Comment on "Roles of donor and acceptor nanodomains in 6% efficient thermally annealed polymer photovoltaics" [Appl. Phys. Lett. 90, 163511 (2007)]

Moritz K. Riede,[1,a)] Toni Mueller,[1] Bert Maennig,[1,b)] Karl Leo,[1] Kristian O. Sylvester-Hvid,[2] Birger Zimmermann,[2] Michael Niggemann,[3] and Andreas Gombert[3]

[1]*Technische Universität Dresden, Institut für Angewandte Photophysik, D-01062 Dresden, Germany*
[2]*Freiburger Materialforschungszentrum, University of Freiburg, Stefan-Meier-Strasse 21, D-79104 Freiburg i. Br., Germany*
[3]*Fraunhofer Institute for Solar Energy Systems ISE, Heidenhofstrasse. 2, D-79110 Freiburg i. Br., Germany*

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In a recent letter, Kim *et al.* report the production of polymer solar cells with a photoactive composite of poly(3-hexyl-thiophene) (P3HT) and 1-(3-methoxy-carbonyl)propyl-1-phenyl-(6,6)C_{61} (PCBM) claiming power efficiencies in excess of 6% measured under a standard AM1.5g spectrum with an intensity of 100 mW/cm^2.[1]

We have serious concerns about the validity of the presented data with regard to the obtained values of the short circuit current density J_{sc} and, hence, the reported power conversion efficiencies.

Within a given absorption range, the maximum attainable J_{sc} is limited by the spectrum and intensity of the illumination used for the electrical characterization of solar cells. This illumination should resemble an AM1.5g reference spectrum with an intensity of 100 mW/cm^2, as used under the standard reporting conditions (see references in Ref. 2). In Fig. 1, we show the accumulated values of J_{sc} on integrating the AM1.5g reference spectrum[3] from 300 nm (with a variable upper limit λ_l) up to 800 nm, either assuming EQE=1 or using the best EQE shown by Kim *et al.* (redrawn and digitalized EQE from Ref. 1 for the annealed D1 cell at 297 K). With the latter EQE a maximum J_{sc} of 8.5 mA/cm^2 is obtained contrasting the claimed ~12.5 mA/cm^2, a discrepancy of about 32%.

For their best solar cell (termed D2), J_{sc} approaching 16 mA/cm^2 is reported which from Fig. 1 would require an EQE of unity up to ~650 nm, where the spectral response for P3HT:PCBM solar cells normally declines abruptly. This is clearly unrealistic, as further underlined by their statement of the EQE for the D1, D2, and D3 solar cells as being "similar," i.e., with the same curve shape and also declining abruptly at ~650 nm. It is unfortunate that the authors have shown only the EQE for the worst performing solar cell (D1).

Our concerns are further substantiated by optical simulations on P3HT:PCBM solar cell by us and others, which take into account optical interference effects in the thin film system as well. From these simulations an upper limit for J_{sc} as function of film thickness can be estimated.[4–9] Hence, in Fig. 2 we show the upper limit for J_{sc} versus P3HT:PCBM film thickness, derived from optical (near field) simulations assuming EQE=1 and irradiation with an AM1.5g spectrum at 100 mW/cm^2. From the undulating behavior of the simulated limit for J_{sc}, at no point is a value of 16 mA/cm^2 reached. Although not directly comparable, in Fig. 2 we have indicated the *approximate* thickness range that typically corresponds 1500 rpm for our own solar cells (P3HT:PCBM 1:0.7, 1 mg P3HT/ml Dichlorobenzene, $M_w \sim 75.000$).[4] Again it is unfortunate that nowhere have the authors given the absolute values of the P3HT:PCBM layer thicknesses of the reported solar cells.

Thus, we have serious doubts that the photocurrents reported by Kim *et al.* have been determined under appropriate conditions. There are many possible sources of errors that can affect photocurrent measurements, especially in organic solar cells.[2]

Considering the importance of the conversion efficiency as a number of merit for solar cells, we stress the necessity of adopting testing standards for the device performance as has happened for inorganic solar cells. We note that the highest *certified* power conversion efficiency for a P3HT:PCBM based organic solar cell is currently at 4.01% with J_{sc} =10.0 mA/cm,[2] whereas higher efficiencies $(4.8\pm0.2\%)$

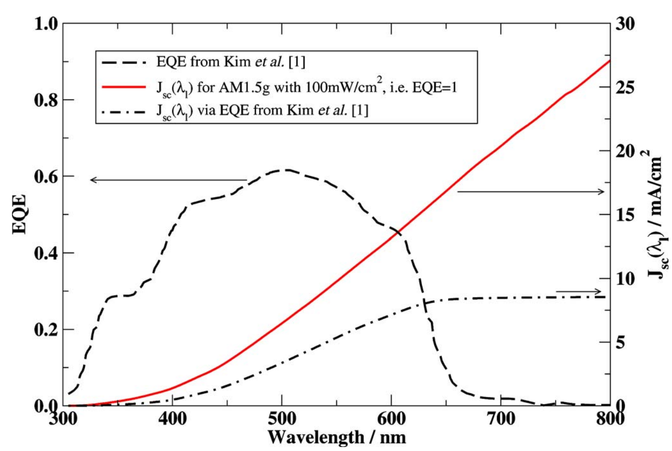

FIG. 1. (Color online) The best EQE of device D1 redrawn from Ref. 1 (dashed curve, claimed $J_{sc} \approx 12.5$ mA/cm^2) and the accumulated short circuit current density J_{sc} vs the upper wavelength limit λ_l of EQE, based on the standard AM1.5_g spectrum with 100 mW/cm^2. The lower limit is fixed at 300 nm. For EQE=1 the maximum attainable limit of J_{sc} is obtained (solid curve), which for example yields ~16.8 mA/cm^2 at a cutoff wavelength λ_l of 650 nm. For the shown EQE from Ref. 1, the limit is 8.5 mA/cm^2 (dash-dotted curve).

a)Electronic mail: moritz.riede@iapp.de.
b)Present address: Heliatek GmbH, Dresden, Germany.

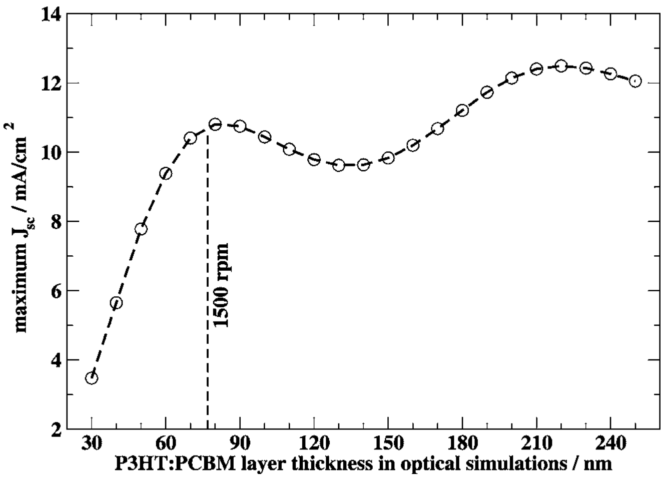

FIG. 2. The simulated upper limit for J_{sc} calculated for an ITO(140 mm)|PEDOT:PSS(51 nm)|P3HT:PCBM|Al(100 nm) solar cell with varying P3HT:PCBM layer thickness assuming an internal quantum efficiency (IQE) of unity. The optical constants were derived from ellipsometric data obtained from an annealed blend (150 °C) with a ratio of 1:0.7 P3HT:PCBM. The *approximate* thickness that typically corresponds 1500 rpm in our own solar cells is indicated.

are only confirmed as notable exception for a proprietary polymer:PCBM combination.[10]

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