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Inorganic Phototropic Growth of Materials that See the Light

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Abstract

We have discovered a materials phenomenon, which we term inorganic phototropic growth, in which materials grow in real time, in 3-D space, towards a uniform intensity, uncorrelated beam of low intensity light, as occurs in for example palm trees, sunflowers, and corals. The growth results in the rapid, light-directed formation of anisotropic complex, three-dimensional mesoscale morphologies of materials over macroscopic areas, providing access to nanostructures and morphologies that can not readily be made by any other method. The phenomenon transcends traditional chemical and engineering disciplines: no lasers, no physical masks, no lithographic processing, no direct-write technology, no far-field modulation, no templates, and no chemical agents (ligands, surfactants) are used to direct the patterning, but full 3-D control is obtainable over the resulting morphology of the structure by manipulation the properties of the incident light stimuli during growth. The nanostructures are created in a single-step synthesis and are determined both by the inherent response of the electronic processes within semiconductors to the presence of light, and by the tunable properties (e.g. wavelength, polarization, and direction) of light present during the electrodeposition. We have experimentally explored this emergent phenomenon by determining how specific optical inputs encode for specific morphologies, and have developed a model that accurately reproduces the experimentally observed nanostructures for the optical inputs and material systems explored thus far. Our work to date has been focused on the growth of Group II-VI materials (i.e. Se-Te alloys and PbSe); however, we expect that the emerging phenomenon underlying the growth process will prove general for the electrodeposition of semiconductors in the presence of light. We provide a brief overview of our work to date, and outline research directions designed to provide the further scientific insight into the processes behind this novel route to nanoscale and mesoscale materials design and synthesis that will be essential to the development of future technologies that exploit the phenomenon.