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Team «Components for Optoelectronics and Photovoltaics» (OPTO – PV)

Title: «Photonic engineering in organic solar cells»

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Abstract: The team "Components for Optoelectronics and Photovoltaics" (OPTO-PV) is involved in organic and silicon photovoltaic cells: modelling of absorption in nanostructured films for photovoltaic cells [1], optical characterization of materials (ellipsometry, atomic force microscopy,…), electrical characterization of materials (light beam induced current, minority carriers and surface recombination measurement, DLTS and CV analysis…). The team is able to perform the fabrication of components in clean room environment.

In this presentation, we will discuss results obtained by using a software for automatic optimization of the optical field in organic solar cells [2]. Interference effects are taken into account inside the whole structure submitted to the AM1.5 polychromatic incident light. The effect of layer thickness variation on optical properties of single and multi-heterojunctions solar cells is demonstrated. Some optimization examples are given:

- Investigation of the short-circuit current density of organic solar cells based on P3HT/PCBM blend [3]. The dependence of short-circuit current densities versus the thickness of the blend is analyzed and compared with experimental data and with data extracted from the literature.

- Optimization of pentacene/PTCDI blends through optical modelling [4]. Comparison of experimental and simulated short circuit currents assuming no charge recombination allows us to evaluate the recombination losses at 31%. It is shown cells made with pentacene/PTCDI blends have the potential to reach short circuit currents as high as 13 mA cm^{-2}.

- Modelization of the influence of the (PEDOT:PSS) layer on the short circuit current density (J_{sc}) of single planar heterojunction organic solar cells based on CuPc/C60 active layer [5]. From external quantum efficiency and from our computations, the excitons diffusion length in CuPc and in C60 is estimated.

- Investigation of the potential and the efficiency limits of multi-heterojunction organic solar cells [6]. Different solar cells composed of the stack of n heterojunctions (n=3, 4 or 5) are optimised to predict the best device architecture as a function of the number of blend heterojunctions.

Another way to improve "light harvesting" in organic photovoltaic cells is the use of photonic nanostructures. We theoretically study a P3HT/PCBM ordered heterostructure periodically nanostructured in the form of a photonic crystal to increase its absorption of long wavelength photons. The periodic nanostructuration allows "slow Bloch modes" (group velocity close to zero) to be coupled inside the material. The P3HT/PCBM photonic crystal parameters are adjusted to maximize the density of Bloch modes and obtain flat dispersion curves. The light – matter interaction is thus strongly enhanced which results in a 35.6% increase of absorption in the 600 nm to 700 nm spectral range.

1. C. Hubert, C. Fiorini-Debuisschert, P. Raymond, J. M. Nunzi, J. J. Simon and L. Escoubas, "Spontaneous photo-induced structuration of the surface of Azo-Benzene polymer films by the molecular migration effect", J. of Non-linear Optics and Quantum Optics, **31**, n° 1/4, 221-230 (2004).
2. F. Monestier, Ph. Torchio, J-J. Simon, L. Escoubas, M. Cathelinaud, "Software for Automatic Optimization of the Electromagnetic Field in Organic Solar Cells", Non Linear Optics, Quantum Optics, **37** (1-3), 159 - 168 (2007).
3. F. Monestier, J.J. Simon, Ph. Torchio, L. Escoubas, F. Flory, S. Bailly, R. de Bettignies, S. Guillerez, and C. Defranoux, "Modeling the short circuit current density of polymer solar cells based on P3HT:PCBM blend", Solar Energy Materials & Solar Cells, **91,** 405 – 410 (2007)
4. F. Monestier, A. K. Pandey, J.-J. Simon, Ph. Torchio, L. Escoubas, J.-M. Nunzi, "Optical modeling of the efficiency limits of (Pentacene: N, N'- ditridecylperylene-3, 4, 9, 10-tetracarboxylic diimide)-blend solar cells", J. Appl. Phys. **102**, 034512 (2007).
5. F. Monestier, J-J. Simon, Ph. Torchio, L. Escoubas, B. Ratier, W. Hojeij, B. Lucas, A. Moliton, M. Cathelinaud, C. Defranoux, "Optical modeling of organic solar cells based on CuPc and C_{60}", accepted in Applied Optics.
6. F. Monestier, JJ. Simon, Ph. Torchio, M. Cathelinaud and L. Escoubas "Potential and efficiency limits of multi-heterojunction organic solar cells", EMRS Strasbourg (2007).