Laser Light Used to Fabricate and Drive Complex Micromachines

Researchers from the Institute of Biophysics at the Biological Research Center of the Hungarian Academy of Sciences have developed a method for both building and controlling micron-sized mechanical machines. As reported in the January 15 issue of *Applied Physics Letters*, P. Galajda and P. Ormos have combined the phenomenon whereby microscopic particles trapped in the focus of a laser beam tend to rotate with an optical method in which arbitrary shapes are formed by the polymerization of resins. These particles are used as machine components, which, through controlled rotation, can drive complex micromachines. This approach has resulted in the construction and demonstration of several micromechanical rotors and a rotor/cogwheel assembly.

Using the two-photon polymerization technique, the researchers fabricated microscopic particles, or micromachine rotors, from a UV-light-curing optical adhesive (Norland NOA 63). The material was polymerized using the 514-nm wavelength line of a 20-mW Ar ion laser beam. Although this material is UV-sensitive, polymerization in this study was initiated by two-photon excitation, thus allowing a higher spatial resolution during particle fabrication. The desired particle shape was achieved by moving a three-axis, piezo-controlled sample stage along a predefined trajectory through the laser focus. The scientists formed polymerized, glasslike resins of varying shapes with approximately 0.5-μm spatial resolution. They fabricated particles with varying degrees of rotational symmetry, including helixes, propellers, and conical modified sprinklers.

Once the particles were formed, the nonpolymerized material was dissolved in acetone, providing the solution in which the rotation experiments were performed. A laser-tweezers system, operating at a wavelength of 994 nm, was used to optically trap, or hold, the polymerized particles within the solution. The force required for particle rotation was supplied during the deflection of the 994-nm near-IR light by the trapped particle. Due to the momentum change associated with deflection of the light, a torque was exerted on the body that was in equilibrium with the viscous drag experienced by the rotating particle. The viscous-drag torque, calculated from experimental observation of the particle's angular speed, was shown to be in agreement with previous estimates. The researchers' results also showed that while the average rotation rate is independent of the polarization state of the trapping light, it is linearly proportional to the laser light intensity. For one of the structures studied, 20 mW of laser light intensity was sufficient to produce rotation rates of several hertz.

To demonstrate the viability of their technique, the researchers fabricated a system in which a light-driven rotor was used to turn two coupled cogwheels. Both the micron-sized rotor and the cogwheels were produced simultaneously using the two-photon polymerization method.

According to Galajda, the polymerization of particles of varying shapes, combined with the laser-induced rotation of micromechanical components, may have a significant impact on nanotechnology. The author said, "The implications are far-reaching—these miniature rotating devices may find application as powerful tools for measuring the properties of microscopic systems. This could be used to determine the torsional elasticity of single particles, such as biological polymers, DNA molecules, and proteins, or as a nanotechnology tool for use in the production and manipulation of microscopic objects."

STEFFEN K. KALDOR