Photonic crystal back electrode design for highly efficient transparent polymer cells

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The specific properties of organic photovoltaic (OPV) cells make them suitable for a large variety of applications where the traditional inorganic semiconductor based photovoltaic technology cannot be used. The inherent semi-transparency of the thin active material layer in an OPV cell may turn out to be very useful in the development of a technology well integrated in building window panes. However, such transparency for the active layer is a necessary but not sufficient condition to develop transparent solar modules. Indeed, a high photo-conversion efficiency (PCE) in organic photovoltaics requires a thick non-transparent metal back electrode. Several attempts have been made to substitute such thick metal layer by a transparent electrode [1,2]. However, transparencies above 25% in the visible range invariably lead to PCEs below 4 %.

In the current paper we consider the combined use of a thin transparent silver layer and an ad hoc photonic crystal designed to enhance the performance of the photovoltaic cell for the infrared wavelengths while simultaneously maintain the transparency in the visible. The starting point was an organic cell with an average PCE of 8.1%, fabricated using a bulk hetero-junction of PTB7:PC71BM and finished with a thick silver layer as back electrode. When thinning down such back silver electrode to 10 nm, light trapping provided by the back reflector is essentially lost and we observe a reduction in short circuit current that results in PCEs of 4.8% approximately. To recover the lost light harvesting efficiency we thermally evaporated several dielectric layers to form a one-dimensional non-periodic photonic crystal on top of the thin electrode. The evaporation procedure followed introduced a minimal damage to the organic cell and we succeeded at maintaining the open circuit voltage and fill factor of the original cell. As shown in Figure 1a, infrared light trapping induced by the photonic crystal leads to a 15% recovery for the short circuit current. In such conditions, the short circuit current recovery is sufficient to obtain cells with PCEs above 5.6%, while the transparency, shown in Figure 1b, is above 40 % in a broad range of visible wavelengths, corresponding to a luminosity through the cell above 30%. The photonic crystal also offers the possibility to tune the cell color, as shown in Figure 2, while maintaining the efficiency. To conclude, we report on a competitive transparent solar technology based on organics. Using the light trapping provided by a thin metal layer combined with an ad hoc photonic crystal, efficient transparent solar cells can be fabricated.

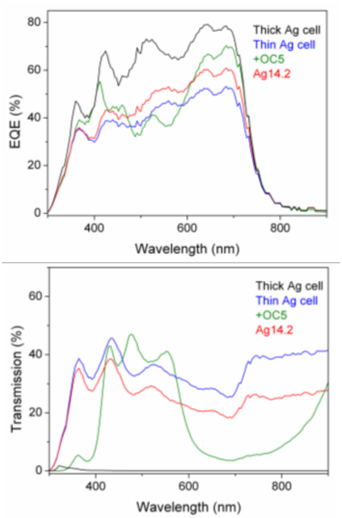

Figure 1: (a) External quantum efficiency and (b) transmission spectra for the device incorporing a five-layers photonic crystal (green) compared to the original device with a 10 nm thin Ag electrode (blue) and a device with a back electrode of 14.2 nm Ag that provides the same performance but lower transmission than the device with the integrated photonic control.

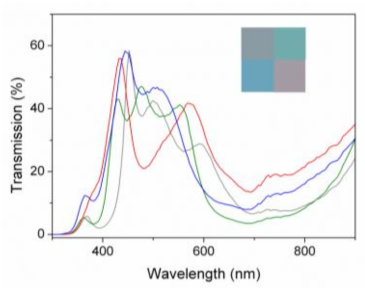

Figure 2: Color tuning using ad hoc photonic crystals and keeping the luminosity over 30%.

References

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