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PSEUDODISORDERED STRUCTURES FOR LIGHT TRAPPING IMPROVEMENT IN MONO CRYSTALLINE SI THIN FILMS

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1) Context / Study motivation

Light trapping structures are of crucial importance for ultra thin film crystalline Silicon solar cells, mainly due to the low absorption of this material in the red and near infrared part of the solar spectrum.

Photonic Crystals (PC) consisting in a direct square lattice of holes etched in the absorbing material have shown theoretically and experimentally [1, 2, 3] their ability to drastically enhance the absorption of the impinging light and thus of the short circuit current.

To go further, more complex designs have been proposed, such as pseudodisordered PC, consisting in periodic arrangements of large supercells of quasi randomly distributed holes (Fig. 1). Such optimized designs exhibit a well distributed and larger spectral density of modes, and thus a larger absorption [4, 5, 6].

This work aims at experimentally demonstrating the potential of pseudodisordered structures, compared to simple square lattices of holes, in a stack close to a realistic PV ultra thin film Si solar cell: mono-Si on Al on glass substrate.

2) Description of approach and techniques

The 1 μm thick thin film of mono crystalline material considered in this study is obtained by the "epifree" process and is bonded with an Al layer on a glass substrate [7].

The optimized designs have been obtained using an in-house developed electromagnetic RCWA simulation code.

A square lattice of holes, defined the period a , the radius r and the etching depth h of the holes, is optimized such as to maximize the integrated absorption.

The pseudodisordered structures have $N \times N$ holes, N an integer. They are defined by the size of the supercell that is defined by $N \times N$ times the period a and the individual displacements are measured by the fraction of the whole area which is perturbed ΔS . In this study, only a disorder in position is introduced, by shifting the center of each hole of the supercell.

For these preliminary samples, direct e-beam patterning of the resist has been used. The pattern has thus been transferred into a SiO_2 hard mask then into the Si using SF_6 :Ar RIE etching, offering good verticality of the side walls (Fig. 2).

Given the limited size (100x100 μm) of these preliminary samples, a micro reflectance setup was used to estimate the reflection and thus global optical absorption under normal incidence, but without the collection of some diffracted orders, inducing a slight overestimation of the absorption.

For several values of ΔS (0.5, 1, 1.5 and $2a^2$), 5 samples have been simulated, then fabricated and measured. For the absorption optimized periodic structure, 3 samples are available.

3) Results / Conclusions / Perspectives

Both preliminary simulations and measurements show an average improvement of the integrated absorption of about 2% by introducing a limited, properly chosen pseudodisorder in a regular, optimized square lattice of cylindrical holes having $a = 667$ nm, $r = 213$ nm, and $h = 213$ nm (Fig. 3).

As explained before, the experimental overestimated absorption compared to the simulated one is related to the measurement method. The discrepancies between the experimental and simulated series are due to remaining technological imperfections. Such imperfections also slightly impact the periodic structures.

Even if the global absorption is important (Fig. 4), optimization is still ongoing, in order to take into account an antireflection coating and to limit the absorption in the Al back mirror, e. g. thanks to the use of an electrically conductive optical spacer.

4) Acknowledgement

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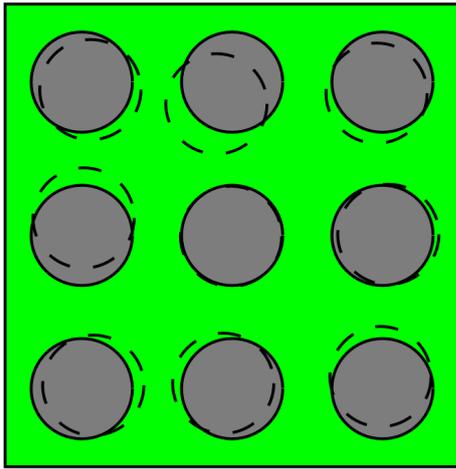


Figure 1: 3x3 pseudo-disordered supercell with $\Delta S = 1. a^2$

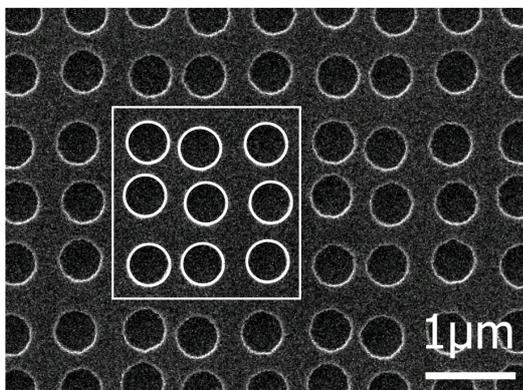


Figure 2: SEM view of the corresponding Si (1 μ m) /Al/glass sample

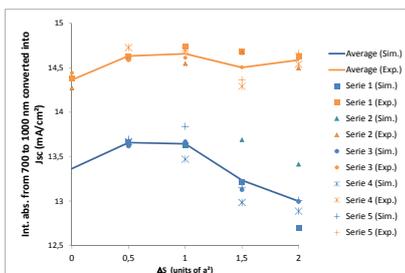


Figure 3: Experimental and simulated absorptions for several series of various amount of pseudo disorder.

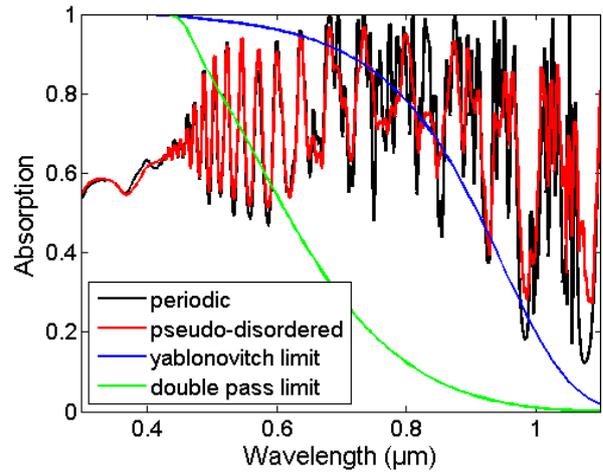


Figure 4: Simulated spectra of the total absorption of periodic and pseudo disorder samples shown in 3x3 pseudo-disordered supercell with $\Delta S = 1. a^2$

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