Symmetry-Breaking in Light-Trapping Nanostructures on Silicon for Solar Photovoltaics

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Current c-Si solar cells, which comprise 80-90% of the solar cell market, typically use 100-300 μm thick silicon wafers to absorb sunlight adequately and these wafers account for about a half of the total module cost. To reduce the cost by using thin c-Si films, highly efficient light trapping is required. For thin-film photovoltaics, nanoscale structures are typically involved for light trapping because the film thickness becomes comparable to the wavelength of sun light. While diverse nanostructures have been studied to break the light-trapping limit of geometric optics, known as the Lambertian limit, highly efficient nanostructures that can be easily manufactured have not been demonstrated. We have previously predicted that symmetry-breaking in light-trapping periodic nanostructures on thin films can approach the Lambertian limit very closely. Herein, we will present how the systematic symmetry-lowering increases light-trapping in thin-film photovoltaics. Specifically, we will show that, as the symmetry is systematically lowered, the number of optical absorption peaks increases in a manner consistent with group theory. When the nanostructures were optimized to maximize the integrated absorptance over a spectral band of interest, the integrated absorptance increased by symmetry-breaking. Further, we will demonstrate the experimental realization of such low-symmetry structures using simple wet etching methods on c-Si(100) wafers. Our method of symmetry breaking would provide an ideal experimental platform to study the effect of symmetry breaking on diverse phenomena beyond light trapping.

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