Molecular Brushes as Components for Nanomechanical Devices

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This proposal was submitted in response to the solicitation "Nanoscale Science and Engineering" (NSF 00-119). Miniature actuators, which produce large strains at short response times are of interest for nano-and biotechnologies. They can be used to construct micro fluidic pumps, tiny locomotives, and micromanipulators. It is generally believed that extremely efficient and fast actuators can be prepared from single macromolecules. Cylindrical brush molecules consisting of a flexible backbone and densely grafted side chains are possible candidates because they can change their length in response to variations in their surrounding environment and the effect of an external field. It is proposed to use soft cylinders with a stimuli-responsive shape as a multifunctional platform for the development of nanomechanical devices. One of the most interesting applications is envisioned for an array of molecular brushes, which are tethered with one end to a solid substrate and change their conformation under incident light. The layers will be designed to generate surface-relief-gratings, which propagate along the substrate plane and transport different fluids, small particles, and ultimately biological cells. For this purpose, either IR-absorber dyes or photosensitive azobenzene and spiropyran moieties will be introduced in the chemical structure of brushes. Similar to tracheal cilia, the tethered molecules will beat back and forth in a coordinated way and propel overlaying substances in a certain direction.

The project will address three fundamental questions:

(i) What are the molecular and external parameters controlling the length of brush molecules?

(ii) What is the force developed during contraction/extension of brush molecules?

(iii) What are the dynamic properties of the tethered brushes under the effect of polarized light?

The PI's will achieve their goals of answering these important questions by taking the following steps. First, they will prepare a series of well-defined brushes and investigate the specific effects of the side chain length, the grafting density, and the hotoisomerizable groups on the length of brush molecules. Second, they will study mechanical properties of individual molecules and tethered monolayers by stretching them uniaxially with an atomic force microscope and magnetic tweezers. The experimental studies will be supported by theoretical analysis of brush conformations. Third, an optical set-up combined with an atomic force microscope will be built for in-situ investigation of the morphology and the diffraction efficiency of the surface relief grating. This will allow the measurement of the access and relaxation times of the double-brush monolayer, and the monitoring of the transport of the overlaying substances.

This interdisciplinary project will be based on precise chemistry, rigorous physics, and biological concepts. It presents a perfect opportunity for students to master several of these fundamental disciplines and at the same time gain experience at the cutting edge of nanotechnology.