Soft Nanostructured Materials

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The control of self-assembly, the process by which order arises from a collection of disordered molecules or objects, to achieve functional materials that could provide the basis of devices (e.g., switches, gates or memory elements) remains a significant challenge and constitutes a major goal in materials chemistry. Unlike top-down fabrication approaches, self-assembly offers the potential of preparing materials in inexpensive, low energy consumption, "multiple copies" fashion. In addition, the self-assembly of molecules provides a means by which to pattern functional nanostructures with feature sizes not achievable *via* lithographic ("top-down") approaches and to construct patterned three dimensional structures. Although a considerable amount of effort has been directed towards the study of self-assembly, few guiding principles for the *de novo* design of functional self-assembled nanostructures have emerged. The lack of a directed/rational approach to achieving functional, self-assembled materials is the result of both the complexity of the objects and forces that control the self-assembly process and the limitations of the techniques now available for the characterization of self-assembled soft materials. Thus, improving the characterization of static, dynamic, and *in-situ* self-assembly remains a current and significant challenge.

Although the development of scanning probe / microscopy techniques has yielded notable advances in characterization of materials, the study of soft materials with these techniques is often not possible without altering or perturbing the samples. X-ray scattering techniques therefore remain the preferred approach to study such systems, since they can probe structure on the mesoscopic (nanometer to micron) length-scale and can probe bulk phase materials in a non-perturbing, non-destructive way under realistic sample environments (e.g., high levels of hydration). X-ray scattering techniques such as SAXS, GISAXS, USAXS, and reflectivity can be used to determine structure under controlled environmental conditions (*e.g.,* under the influence of applied electric or magnetic fields) and to monitor the *in-situ* self-assembly process. Current approaches, however, provide low to medium resolution structure determination in reciprocal space. Improvements are needed to further increase the structural resolution and to be able to achieve this in one, two and three dimensions. A major advancement would be the development of experimental approaches to provide real-space imaging, such as those obtained by scanning probe methods. For example, 3-D tomography would yield high resolution images of soft materials and would represent a significant advance over current capabilities, bridging the gap between electron microscopy and optical microscopy. Lastly, due to the diversity of interactions among molecules, a true understanding of self-assembly will require probes that are sensitive to both local and extended structure over a wide range of spatial and temporal dimensions (multi-time domain probes). Such information may only be provided by coupling scattering techniques with spectroscopic and imaging methods.