Design and Realisation of Organic-Metallic Rectenna Solar Cells

C. A. Reynaud[1], D. Duché[1], C. M. Ruiz[1], J. Le Rouzo[1], S. Labau[3], M. Pannebière[3], C. Gourgon[3], F. Pourcin[2], O. Margeat[2], J. Ackermann[2], J-J. Simon[1] and L. Escoubas[1]

[1] Aix Marseille Univ, Univ Toulon, CNRS, IM2NP, Marseille, France
[2] Aix Marseille Univ, CNRS, Cinam, Marseille, France [3] LTM CNRS, CEA Minatec, Uni. Grenoble Alpes, France

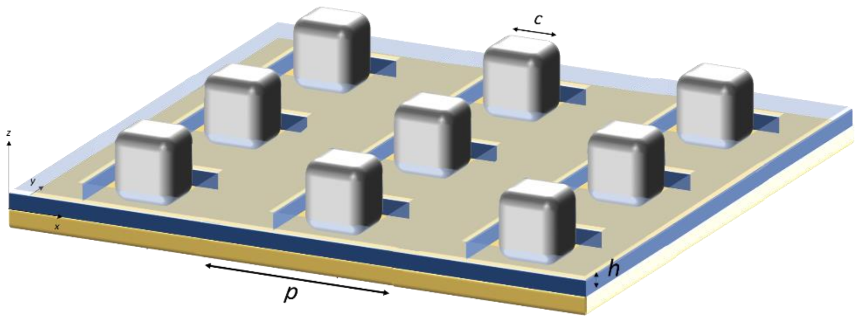

Fig1. Design of the rectenna nanocube-based array

Going beyond the limitation of current photovoltaic technologies requires a technological breakthrough to go further than the Schockley-Queisser limit [1]. In this perspective, rectennas solar cells could offer an alternative. The concept of optical rectennas goes back to the 70's when Bailey proposed that a nanoscale antenna coupled with a rectifier could harvest electromagnetic waves in the visible and infrared region [2]. Later, Joshi and Moddel built a photon assisted theory and predicted conversion efficiencies close to 100% for a monochromatic rectenna in the visible range. As for the performance under a realistic sun illumination, it was found to be 44% for a single rectenna geometry [3]. Unlike the Schockley-Queisser limit, this 44% limit does not rely on the material, but strongly depends on the rectenna geometry. This feature makes rectenna arrays good candidates for tandem-like structures based on several antennas sizes and shapes, and compatible with a low-cost process. Today, nanoimprint technologies and nanoparticles synthesis enable the fabrication of sufficiently small 3D structures to act as optical antennas. As for the rectifier element, MIM structures with a very small RC time could be a suitable solution [4], as well as organic molecular electronics which recently shown state of the art rectification ratio up to 10^5 [5].

Recent work have already demonstrated power production originating from optical rectennas [6], but research in this field remains at stage of proof of concept. In this work, we study and develop rectennas solar cells composed of plasmonic nanoantennas associated with rectifying self-assembled molecular diodes. By coupling a plasmon cavity mode between silver nanocubes and a gold plane, we obtain an electric field enhancement up to two orders of magnitude (intensity enhancement up to four orders of magnitude) that allows the rectification process to occur without any applied bias. The nanocubes are self-assembled thanks to dithiols rectifying molecule. By choosing a given molecule length, we can tune the gap thickness with a nanometer accuracy. A holed polymer matrix permits to control the periodicity of the nanocubes array, which has a crucial role in the optical behavior of the device (Fig1). We present optical characterisation of such samples of nanoantenna nanocube-based arrays (reflection measurements, Scanning Electron Miscroscope images, Raman spectroscopy and photoluminescence) compared with Finite Difference Time Domain (FDTD) simulations. Electric measurements under dark and illumination conditions are conducted at a local scale using a conductive-Atomic Force Microscope (c-AFM) coupled with a super continuum laser to detect power production in the visible range.

[1] W. Shockley and H. J. Queisser, *J. Appl. Phys.*, vol. 32, no. 3, pp. 510–519, 1961.
[2] R. L. Bailey, *J. Eng. Power*, vol. 94, no. 2, p. 73, 1972.
[3] S. Joshi and G. Moddel, *Appl. Phys. Lett.*, vol. 102, no. 8, pp. 1–5, 2013.
[4] S. Grover and G. Moddel, *IEEE J. Photovoltaics*, vol. 1, no. 1, pp. 78–83, 2011.
[5] X. Chen *et al, Nature Nanotechnology,* no. July, pp. 1–7, 2017.
[6] E. H. Shah and B. A. Cola, *IEEE Trans. Nanotechnol.*, vol. 16, no. 2, pp. 230–238, 2017.