Surface Arrays of Subwavelength Features for Photovoltaic Applications

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Abstract

Light trapping and the broadband absorption of the solar radiation is of interest to various solar energy harvesting applications. We report a new paradigm for light trapping, that is light trapping based on arrays of subwavelength nonimaging light concentrators (NLCs). We numerically show that silicon NLC arrays provide>75% broadband absorption and nPCE enhancement of the solar radiation compared with that of optimized nanopillar arrays. We next, examine both numerically and experimentally omnidirectional light trapping driven by deep sidewall subwavelength structures (DSSS) in silicon nanopillar (NP) arrays (DSSS arrays). Specifically, we show a decrement in the omnidirectional broadband specular reflection of up to 40% for certain angles of illumination, and about 13% decrement in the total reflectivity for DSSS array relative to SSNP array. Importantly, it is shown that the introduction of DSSS systematically blue-shifts the absorptivity peaks of the NP arrays and in this manner a deterministic light trapping is possible.

To this end, various surface silicon arrays are realized in a top-down fabrication process: NP arrays, NP arrays incorporated with DSSS (DSSS arrays), NP arrays incorporated with qNL (qNL arrays), NP arrays incorporated with qNL and DSSS (qNL-DSSS arrays) and NP arrays that are transformed into LF arrays and are complimented with qNL and DSSS (qNL-DSSS-LF arrays). It is shown experimentally that the utilization of deep subwavelength features produces a decrement in broadband reflection, relative to an SSNP array, with an almost 80% decrement for normal incidence and 60% decrement for angle-of-incidence of 80°, both for unpolarized illumination. Similar response is also measured for polarized illumination. Also, the introduction of deep subwavelength features concludes a decrement of 20% in the broadband diffused reflection in comparison with the undecorated NP arrays. The research methodology combines numerical and experimental work. The optical response of subwavelength arrays was studied using finite-difference time-domain (FDTD) electromagnetic calculations, and the electrical performance was conducted using device calculations solving the Poisson and Continuity equations. The experimental work involves far-field spectroscopy.