Nanostructured P3HT/C60 solar cells using oblique angle thermal deposition of C60 into nanoimprinted P3HT gratings

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In recent years, research in organic solar cells (OSCs) has been advanced tremendously, driven by the potential for low cost, large area devices with attractive market perspectives. One major challenge for OSCs is its relatively low power conversion efficiency (PCE ~6%), which is limited by active layer morphology, properties of material and surface/interfaces. Nanoimprint lithography (NIL) has emerged as a new technique to obtain ordered and continuously interdigitized active layer morphology [1], which is generally not possible using traditional techniques of spin coating and thermal annealing used in making bulk heterojunction devices. For the nanoimprinted solar cells to obtain high performance, the complete infiltration of acceptor materials into the nanostructured polymer layer, typically by spincoating, is critical to form good and large junction interface for efficient exciton dissociation, charge separation and collection. However, such process is challenging due to limited availability of orthogonal solvents, material incompatibility, and spincoating non-uniformity.

In this study, we present the fabrication of P3HT/C60 organic solar cell devices with good infiltration of C60 into the nanoimprinted P3HT nano-gratings, resulting in improved solar cell performance. As shown in Fig.1, the C60 layer is deposited using oblique angle thermal evaporation instead of spincoating to avoid the need of orthogonal solvents. Fig. 1b and 1c show SEM images the partial and complete coverage of P3HT nanogratings for the deposition of C60 from one side and both sides of the nanogratings respectively. Due to the self-shadowing effect of P3HT nanostructures, the uniformity and step coverage of C60 deposition is strongly related to the evaporation angle.[2] As a result, the device performance strongly depends on the evaporation angle, as shown in Fig. 2. Device performance parameters extracted from the J-V curves are shown in Table 1. The highest efficiency of 0.93% at 15 ^{o} is obtained after annealing at 180 ^{o}C for 3 minutes, and it can be explained by the enhanced step coverage of C60 on patterned P3HT at this angle. We will present systematic study of the quality of P3HT/C60 interface for various deposition angles and C60 thickness and their effects on overall solar cells performances.

1. Aryal, M et al., J. Vac. Sci. Technol. B 26(6), (2008).
2. Karabacak, Tansel et al., J. Appl. Phys. 97, 124504 (2005)

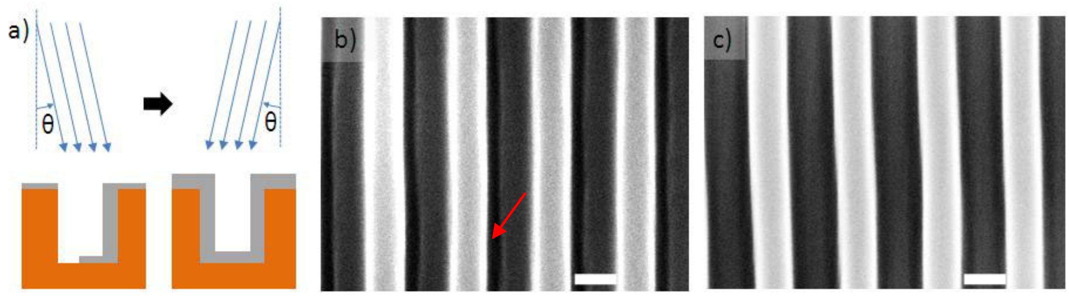

Fig 1: Oblique angle deposition of C60: a) schematic of deposition process; b) SEM images of 30 nm C60 deposition on P3HT nanogratings of w=100 nm, p=200 nm and h=60 nm from one direction where only one wall is covered (shown by arrow), c) from both direction for complete coverage. Scale bar is 100 nm.

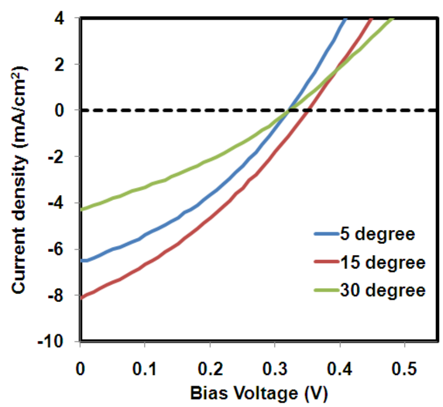

Figure 2: I-V characteristics of nanoimprinted solar cells where C60 was deposited on P3HT nanograting with oblique angles of 5º (blue), 15º (red) and 30º (green) respectively.

C60 Deposition Angle	Parameters			
	V_{oc} (V)	I_{sc} (mA/cm^2)	FF	Efficiency (η)%
5 º	0.33	6.51	0.34	0.74
15 º	0.35	8.12	0.33	0.93
30 º	0.32	4.29	0.28	0.39

Table 1: Summary of derived device parameters for nanoimprinted solar cells. Nanoimprinted solar cells show good performance for P3HT/C60 material system. Solar cells with the deposition angle of 15º shows enhancement in short circuit current and open circuit voltage indicating conformal coating and better charge separation at this angle.