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► **To cite this version:**

Romain Peretti, Thierry Deschamps, Guillaume Gomard, Xianqin Meng, Loïc Lalouat, et al.. Nanophotonics in photovoltaic cells for solar or indoor light trapping. META'13, the 4th International Conference on Metamaterials, Photonic Crystals and Plasmonics, Mar 2013, Sharjah - UAE, United Arab Emirates. hal-00804156

HAL Id: hal-00804156

<https://hal.science/hal-00804156v1>

Submitted on 25 Mar 2013

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Nanophotonics in photovoltaic cells for solar or indoor light trapping

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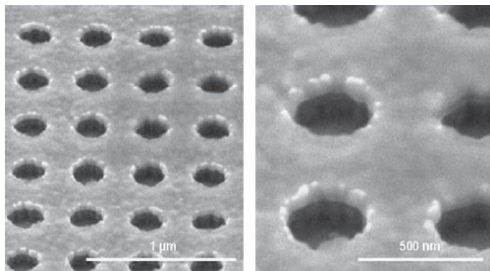
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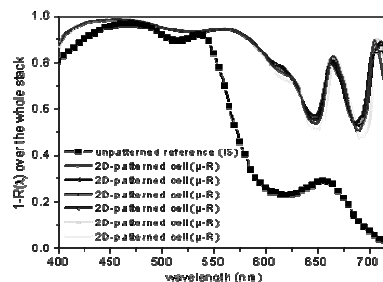
Abstract- We first introduce selected approaches, concepts and technological strategies to control light collection and absorption in photovoltaic ultrathin film cells for both solar and indoor light harvesting. We then illustrate light trapping into photonic crystal structures with examples of structures and devices, including 100nm thick hydrogenated amorphous silicon and 1 μ m thick crystalline layer solar cells. Finally, we discuss on the interest of photonic crystal structures to enhance non linear optical processes like down conversion for 3rd generation solar cells.

During the past decades, research in the field of photovoltaic (PV) solar cells was mainly driven by material development, technological upgrading and cost reduction. New challenges have emerged with third generation PV devices, with a view to achieving very high efficiency and low cost systems by using a wider spectral range. In this scope, the recent development of Nanophotonics has triggered the emergence of novel concepts for light management in photovoltaic cells. This includes incident light trapping and strategies to control light absorption in thin film photovoltaic cells especially with Photonic Crystal (Ph.C.) [1]: it enables to reach higher absorption increase with a high angular tolerance, over the whole solar spectrum that enables to reach a very high absorption increase, over the whole solar spectrum. These approaches allow facing specification of light absorption for both solar and indoor light. In the first case, the major issue is to enable a broadband absorption enhancement mostly under a normal incidence while in the second case, the Ph.C parameters are adjusted to achieve a robust optical response over a broad range of solid angles as well as to match the particular emission spectra of the indoor light sources.

a)



b)



Figures 1. SEM views of the photonic crystal structure (a), and absorption spectra under normal incidence measured for the reference and patterned structures (b).

In this communication, we will first introduce the design [2], fabrication, and optical characterization of photonic crystal hydrogenated amorphous silicon (a-Si:H) solar cells structures using 1D [3] or 2D Ph.C. [4, 5] as shown in fig 1. Such a corrugation of the cell allow to a broader spectral absorption but also a better angular response allowing being good candidate in both solar and indoor photovoltaic.

Then, we introduce designs and experimental results obtained for solar cell structures based on crystalline silicon layers with thicknesses in the micrometer range [6] demonstrating spectral and angular absorption enhancement.

In parallel, and to go further in the complexity of the cells, a better understanding of the phenomenon playing a role in light absorption in PV cell was studied [7, 8]. We used the “time domain coupled mode theory” to model light absorption in our device especially focusing in 2 modes interaction.

Lastly, as an outlook, we discuss on the possibility to assist UV light absorption and IR light emission, using a down conversion layer [9], especially useful in the case of indoor photovoltaic cells. For instance, rare earth doped thin layers can absorb UV light and convert down to IR light with an efficiency upper than 1 (1.3 in our case), which is more efficiently converted into an electrical current by a c-Si solar cell. The efficiency of this process can be greatly increased if, e.g., UV light absorption can be strongly enhanced by photonic crystals.

To conclude, using the possibility to take control of the properties of optical modes, including their photon lifetime and their radiation pattern, is a great opportunity to generate novel generations of photovoltaic cells exhibiting specifically designed characteristics that can handle absorption enhancement in both solar and indoor light harvesting.

Acknowledgements, This work was supported by Orange Labs Networks contract 0050012310-A09221, by the European Union (EU) PhotoNVoltaics project (Grant Agreement No. 309127), by the ANR “Sparcs” and “Nathisol” project and by the “Repcop” IMUST project.

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