Project Abstract

The goal of this proposal is to discover how to create synthetic materials that have the complexity and functionality of living ones. Biological systems can assemble structures that we cannot fabricate on the nanoscale, but would have significant engineering impact if they could be made robustly with standard materials. Examples range from twisted filaments, to reconfigurable containers and structural supports, to systems for sensing and precisely filtering small molecules. Even more revolutionary would be the development of synthetic materials with the essential properties of living systems, including self-replication and the ability to naturally develop coupled catalytic reactions. The recent revolution in the ability to functionalize submicron scale objects – such as colloidal particles, nanotubes and nanoparticles – with molecules that can create specific and reversible interactions between the objects have opened the possibilities of programming complex assemblies and behaviors into ordinary materials.

Taking advantage of these capabilities requires surmounting a critical challenge. The properties that we seek to emulate are very special, existing in only a small part of an immense parameter space. Biology finds the correct regime through billions of years of natural selection. We must discover how to find the relevant regime ourselves, in materials of importance for engineering. Our technical approach uses three distinct methods, including (i) algorithm development and brute force search; (ii) biomimetic design, based on analogous systems in biology; and (iii) the development of experimental evolution approaches. The materials we seek to design consist of a combination of submicron- or nano-particles and polymers—synthetic analogues of the proteins and nucleic acids that give such rich behaviors in living systems. The ultimate aim is both to develop a fundamental understanding into the difference between living and dead materials, and to find qualitatively new materials with novel electrical, mechanical and chemical properties for a variety of DOD missions.