

## AN ORGANIC DONOR/ACCEPTOR LATERAL SUPERLATTICE AT THE NANOSCALE: TOWARDS AN OPTIMUM MORPHOLOGY FOR PHOTOVOLTAIC APPLICATIONS

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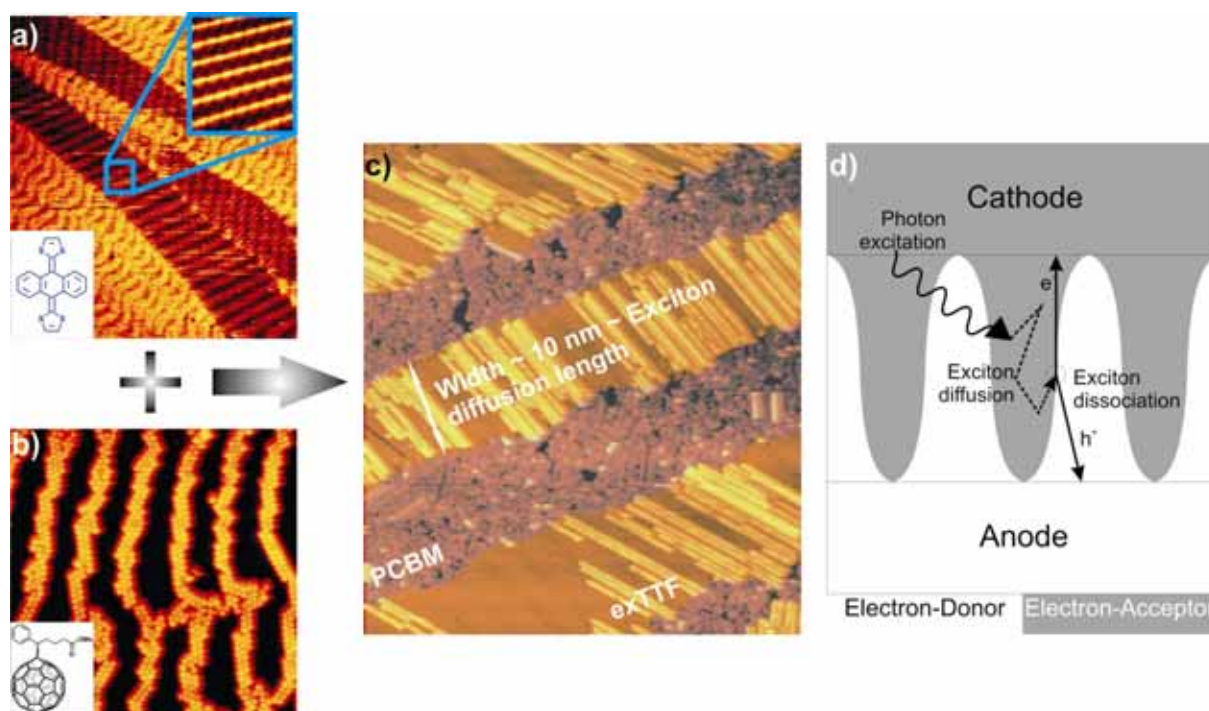
Photon absorption by organic molecules with adequate HOMO-LUMO gap excites metastable electron-hole pairs, whose energy can be converted into electrical power by driving the photogenerated electrons and holes to the different electrodes of a solar cell [1]. Facile processing, mechanical flexibility and low cost are some of the advantages of these “plastic” solar cells [2], which have already reached energy conversion efficiencies higher than 5%. Achieving higher efficiencies is however limited by the fact that, instead of free electron-hole pairs, photon absorption usually leads to the formation of tightly bound excitons (bound states of an electron-hole pair) which can diffuse only for a characteristic length of about 10 nm before radiative recombination occurs [3]. The hitherto most successful approach to promote the dissociation of the photogenerated excitons is to use blends of phase-segregated electron-donor/electron-acceptor molecules – the so-called bulk heterojunction concept [1]. At the interface between electron-donor and electron-acceptor areas, the difference in electron affinities drives the exciton dissociation by injecting free electrons (holes) into the electron-acceptor (electron-donor) areas. Provided that continuously connected paths between the interfaces and the electrodes exist, the free electrons and holes will be collected therein. From these considerations a number of morphological criteria can be extracted for optimum solar cell performance: first, the segregated electron-donor and acceptor domains must have a typical sizes of the order of the exciton diffusion length, in order to avoid wasteful radiative recombination events; second, the interface area between donor and acceptor domains, where exciton dissociation takes place, must be maximized; and, finally, donor (acceptor) domains must be continuously connected to the cathode (anode) to favour efficient charge transport. A schematic representation of a morphology that would satisfy these three criteria is shown in panel d) of the Figure: interdigitated donor-acceptor domains and elongated structures (to maximize interface area) with typical diameters of no more than 10-20 nm (to suppress exciton radiative recombination events) connected to the electrodes [4].

In this work we describe variable-temperature Scanning Tunneling Microscopy (STM) experiments that show how monolayer-thick blends of the electron donor molecule 2-[9-(1,3-dithiol-2-ylidene)anthracen-10(9H)-ylidene]-1,3-dithiole (exTTF, see Figure a) [5] with the electron acceptor [6,6]-phenyl C<sub>61</sub> butyric acid methyl ester (PCBM, see Figure b) [6] on a reconstructed  $22 \times \sqrt{3}$  Au(111) surface, segregates laterally into “nanostripes” whose width is of the order of the exciton diffusion length (Figure c); it thus corresponds closely with the morphology for optimum solar cell performance described in Figure d. The reason for such a peculiar nano-scale morphology can be traced back to the different interactions between the two molecular species and the herringbone reconstruction of Au(111). Our results demonstrate the potential of atomistic studies about the growth of organic semiconductors to open new directions for the design and construction of highly-efficient organic electronic devices.

## References:

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## Figures:



**Figure caption.** a) exTTF striped islands on Au(111) ( $176 \times 198 \text{ nm}^2$  STM image). b) PCBM selective growth on FCC areas of the  $22 \times \sqrt{3}$  herringbone Au(111) reconstruction ( $59 \times 60 \text{ nm}^2$  STM image recorded at 150 K). c) Lateral segregation into nanoscale “fingers” whose width is about 10 nm, which is comparable to the exciton diffusion length ( $118 \times 132 \text{ nm}^2$ ). d) Schematic representation of a hypothetical morphology for optimal solar cell efficiency.