



**Comment on “Enhanced optical field intensity distribution in organic photovoltaic devices using external coatings” [Appl. Phys. Lett. 89, 233502 (2006)]**

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# Comment on “Enhanced optical field intensity distribution in organic photovoltaic devices using external coatings” [Appl. Phys. Lett. 89, 233502 (2006)]

Q. L. Song and C. M. Li<sup>a)</sup>

School of Chemical and Biomedical Engineering and Center for Advanced Bionanosystems, Nanyang Technological University, 70 Nanyang Drive, Singapore 637457, Singapore

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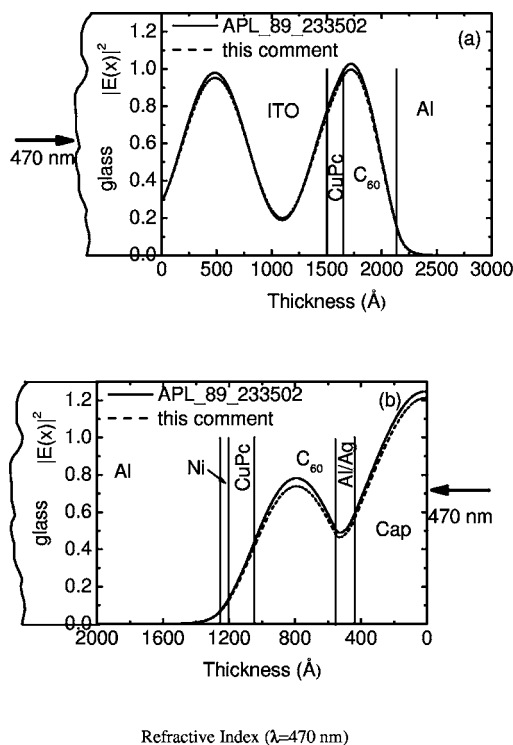
O'Connor *et al.*<sup>1</sup> reported the enhancement of light intensity at a donor-acceptor (D-A) interface in organic solar cells, in which an external coating of an aluminum hydroxiquinoline (Alq<sub>3</sub>) cap layer was used. Since the enhancement of light intensity at the D-A interface is periodic with the thickness of Alq<sub>3</sub> and the lifetime of an organic solar cell based on copper phthalocyanine (CuPc)–C<sub>60</sub> is sensitive to air,<sup>2,3</sup> the suggestion of protecting the cells by external coating of Alq<sub>3</sub> seems like a great idea that not only improves the cell photocurrent but also protects the cells from the ambient, particularly with the use of thick Alq<sub>3</sub>. However, as the discussion in this letter later, this may be not true. © 2007 American Institute of Physics. [DOI: 10.1063/1.2817589]

The authors do not consider the absorption of each component material that needs to be accounted, especially the results in Fig. 2 of Ref. 1. Another shortcoming of the report of O'Connor *et al.* is that the integration of light absorption within the exciton diffusion length away from the D-A interface should be used instead of the light intensity at D-A interface used in Ref. 1 if the photocurrent is believed to be coming from the exciton dissociation at D-A interface.

To illustrate the effect of absorption of CuPc and Alq<sub>3</sub>, Figs. 1 and 2 in Ref. 1 are recalculated by using the established transfer matrix method.<sup>4–7</sup> Though the absorption of CuPc and Alq<sub>3</sub> is small at 470 nm,<sup>5,8</sup> its effect on the final calculation is shown in Figs. 1 and 2. In fact, periodic modulation of light without decrease of amplitude by the external coating Alq<sub>3</sub> is not possible. The difference of our calculation and the experimental results reported in Ref. 1 is even larger. In general, excitons are dissociated at the D-A interface in heterojunction organic solar cells.<sup>2,3,5,9</sup> Thus, the excitons produced within the diffusion length ( $L_D$ ) away from the D-A interface have a chance to reach at the interface and dissociate there. The light absorption away from ( $L_D$ ) D-A interface other than the light intensity at D-A interface should be considered. The effect on the exciton diffusion is also given in Fig. 2. The average light intensity around the D-A interface is much larger than that at the D-A interface. This is because of the fast variation of the light intensity around the D-A interface, as shown in Fig. 1. Figure 3 shows the light absorption within the exciton diffusion length (10 nm at CuPc side and 40 nm at C<sub>60</sub> side,<sup>5</sup> in which the device structure is the same as that given in Fig. 2 of Ref. 1). It is clear that the highest output photocurrent of InGaAs, which is proportional to the light absorption around D-A interface, is due to the relatively high absorption of C<sub>60</sub> at 470 nm when using the same power level of the light source.

Apart from the reason proposed by O'Connor *et al.*,<sup>1</sup> the larger difference between our calculation and the experimen-

tal results reported in Ref. 1 might be ascribed to the extremely small experimental photocurrent. It has been proved<sup>9</sup> that direct contact of Al with C<sub>60</sub> is a bad choice when CuPc and C<sub>60</sub> form a heterojunction. Direct deposition of Al onto C<sub>60</sub> could result in small photocurrent to deviate from the



Refractive Index ( $\lambda=470$ nm)			
$n_{\text{glass}}=1.42$	$n_{\text{Al}}=0.69+i*5.7$	$n_{\text{CuPc}}=1.6+0.065i$	$n_{\text{cap}}=1.7+i*0.024$
$n_{\text{ITO}}=1.937+i*0.016$	$n_{\text{C60}}=2.2+i*0.35$	$n_{\text{Ag}}=0.13+i*3.07$	$n_{\text{Ni}}=1.65+i*2.77$

FIG. 1. Recalculation of Fig. 1 in Ref. 1. The calculation parameters are the same as those in Ref. 1 except for CuPc and Alq<sub>3</sub>, whose small extinction coefficients are taken into account (the refractive index of Ni, which is not explicitly given in Ref. 1, is supposed to be the same as the one we used). The light intensity distribution difference is clear especially at the peaks.

<sup>a)</sup> Author to whom correspondence should be addressed. Electronic mail: cml@ntu.edu.sg

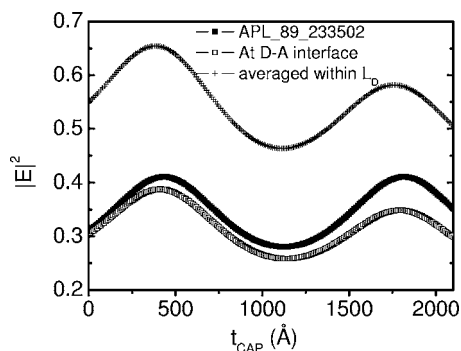


FIG. 2. Plot of the calculated  $|E_{DAI}|^2$  (the filled square is the optical intensity at D-A interface without considering absorption of CuPc and Alq<sub>3</sub>, the opened square is the optical intensity at D-A interface considering absorption of CuPc and Alq<sub>3</sub>) and the averaged  $|E|^2$  within  $L_D$  (exciton diffusion lengths of 10 nm at CuPc side and 40 nm at C<sub>60</sub> side) vs the thickness of capping Alq<sub>3</sub>. The absorption of CuPc and Alq<sub>3</sub> causes the light intensity drop, while the effect of  $L_D$  averaging causes its increase.

assumption of the photocurrent being proportional to the light absorption around D-A interface.

A device structure similar to that in Fig. 2 of Ref. 1 is proposed here to clearly compare the calculated and experi-

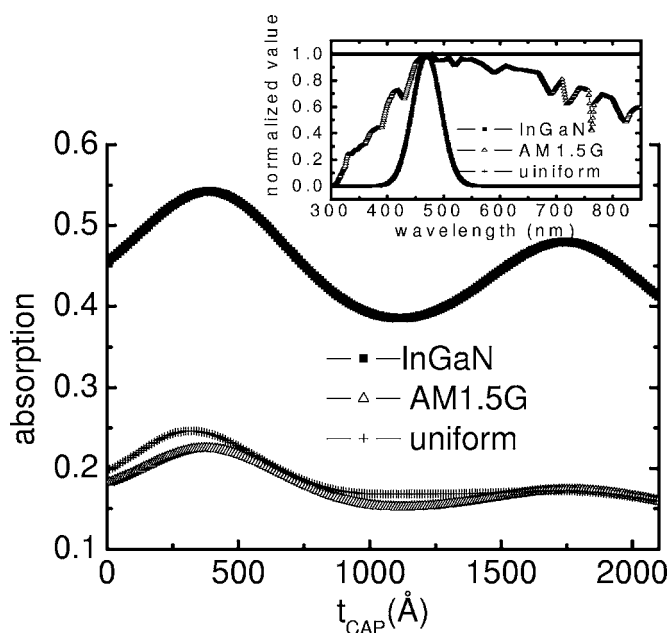


FIG. 3. The absorption within  $L_D$  away from D-A interface for different illumination light sources. The power for each illumination source is the same. InGaN is a blue light diode with peak wavelength at 470 nm and a Gaussian spectral distribution with half width of 25 nm; AM1.5 G is the simulated sunlight spectrum; *uniform* is a spectrum with uniform distribution from 300 to 850 nm. The spectra of the InGaN, AM1.5G, and *uniform* are given in the inset.

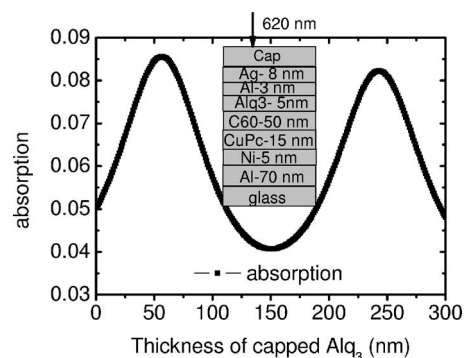


FIG. 4. The suggested photocurrent experiment vs the thickness of the capped Alq<sub>3</sub>. Alq<sub>3</sub> buffer is used for enhancing photocurrent and 620 nm wavelength light source is suggested because of almost no absorption of Alq<sub>3</sub> (cap) at this wavelength. The device structure is given in the inset.

mental results. The only difference from the device in Ref. 1 is 5 nm of Alq<sub>3</sub> buffer inserted between C<sub>60</sub> and Al. During photocurrent measurement versus thickness of capped Alq<sub>3</sub>, the light with a wavelength of around 620 nm is suggested because the absorption of CuPc is quite large, while the absorption of Alq<sub>3</sub> can be neglected. Figure 4 is the calculated absorption of the device around D-A interface versus the thickness of Alq<sub>3</sub>. Due to the extremely weak absorption of Alq<sub>3</sub> at 620 nm, the amplitude decrease of the second peak is quite small. The increase of absorption (photocurrent) is about 65%, much larger than that given in Ref. 1 (in fact, it should compare it with the filled square curve in Fig. 3). The experimental photocurrent would be observed easily because of the introduction of Alq<sub>3</sub> buffer.

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