Light-trapping optimization in wet-etched silicon photonic crystal solar cells

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Abstract

We demonstrate, by numerical solution of Maxwell's equations, near-perfect solar light-trapping and absorption over the 300-1100 nm wavelength band in silicon photonic crystal (PhC) architectures, amenable to fabrication by wet-etching and requiring less than 10 mu m (equivalent bulk thickness) of crystalline silicon. These PhC's consist of square lattices of inverted pyramids with sides comprised of various (111) silicon facets and pyramid center-to-center spacing in the range of 1.3-2.5 mu m. For a wet-etched slab with overall height H - 10 mu m and lattice constant a - 2.5 mu m, we find a maximum achievable photo-current density (MAPD) of 42.5 mA/cm(2), falling not far from 43.5 mA/cm(2), corresponding to 100% solar absorption in the range of 300-1100 nm. We also demonstrate a MAPD of 37.8 mA/cm(2) for a thinner silicon PhC slab of overall height H - 5 mu m and lattice constant a - 1.9 mu m. When H is further reduced to 3 mu m, the optimal lattice constant for inverted pyramids reduces to a - 1.3 mu m and provides the MAPD of 35.5 mA/cm(2). These wet-etched structures require more than double the volume of silicon, in comparison to the overall mathematically optimum PhC structure (consisting of slanted conical pores), to achieve the same degree of solar absorption. It is suggested these 3-10 mu m thick structures are valuable alternatives to currently utilized 300 mu m-thick textured solar cells and are suitable for large-scale fabrication by wet-etching. (c) 2015 AIP Publishing LLC.

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