% w/w, respectively. According to HR-TEM images, the gold nanoparticles are distributed between both polymer and fullerene phase. Figure 1 shows the structure of PCBM which is composed by several nanocrystals arranged at different orientations (marked regions).[2] Table 1 shows the photovoltaic properties of the devices extracted from J-V curves (Figure 2). There was an enhancement of the photocurrent and fill factor when gold nanoparticles are incorporated into the P3HT/PCBM system. This enhancement can be associated with an intense electric field existing near to the particle surface (plasmons surface) leading to an increase of exciton dissociation at the interface P3HT/PCBM and also to an increase in hole transfer, since the nanoparticles mediate the transport between the Pedot-PSS and the HOMO of the polymer. AFM and X-Ray diffraction have also showed an improvement of the crystallinity degree of the P3HT matrix for the P3HT/PCBM/Np-Au nanocomposite.

Table 1: Photovoltaic properties of the devices made with and without Np-Au

	J_{sc} (mA/cm^2)	V_{OC} (V)	FF (%)	R_s (Ω)	Eficiência (%)
PCBM+P3HT	0.28	0.48	22	2285	0.05
P3HT/PCBM/Np-Au	0.41	0.44	38	318	0.12

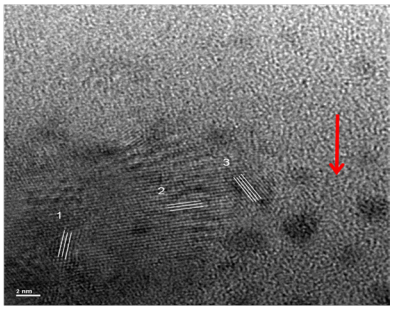

Figure 1: HR-TEM images of the PCBM nanocrystals. At this micrograph is possible to see nanocrystals directions marked with the numbers 1, 2 e 3. The red narrow shows the gold nanoparticles dispersed in the polymeric matrix

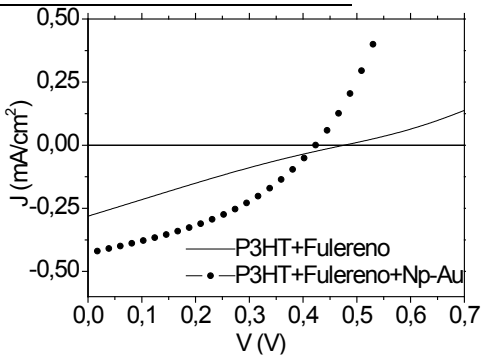

Figure 2: J-V curves of the photovoltaic devices under 60 mW/cm^2. Active area of the devices was 0.15 cm^2.

[1] K. Araki, E. Mizuguchi, H. Tanaka and T. Ogawa, *J. Nanosci. Nanotech.*, 6, 3, 708, **(2006)**
[2] M. Reyes-Reyes, R. López-Sandoval , J. Arenas-Alatorre , R. Garibay-Alonso, D.L. Carroll and A. Lastras-Martinez *Thin Solid Films* 516, 52, **(2007)**