Optimization of photonic crystals to reduce the reflectance of silicon surfaces for solar cell applications.

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One factor that prevents silicon solar cells from reaching the 100% of their theoretical efficiency is the light reflection that occurs at their front surface. Many efforts have been done in the last few decades to reduce the reflectance by applying single or multi layers as antireflection coating [1-3] or by texturizing the front surface of the cell [4-7].

In this work, different kind of photonic crystals (PCs) have been employed to reduce the reflectance of a silicon surface. Since shape, periodicity, linewidth and height of the PC have an important influence on the spectral distribution of the reflectance, these parameters have been optimized by computer simulation to find the best periodic pattern. Some of the structures have been also fabricated by Laser Interference Lithography (LIL) and Reactive Ion Etching (RIE) and their reflectance has been optically characterized in the wavelength range from 400 to 1000 nm.

The study has been started with three types of 1D PC, shown in Fig. 1. The optimum dimensions of each type of PC have been found obtaining an average reflectance of 17.28%, 15.97% and 10.82% for the circular, rectangular and triangular PC respectively. Therefore, the best 1D PC found is the pattern of lines with triangular profile (Fig. 1 (b)) with a pitch of 460nm and a height of 323 nm. This structure has been fabricated and characterized by scanning electron microscope (SEM). Its reflectance has been measured with a spectrophotometer and compared with the simulation values, showing very good agreement (Fig. 2). As it can be seen in the graph, silicon reflectance has been reduced from values over 30% to an almost constant value of 10% for the simulated data and of 12% for the measurements in the range of wavelength from 600 to 900 nm.

Since triangular lines where the best 1D PC, inverted pyramids (2D PC) were also studied since they can be fabricated similarly to the triangular lines (Fig.3). This type of PC has been also optimized by computer simulation varying its parameters (pitch and height). The optimum structure found has a pitch of 760nm and a height of 537nm. Its reflectance is shown in Fig. 4 and can be compared with the reflectance of the best 1D PC. Except for a little peak at 640nm, the reflectance of the 2D PC is better than the one of the 1D PC in all the range of wavelengths simulated. The average reflectance for the inverted pyramids is of 9.5% in this range, having a minimum of 5% at 760nm.

References

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Figures

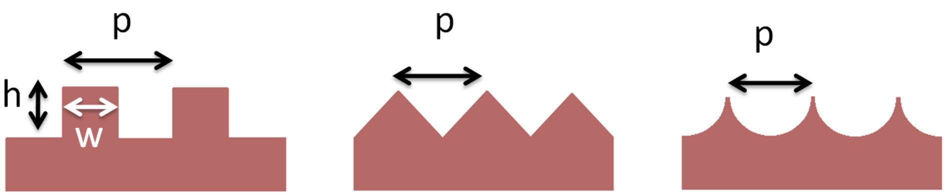

Fig 1. Designed 1D PCs with different profiles: (a) Rectangular; (b) triangular; (c) Circular.

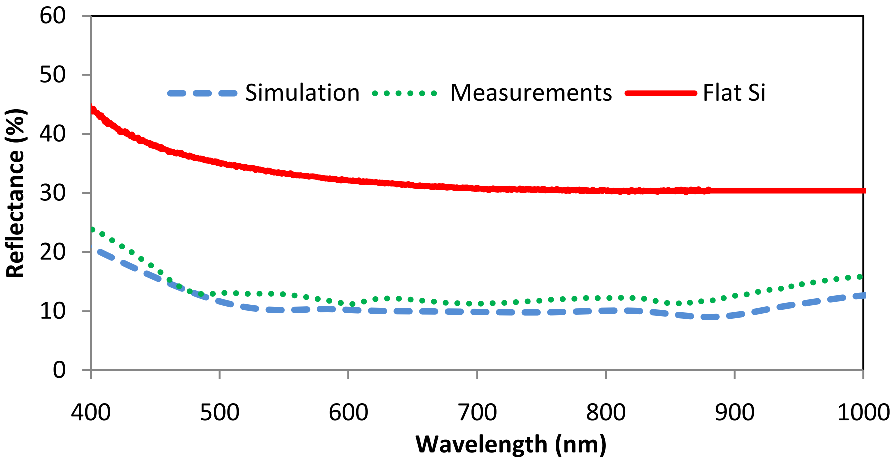

Fig. 2 Comparison between simulation and experimental measurements for the best 1D PC

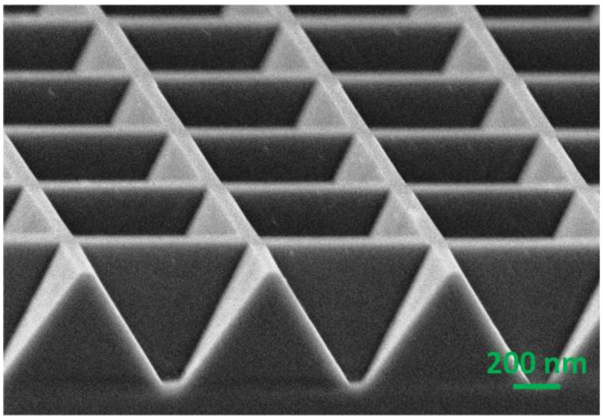

Fig 3. A SEM Image of a fabricated Inverted Pyramids pattern.

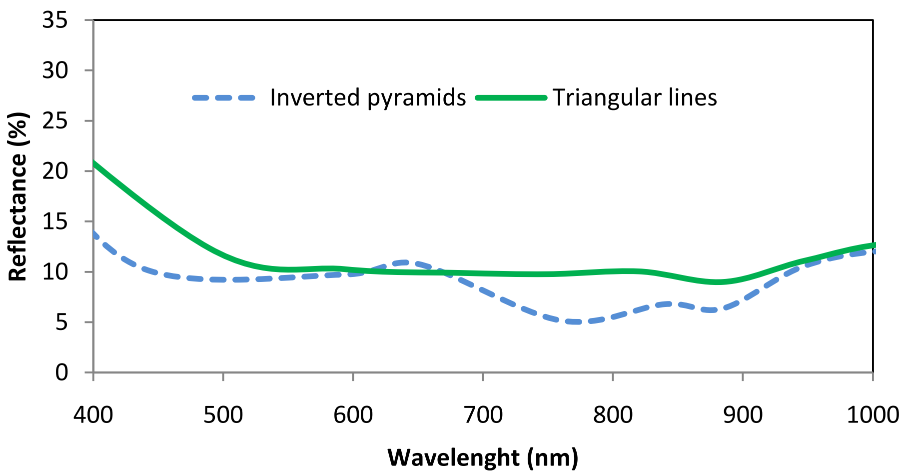

Fig. 4. Comparison of simulated reflectance for the best 1D PC and the best 2D PC.