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Analysis of Light Trapping Effects in Si Solar Cells with Textured Surface by Ray Tracing Simulation

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Introduction

Attainment of enhanced light confinement to increase cell efficiency has been one of the main foci in Si solar cells, and is becoming more crucial due to the recent efforts to fabricate thinner Si solar devices of low cost. Forming a lambertian surface using suitable texturing methods was proved to be an effective way of increasing light trapping, and has become an essential part of Si solar cell technologies. Most of the studies on surface texturing of Si surface and its effect on light trapping have been carried out experimentally by using wet etching techniques in which various etchants and processing parameters were tested repeatedly to obtain optimum texture. Numerical modeling could pave the way for not only for designing texture patterns as well as analyzing the effects of textured states on light trapping efficiency. However, only limited applications of numerical simulation for such purpose has been performed largely due to the fact that most of numerical models relied on an indirect or an approximated method, there by leading to inability to take into account of fully realistic optical environment and resulting in inevitable inaccuracy in calculation. Recently, we introduced a direct calculation method based on Monte-Carlo ray tracing techniques, in which direct calculation of the accurate amount of absorbed energy regardless of coherent and/or incoherent light inside the medium by separating the light passing through the medium into the coherent part and the incoherent part in the course of non-sequential ray tracing throughout the whole region of solar cell structure. In this study, we performed simulations on three-dimensional (3-D) pyramid patterns on Si surface, which are usually produced in wet chemical etching of (100) Si surface, with varying pyramid pitch and space between them, and analyzed the effects of pyramid pitch and space on optical reflectance by comparing with available experimental results.

Simulation & Experiment Results

● Optical simulation parameters and results

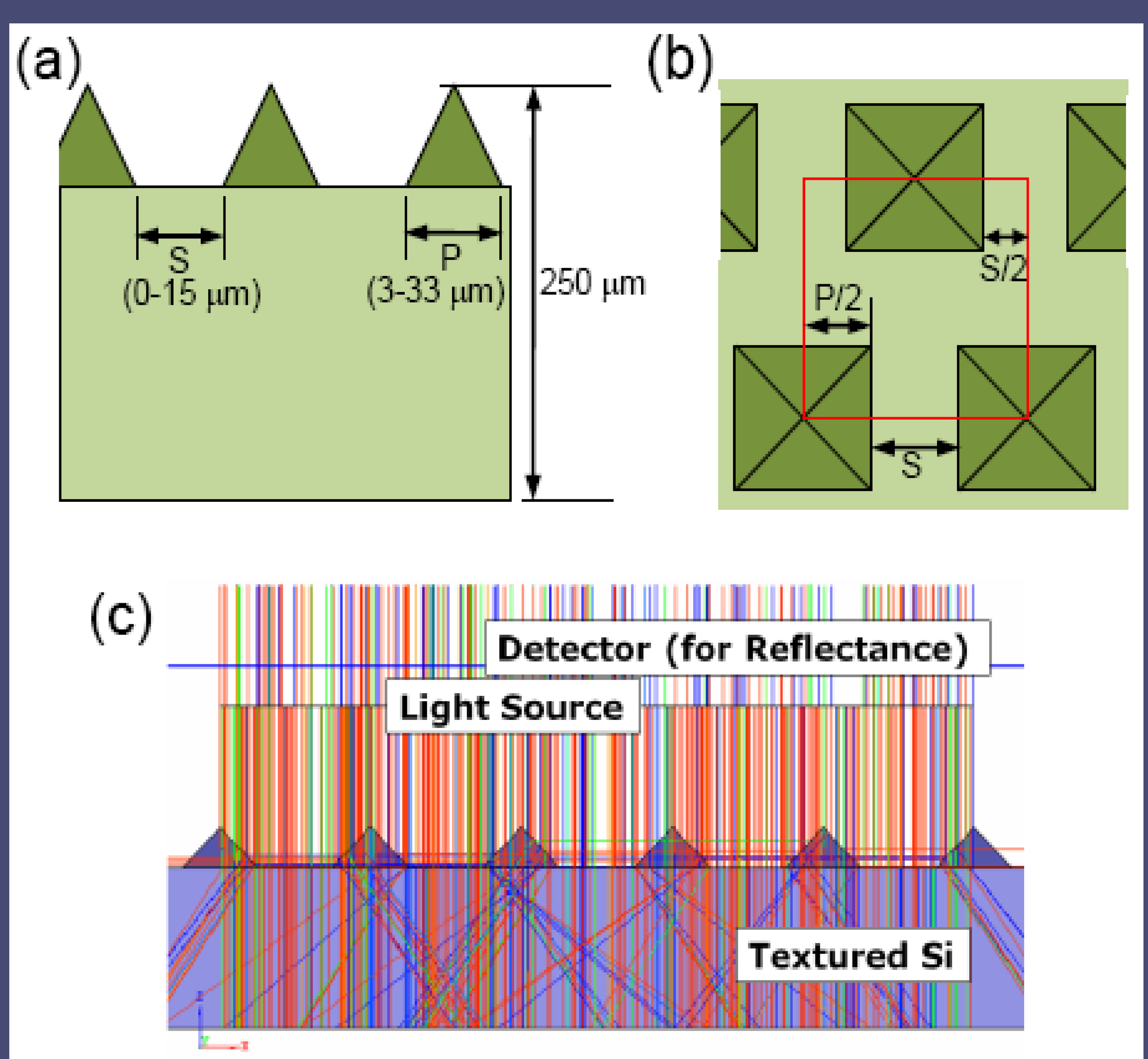
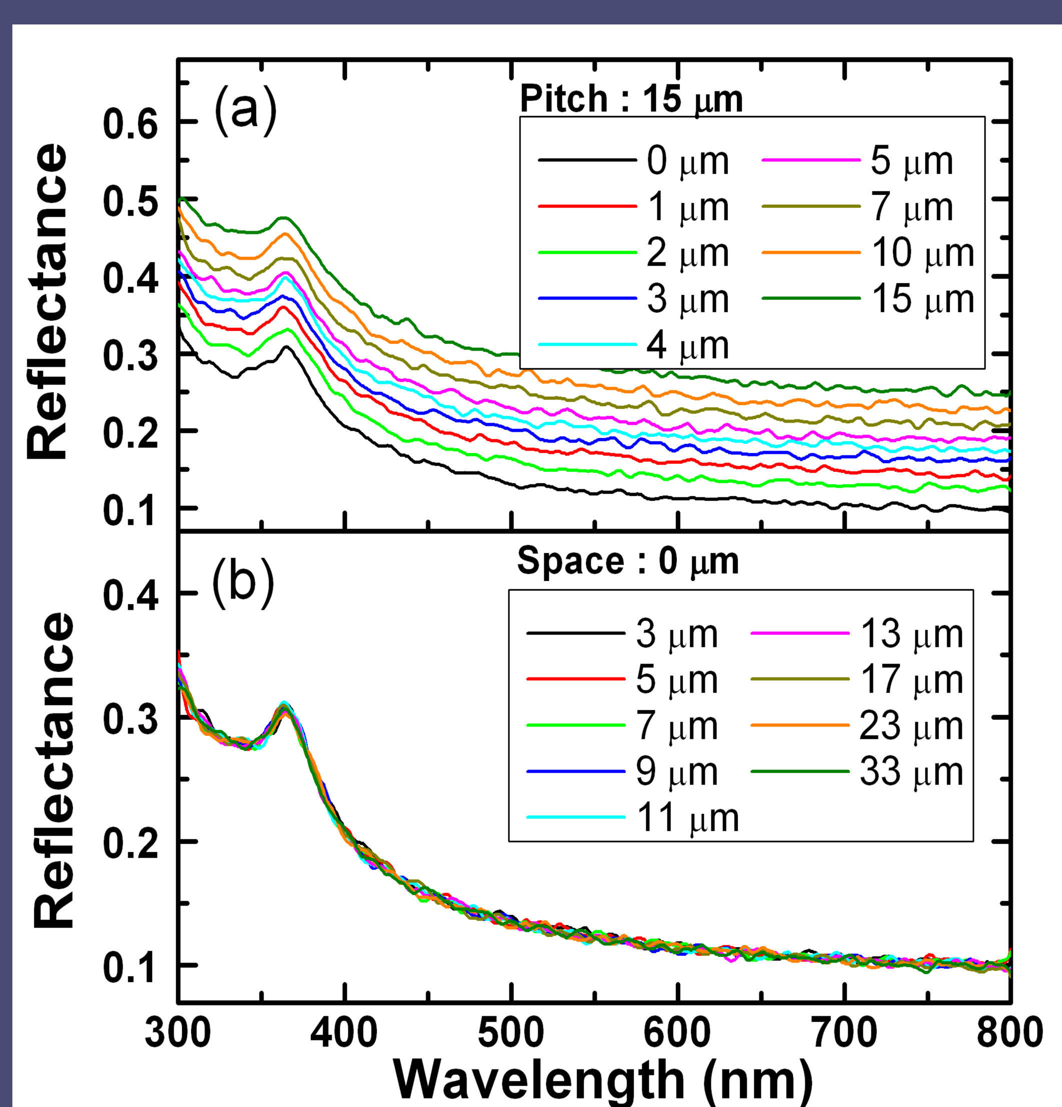


Fig. 1. Schematics of cross sectional (a) and plan view (b) for simulation geometry, and (c) optical simulation structure for reflectance and absorption .



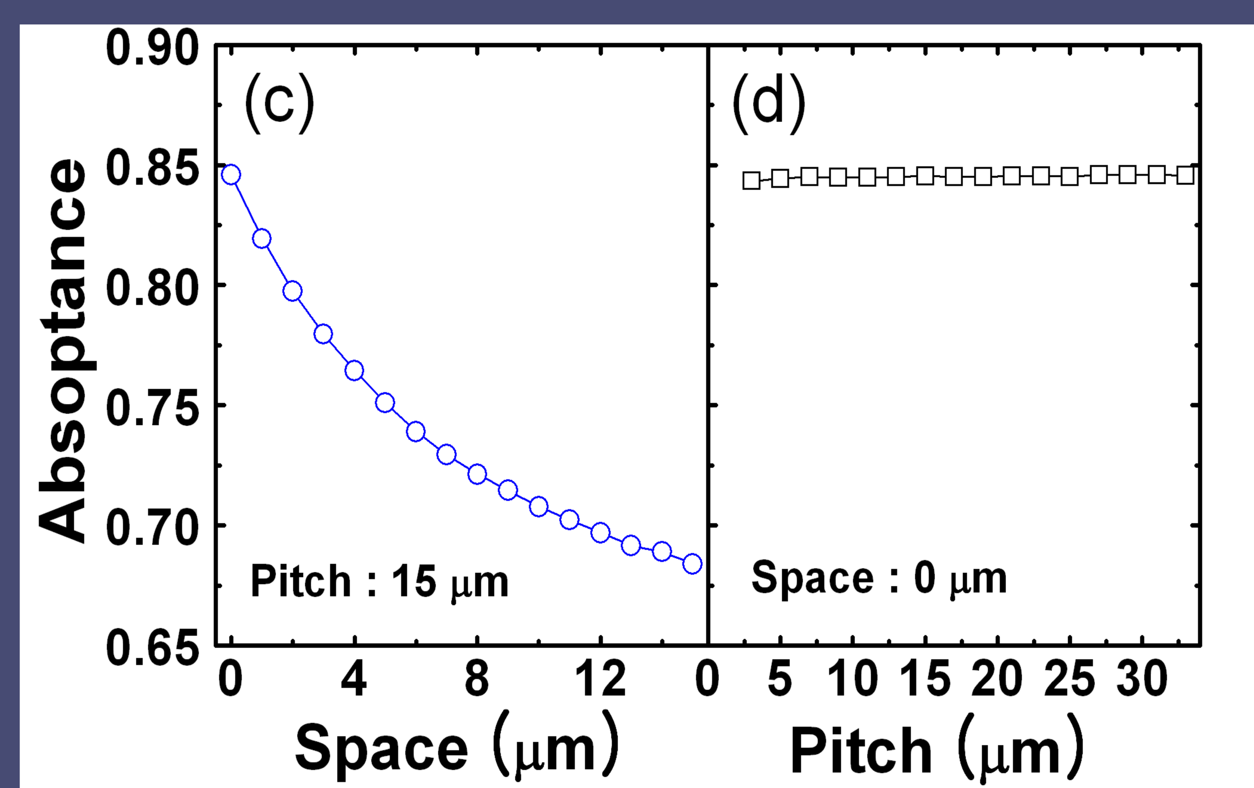
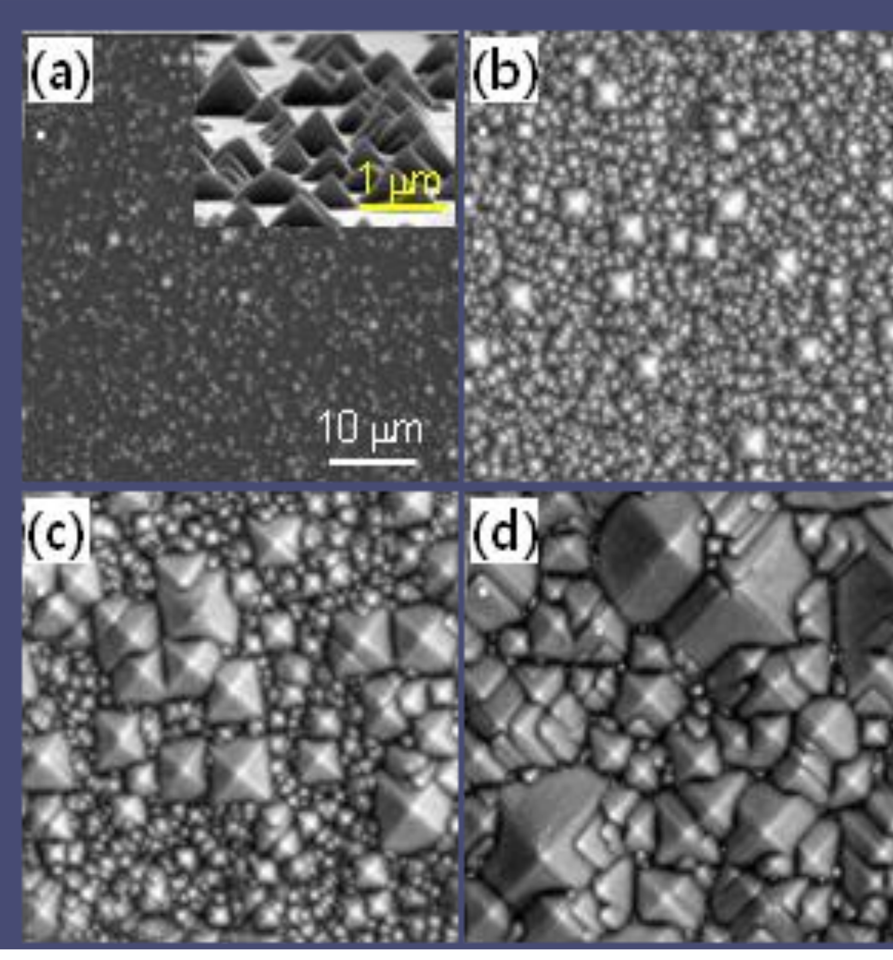


Fig. 2. Simulated reflectance spectra of textured surface with varying space (a)and pyramid size (b). (c) and (b)(d) are the average absorptance (c)corresponding to (a) and (d), (d)respectively.

● Chemical etched Si surfaces and measured reflectance



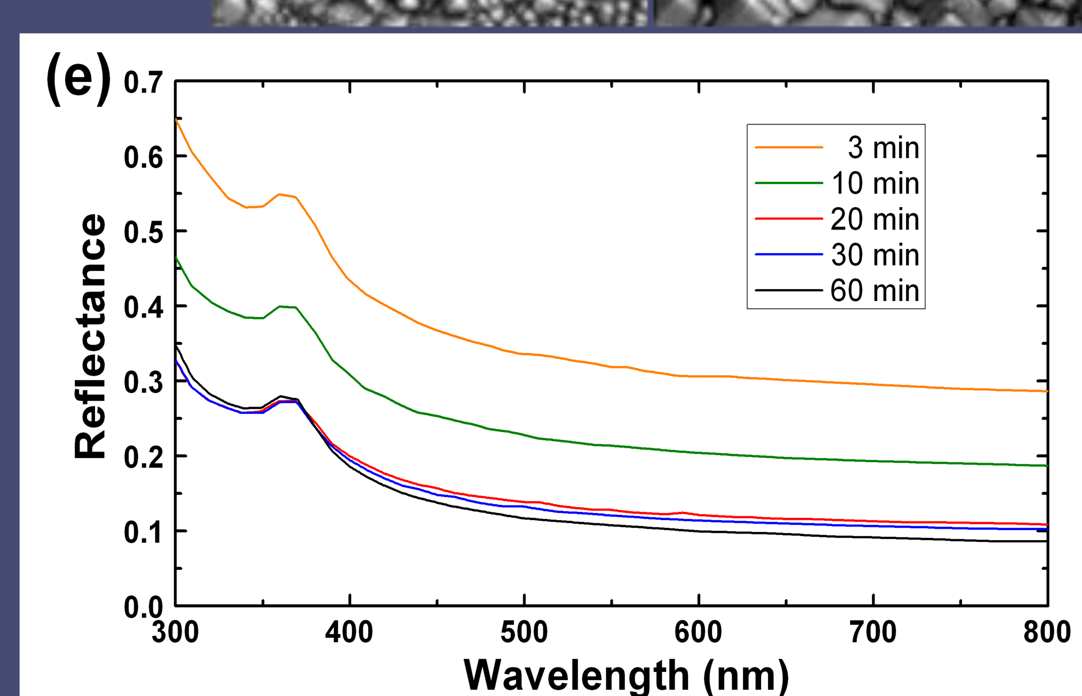


Fig. 3. SEM micrographs of Si surfaces etched for (a) 10, (b) 20, (c) 30 and (d) 60 min. (e) The measured reflectance spectra of etched Si surfaces.

Conclusions

➢ In this study, we examined the effect of pyramid size and space between pyramids on the optical reflectance and absorptance by comparing the simulated results with experimentally observed results.

➢ Simulation was carried out by using newly developed "RaywizSOLAR" which is capable of direct calculation of the accurate amount of absorbed energy regardless of coherent and/or incoherent light inside the medium.

➢ Simulation showed that pyramidal pitch did not affect the optical reflectance and that optical reflectance decreased monotonically with decreasing space between pyramids, i.e., increasing density of pyramid.

➢ Experimentally textured surfaces exhibited corresponding behavior with the simulation, indicating that surface coverage of pyramid is most important factor in deciding the optical behavior of the textured Si surface. But it was suggested that the larger size of pyramids was better in that large pyramids decrease the probability of forming relatively flat region in valleys between the pyramids.

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