MOLECULAR MOTORS

Drop in attendance at motor show

Smart coupling of light-induced molecular motion with a change in surface wettability provides an efficient way to drive a liquid drop up an incline.

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Inspired by the molecular motors found in nature, and enabled by a deepening understanding of the relationship between structure and function, researchers are seeking to build artificial molecular motors. There have been some very notable advances, such as those reported by Montamagno and co-workers, who succeeded in assembling a 'nanocoptor' by attaching the protein ATPase to a tiny nickel propeller[1]. Now, writing in this issue, Leigh and colleagues describe how, taking inspiration form the hydrophobic surface of the lotus leaf, a liquid droplet can be transported on a surface by a transformation of energy from light to biased molecular motion, through to surface energy, and finally to macroscopic mechanical work[2] (Fig. 1).

Leigh and colleagues placed a drop of a polar liquid (made of molecules with an electrostatic dipole) on a surface covered with a monolayer of molecules consisting of a central rod threaded through a ring. Such molecules are known as rotaxanes and form part of the growing family of supermolecules consisting of interlocked molecular components[3]. The rotaxane in question possesses two stations located at opposite ends of the rod. The main feature of one of the stations is that it changes shape when exposed to light. The main feature of the station at the opposite end is that it is fluorine-rich. Initially, the ring has a greater affinity for the first station and spends more time there. That is, the brownian motion of the ring is biased away from the fluorine-rich end of the rod. When, on exposure to light, the first station changes shape, the affinity of the ring for this station is reduced and the ring spends more time at the opposite end of the rod or, rather more accurately speaking, we should say that the brownian motion of the ring becomes biased toward the fluorine-rich station. The net effect of irradiating the surface is therefore to shield the fluorine and, as a consequence, make the surface more polar. Because the liquid is also polar this makes the drop more wetting at the irradiated edge, which becomes the leading edge of a creeping drop. Eventually, the leading edge creeps so far forward that the following edge contracts and the drop moves in the intended direction along the surface.

Figure 1 Nanoscale shuttles for macroscopic transport. The molecules and molecular assemblies that constitute molecular motors attract a great deal of scientific attention because of their ability to efficiently use energy to bias brownian molecular motion and generate a directed force. Now light-sensitive rotaxanes attached to a surface can transform radiation energy into macroscopic motion of a liquid droplet, thanks to a change in the wettability of the surface[2] (background image).

In certain conditions the force developed is even sufficient to move a drop up a sloped surface.

These and similar surfaces may enable technologies to be developed for pumping very small volumes of liquids, and may find applications in areas as diverse as drug discovery and next-generation electronics.

A key strength of this work is that it clearly relates the observed macroscopic behaviour of the droplet to both the individual and collective behaviour of the molecules on the surface. Such clarity suggests a distinction between (i) discrete molecular motors, in which work is done on a nanoscopic scale by an individual molecule or an assembly of a small number of molecules, and (ii) what might be termed ensemble molecular motors, in which work is done on a macroscopic scale a by large numbers of molecules. The motor described by Montemagno *et al.*[1] is an example of (i), whereas the more recent motor of Leigh and co-workers[2] is an example of (ii). This distinction is useful because it suggests interesting possibilities for the future, including hybrid artificial motors that are capable of performing both nanoscopic and macroscopic work.

REFERENCES

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