

Statement of Objectives: A Vannevar Bush Faculty Fellowship will enable the development of basic science and fundamental concepts for the stabilization, manipulation, and applications of complex smart colloids (CSCs). We recently discovered a transformational scheme for the **scalable production** of CSCs, with **precise shapes** and methods to **dynamically switch** their morphologies. We propose hypotheses for the design of new dynamic forms of liquid matter (i.e. CSCs) that can be used to create **precision 3D objects, structured optical coatings, metamaterials, and biosensors**. Our designs utilize novel polymers, molecules, and molecular switches as structural controlling elements. Our comprehensive, multifaceted, and the basic science approach will empower **novel application concepts**. Objectives 1-4 develop new **fundamental methods/concepts** and Objectives 5 & 6 represent **integrated systems**.

1. **CSCs Comprising 3-5 Immiscible Liquids:** Increasing complexity and mass production of CSCs require multiple innovations. Conventional microfluidic routes to complex liquid colloids containing 3 or more phases are not easily scalable, and our *simplified single-phase manufacturing method* enables large scale production of CSCs. Designer combinations of liquids will be developed, and molecules/polymers will stabilize all interfaces to prevent disproportionation of multi-component CSCs. Polymer and nanoparticle solutes will provide function and/or create “*cytoskeletons*” that stabilize CSCs and control their structures.
2. **Interfacial Tensions and Manufacturing of Precision Objects:** To create intricate CSC structures and their conversion to precision objects requires the balancing of interfacial and line-tensions. The proposed CSCs require *new generations of multicomponent surfactants* at all 1- and 2-dimensional interfaces. Designer surfactants will stabilize interfaces to create complex surfaces that are thermodynamically directed into precisely defined minimum curvature structures (Enneper’s surfaces) and can be converted to 3D objects or gels.
3. **Switchable/Reactive Surfactants:** Active surfactants will be designed that change shape, allow for bioconjugation, or undergo triggered assembly/disassembly. These will endow CSCs with *added functions* and will provide *thermodynamic* insights. These new systems can be stimulated chemically, electrically, magnetically, or optically. Oligomerization, polymerization, and crosslinking will increase surfactant effectiveness and CSC stability.
4. **CSCs for Deposition of Structured Coatings:** New classes of colloids in a variety of *host (continuous) phases* will be used to create responsive coatings. Photo-crosslinkable silicon polymers and acrylates are promising continuous phases to deposit *durable coatings*. CSCs can undergo programed disassembly to provide structured coatings or remain intact within the films for optical switching with prospects as *metamaterials*. Block copolymers will be introduced within the phases to create periodic refractive index contrast within the structures.
5. **Dynamic Optical Systems:** The lensing properties of CSCs have demonstrated utility for displays, meta-materials, and optics. CSCs will be designed to *respond to light, electrical fields, magnetic fields, and chemical reactions*. CSCs-based dynamic lens systems can enable complex patterns with switchable color, focusing, or reflective properties. CSCs containing *birefringent liquids* (i.e. liquid crystals) will be developed. Control of the optical properties in the latter requires surfactants and surface anchoring to organize the liquid crystals.
6. **CSC BioSensors:** We will demonstrate transformative analytical devices that utilize the unique dynamic optics of CSCs. The ability to detect optical responses from individual CSC droplets, provides the sensitivity to detect a single pathogen, enzyme, or molecule of DNA. These systems incorporate emissive dyes and selective anchoring of CSCs to interfaces. *Multiplexed sensors, wave guides, and ring resonator device platforms* will be developed.