Nanotechnology Highlight

Nanostructured Materials as Gatekeepers for the Transport of Molecules

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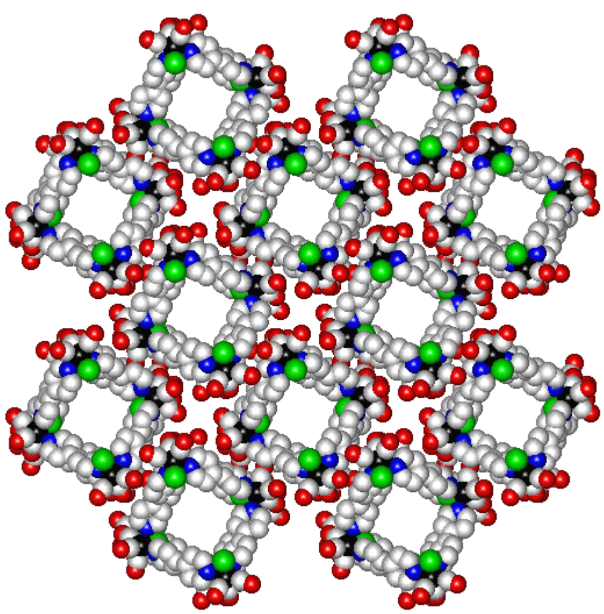
Film-like materials and structures that allow passage of some substances while blocking others are ubiquitous in nature (for example, cell membranes) and are essential for the functioning of virtually all living organisms. Similarly ubiquitous are man-made materials: membranes for osmosis-based desalination of seawater, oxygen-blocking plastic wraps for the preservation of food freshness, and so on. Highly desirable would be new classes of thin-film materials that could be arbitrarily manipulated to allow selective passage of tiny objects – molecules – on the basis of the objects' size, shape, or other properties. Even more desirable would be films or membranes that chemically process and transform the materials passing through them – converting, for instance, plentiful low-cost molecules into valuable complex molecules suitable as building blocks for new disease-fighting drugs. We have invented materials, or components of materials, that perform such functions.

The characteristic length scales of molecules makes this problem one of nanoscale design and engineering. What is required is the massively parallel assembly of nanometer-sized channels and decoration of the interiors of these channels with molecule "selectors" and "processors". Our approach was one based on preprogrammed self-assembly of hollow square or rectangle shaped nanoscale building blocks, followed by condensation of the building blocks into arrays of nanoscale channels. Using this approach we found that we could fabricate thin films that selectively passed molecules on the basis of both size and shape. Once prepared, we found that the materials could be rapidly and predictably altered to allow selective passage of molecules of different size. We further observed, with some materials, that passage occurred 20 to 50 times faster than observed with membranes comprised of more conventional porous materials (polymers) lacking ordered nanoscale channels.



We additionally observed that the nanometer sized cavities of individual "square" building blocks could be used to encapsulate highly potent catalysts and create long-lived, nanoscale chemical reactors. The reactors proved capable of transforming inexpensive hydrocarbon feedstocks into higher value chemicals called epoxides. We found that cavity encapsulation rendered the catalysts quasi-immortal, permitting them to function for up to 100 times longer than naked catalysts, while also transforming the catalysts from indiscriminate feedstock processors into ones that captured and processed only those molecules satisfying predetermined size requirements.