Simply Complex: A Novel Approach to Engineering Complex Materials and Behavior

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Complex structures and behavior that we see in Nature is repeating in multitudinous material systems at vastly different length scales. This strongly suggests the existence of universal rules that govern emergence of such similarities. Although there is no general theory for complex systems, this does not stop us from experimentally exploring controlled creation of complex structures and behavior, inspired especially by biological organisms. In this talk, I will present a novel methodology to fabricate complex structures and to facilitate emergence of complex behavior from completely different materials systems at different length scales. The methodology exploits self-assembly and self-organization far from equilibrium when the system is highly nonlinear and subject to strong fluctuations [1-4]. I will first present how the triple mechanism of nonlinear interactions, feedback and fluctuations can be utilized, controlled and steered towards fabrication of complex structures and behavior of various materials systems, then, I will show demonstrations of the methodology in diverse systems ranging from silicon atoms to colloidal nanoparticles to microorganisms to sub-10 nm particles.

[1] B. Öktem, *et. al.*, "Nonlinear laser lithography for indefinitely large area nanostructuring with femtosecond pulses," Nature Photon. 7, 897-901 (2013).

[2] S. Ilday, *et. al.*, "Multiscale self-assembly of silicon quantum dots into an anisotropic three-dimensional random network," Nano Lett. 16, 1942-1948 (2016).

[3] S. Ilday, *et. al.*, "Rich complex behavior of self-assembled nanoparticles far from equilibrium," Nature Commun. 8:14942 (2017).

[4] O. Tokel, *et. al.*, "In-chip microstructures and photonic devices fabricated by nonlinear laser lithography deep inside silicon," Nature Photon. 11, 639–645 (2017).