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Swell Gels to Dumbbell Micelles: Construction of Materials and Nanostructure with Self-assembly

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Bionanotechnology, the emerging field of using biomolecular and biotechnological tools for nanostructure or nanotecnology development, provides exceptional opportunity in the design of new materials. Self-assembly of molecules is an attractive materials construction strategy due to its simplicity in application. By considering peptidic or charged synthetic polymer molecules in the bottom-up materials self-assembly design process, one can take advantage of inherently biomolecular attributes; intramolecular folding events, secondary structure, and electrostatic interactions; in addition to more traditional self-assembling molecular attributes such as amphiphilicty, to define hierarchical material structure and consequent properties. Several molecular systems will be discussed. Synthetic block copolymers with charged corona blocks can be assembled in dilute solution containing multivalent organic counterions to produce micelle structures such as toroids. These ring-like micelles are similar to the toroidal bundling of charged semiflexible biopolymers like DNA in the presence of multivalent counterions. Micelle structure can be tuned between toroids, cylinders, and disks simply by using different concentrations or molecular volumes of organic counterion. In addition, these charged blocks can consist of amino acids as monomers producing block copolypeptides. In addition to the above attributes, block copolypeptides provide the control of block secondary structure to further control self-assembly. Design strategies based on small (less than 24 amino acids) beta-hairpin peptides will be discussed. Self-assembly of the peptides is predicated on an intramolecular folding event caused by desired solution properties. Importantly, the intramolecular folding event impart a molecular-level mechanism for environmental responsiveness at the material level (e.g. infinite change in viscosity of a solution to a gel with changes in pH, ionic strength, temperature).