Optical properties of disordered vertical nanowire arrays

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At the present time, the majority of the photovoltaic market is dominated by crystalline silicon solar cells and modules based on that technology. In some places, the cost of the energy generated by photovoltaic panels is in the parity with the cost of the electricity from the grid [1]. While the cost of the modules has decreased significantly during the last few years [2], the goal of the photovoltaic industry is to further reduce the cost per watt and to make the renewable solar energy competitive with the energy from fossil fuels. A significant part of the silicon solar panel cost is formed by the crystalline material, which has led to strong industrial efforts to develop technologies for handling of thinner wafers and attempts to further reduce their thickness [3]. However, the reduced wafer thickness does not reduce only cost, but also the absorption inside the silicon or more precisely the device performance.

In this work we study optical properties of vertical silicon nanowire (SiNW) arrays fabricated using metal assisted chemical etching (MACE) coupled with nanosphere lithography (NSL). We have studied optimal configurations minimizing total reflectance of 2 μm long SiNW arrays by modeling and compared their performance with experimental data. Fabricated SiNW arrays have shown lower total reflectance than modeled perfectly periodic ones. This has been found to be due to a variation of NW geometry and the presence of domains caused by the self-assembly during NSL process. We have developed a statistical model (based on rigorous coupled wave analysis) describing geometry variations and also demonstrated that different domains have rotated diffraction pattern with respect to their symmetry axes. The statistical model has been successfully validated on total reflectance and normalized Mueller matrix data. Furthermore, we have found that a very high light trapping can be achieved for nanowires only 125 nm long, which can be exploited in thin and ultra-thin Si solar cells [4].

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