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Innovation towards the fabrication of silicon solar cells on paper

A. T. Vicente, A. Lyubchik, M. J. Mendes, T. Mateus, A. Araújo, P. U. Alves, M. Ferreira, H. Águas, E. Fortunato, R. Martins

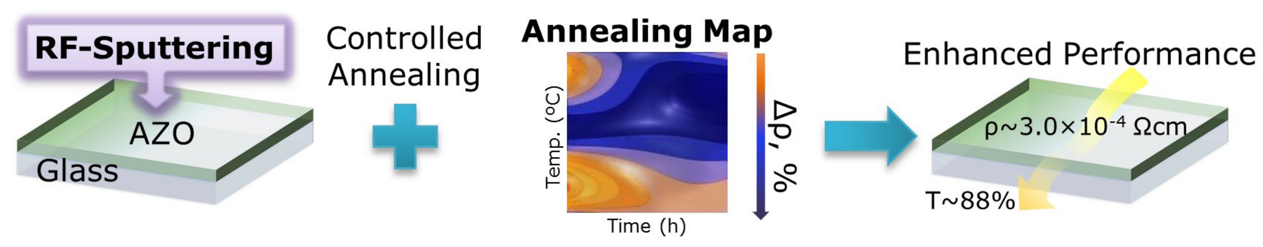
CENIMAT-I3N, Departamento de Ciência dos Materiais, FCT-UNL and CEMOP-UNINOVA, 2829-516 Caparica, Portugal

Introduction

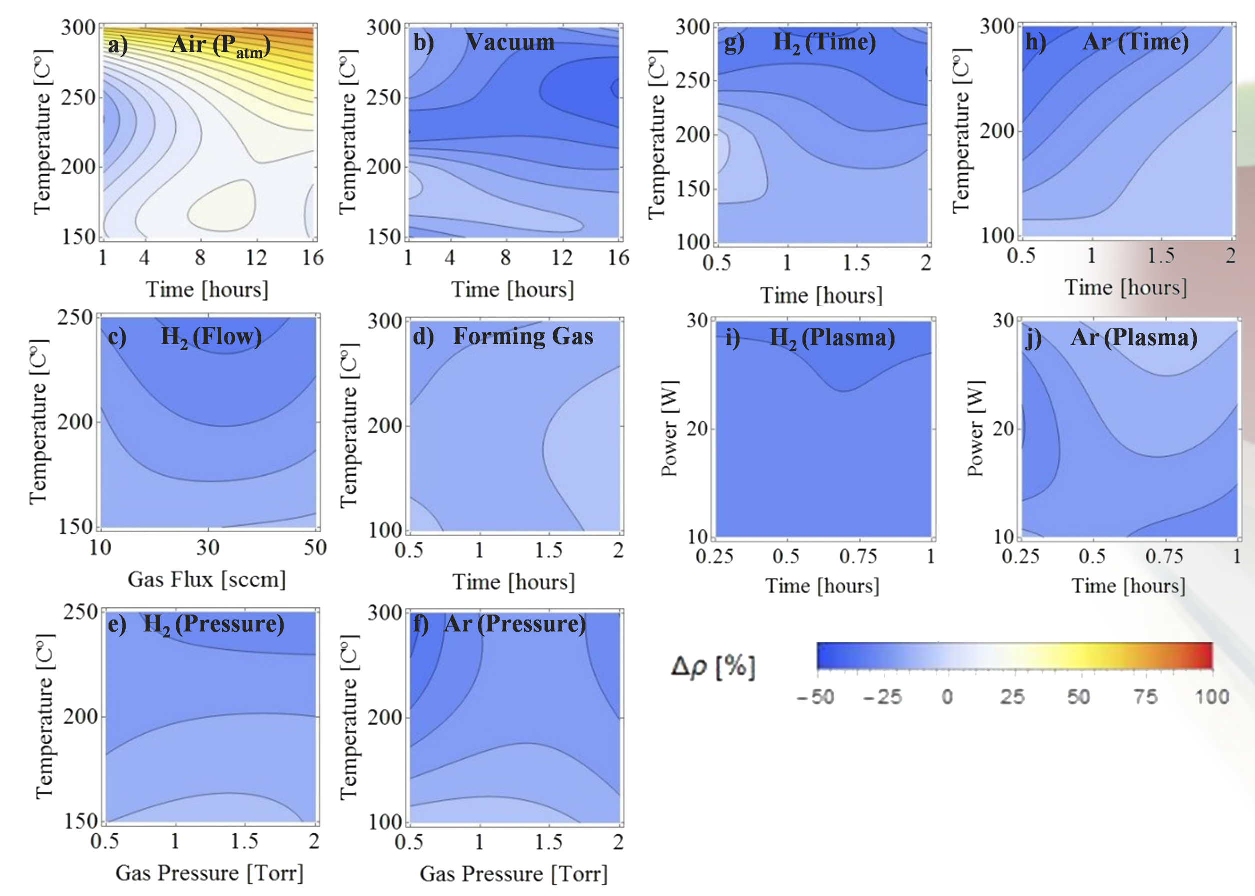
The growing interest in exploring thin film technologies to produce *n-i-p* silicon solar cells (SCs) on low cost substrates (such as ceramic, plastic and more recently, paper), with outstanding performances and capability to address the energy market needs, turns the optimization of their fabrication process a key area of development. A combination of design of experiments (DoE), experimental data, computer simulations and statistical analysis, provides the tools to explore in a multidimensional fashion (Multivariate Analysis, MVA) the interactions between fabrication parameters and maximize the expected experimental outputs. Further improvements can arise from the application of optimized light trapping structures on the device rear and/or front contact, and for cellulose-based substrates, the development of novel coating methods (to eliminate porosity and planarize the paper surface) is a noteworthy strategy to approximate the solar cell efficiency to those fabricated on regular substrates.

Mapping the electrical properties of Transparent conductive oxides (TCOs)

AZO films underwent different post deposition annealing treatments to analyze the thermally-induced physical transformations and optimize their optoelectronic properties.



Annealing maps indicating the relative change of the resistivity for AZO thin films



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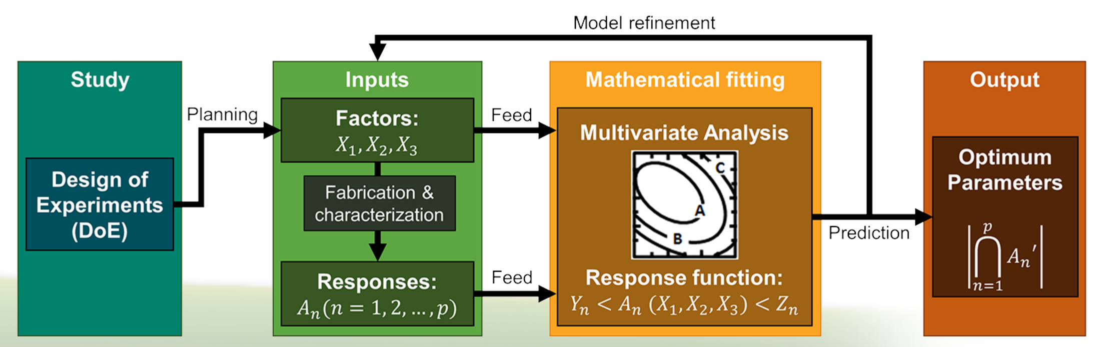
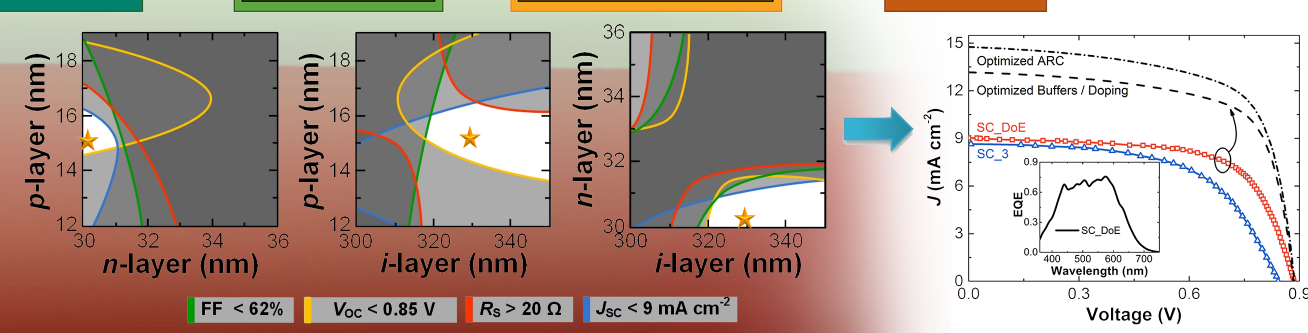
Statistical modelling approach for the optimization of silicon thin films and the photovoltaic structure

A method based in DoE and MVA was developed to optimize:

1) the low temperature deposition (150 °C) of high quality intrinsic amorphous silicon (*i*-a-Si:H);

2) the matching of the *n*-, *i*-, and *p*- silicon layers thickness to maximize the efficiency of thin film solar cells. The model was validated through analysis of variance and comparison with exact numerical simulations.





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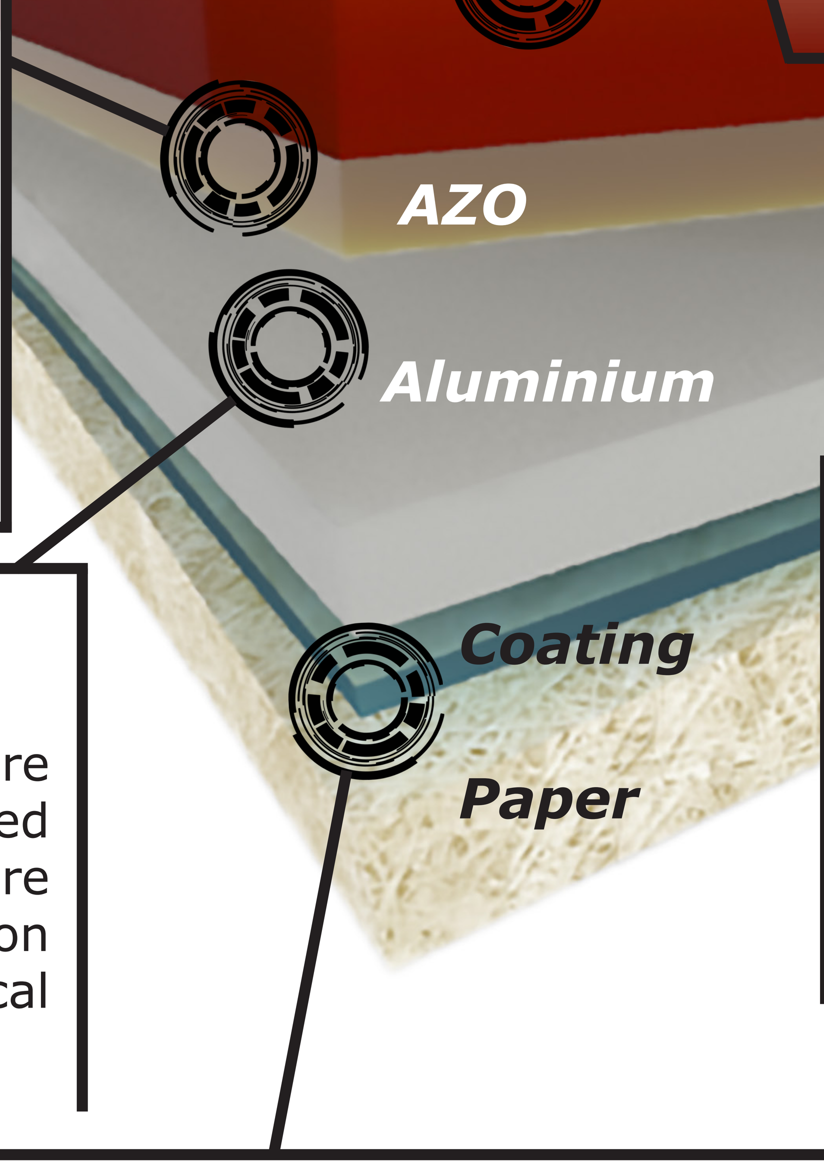
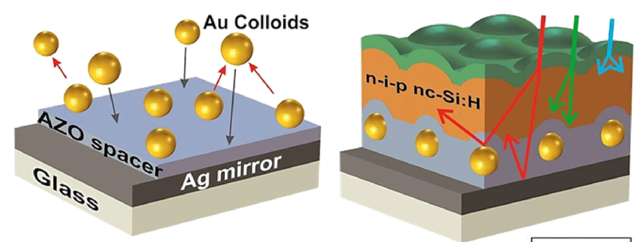
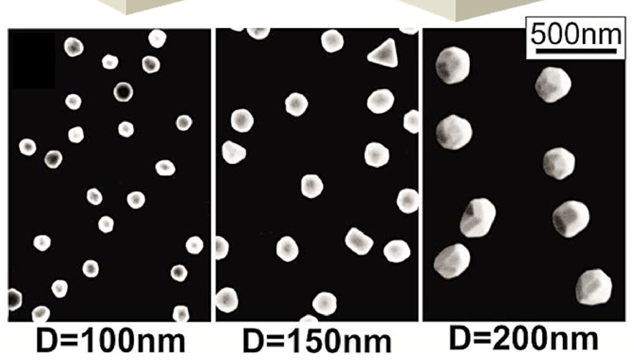
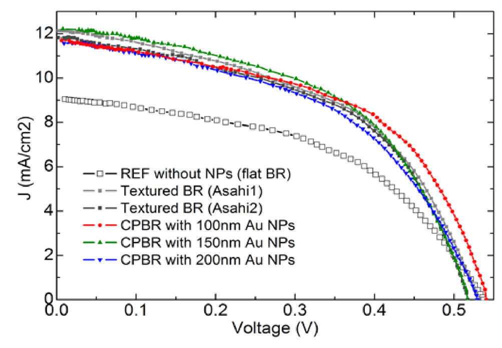


Light trapping with self-organized plasmonic nanospheres

Novel plasmonic back reflector structures were developed using spherical gold colloids for pronounced far-field scattering. The plasmonic back reflectors are incorporated in the rear contact of thin film *n-i-p* silicon SCs to boost their photocurrent generation via optical path length enhancement inside the silicon layer.



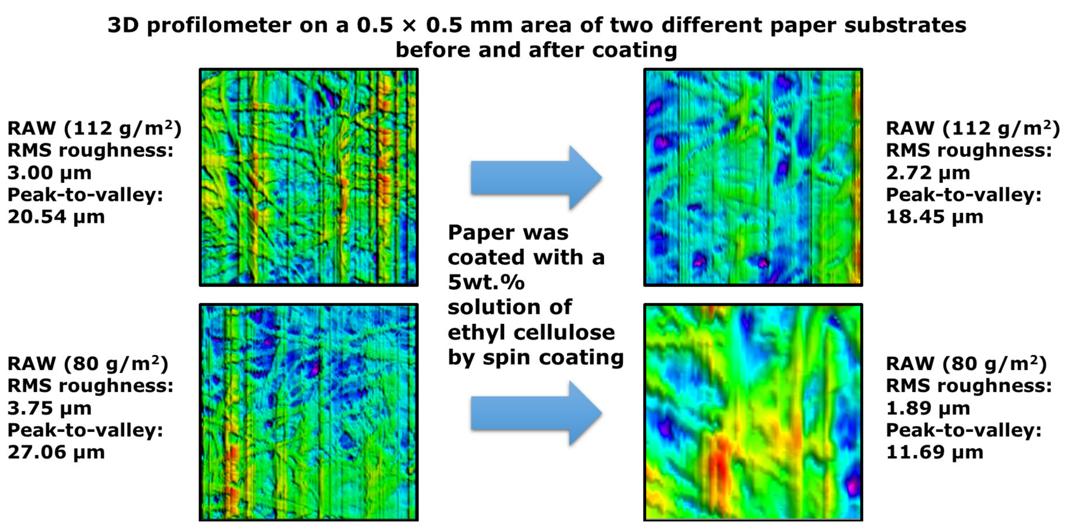




Published in Nanotechnology, 13, 26, 135202 (2015), DOI:10.1088/0957-4484/26/13/135202

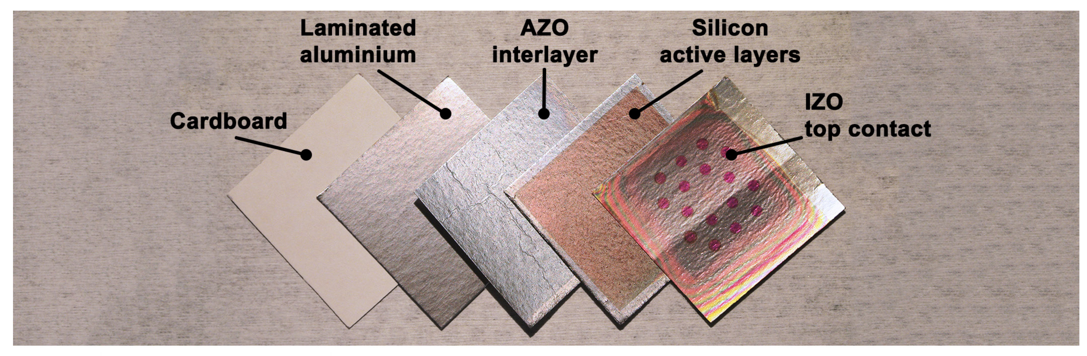
Novel coatings for porosity free and planarized cellulose substrates

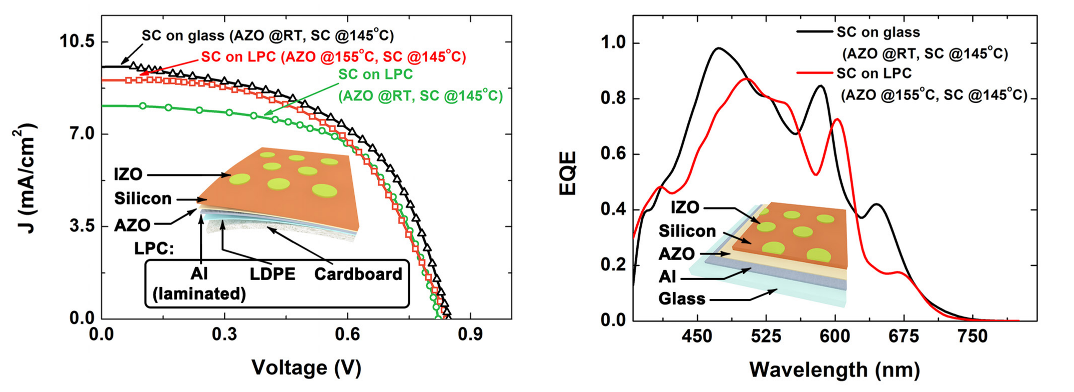
Paper as substrate poses critical challenges, given its highly rough and porous surface, which hinders the quality of the electrical devices and short-circuits solar cells. To overcome such drawbacks, novel coating methods based on sol-gel, ethyl cellulose and microfibrillated cellulose are currently under development, with promising preliminary results.

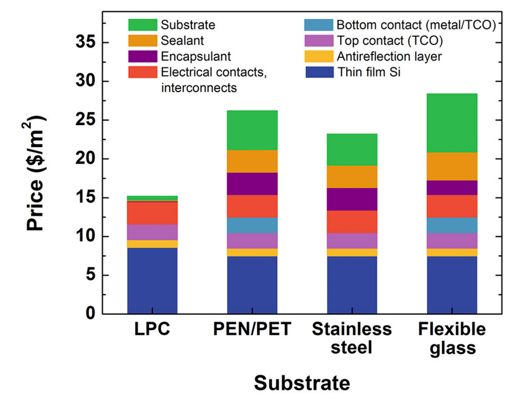


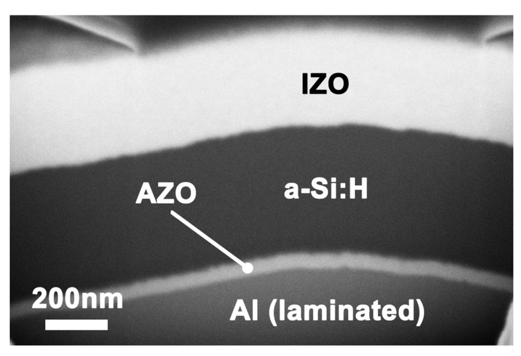
Solar cells for self-sustainable intelligent packaging

The layers' optimization study was implemented in the fabrication of SCs on a cellulose substrate, liquid packaging cardboard (LPC). The use of paper as substrate has significant advantages, since it a renewable source, easily recyclable and ideal for low cost, flexible, and disposable optoelectronic applications.









Published in J. Mater. Chem. A, 3, 13226-13236 (2016), DOI:10.1039/C5TA01752A

Conclusions

Our results confirm that the combination of these methods is an effective approach to reduce time, resources and the number of experimental sampling iterations needed to optimize thin film properties, the SC structural design, and achieve high efficiency SCs on cellulose substrates.

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