Applications of Nanofabrication: Structural Absorption Engineering and Optomechanically-Responsive Photonic Circuits

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Nanofabrication technologies enable the patterning of materials on the scale of the wavelength of light, opening up new vistas in the photonic designer's toolkit. We will present our recent research on the design of photonic materials for thin-film photovoltaics and reconfigurable photonic integrated circuits.

There is growing interest in using nano- and microscale patterning to increase the absorption of light within small volumes, with the ultimate goal of making cheaper, more efficient solar cells. We present our computational work on silicon nanowire arrays for photovoltaics. We use large-scale, parallelized electromagnetic simulations to probe the ultimate efficiency of silicon nanowire structures, with the goal of understanding how the structure can be engineered to increase broadband absorption. We show that optimized nanowire arrays can have higher broadband absorption than unstructured thin films, even though they contain less absorptive material. We then use optimal design strategies to demonstrate aperiodic structures with >100% absorption increase relative to their periodic counterparts. Lastly, we examine the effect of metallic caps on the nanowire tips. Contrary to many examples in which such plasmonic particles increase solar absorption, we find that silver, gold, and copper hemispherical caps all decrease the solar efficiency.

Photonic integrated circuit technologies leverage nanofabrication techniques to control the flow of light on chip. We present designs for a class of integrated photonic devices in which the force of light flowing through the devices results in mechanical motion. We map out several applications of optomechanical response to on-chip optical signal processing. We first present a coupled-waveguide system in which pump light can be used to switch the polarization of a probe signal from linear to circular polarization. We then present calculations illustrating how mechanical motion gives rise to effective Kerr nonlinearities that are mechanical in origin. Finally, we present a photonic-crystal waveguide system that acts as a power limiter.