From Bubbles to Capsules

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Nanocapsules are vessels with diameters in the nanometer range and very thin shells. They can store a tiny volume of liquid and can protect their cargo while transporting it through a foreign medium — such as a human blood vessel — without any loss. Further applications for nanocapsules include the encapsulation of scents, printer ink, and adhesives. Once at their destinations, the payloads are released by pressure or friction.

Japanese researchers have now developed a clever new technique for the production of silicon dioxide nanocapsules: they start with tiny bubbles of carbon dioxide in a silicon copolymer.

Lei Li and Hideaki Yokoyama coated silicon wafers, which act as a support, with thin films of a special plastic that consists of molecules with segments of different types of polymers, so-called block copolymers, in this case made of polystyrene and silicone.

The researchers made their copolymer films such that nanoscopic "droplets" of silicone "float" in a matrix of polystyrene. Supercritical carbon dioxide (CO_2) is then forced into this film under high pressure at 60 °C. (In a supercritical fluid, it is impossible to distinguish between the liquid and gas phases.) The CO_2 lodges within the droplets of silicone in the block copolymer and forms bubbles. It cannot force its way into the polystyrene matrix, however.

In the next step, the scientists cool the film down to 0 °C in order to freeze the polystyrene matrix and then slowly reduce the pressure back to atmospheric levels. The CO_2 returns to the gas phase, expands, and escapes from the bubbles without collapsing them.

Finally, the researchers expose the polymer film to ozone and UV light. Under these conditions, the polystyrene matrix is completely destroyed; the silicone surrounding the bubbles is oxidized to silicon dioxide (SiO_2). This results in a thin film of tightly packed, tiny cavities with a thin shell of silicon dioxide. These nanocapsules have diameters of less than 40 nanometers and walls that are about 2 nanometers wide.

The particular advantage of this method is that the resulting nanocapsules are organized into a two-dimensional structure that can be controlled by varying the segments of the block copolymer.

Citation: Hideaki Yokoyama et. al., Nanoscale Silica Capsules Ordered on a Substrate: Oxidation of Nanocellular Thin Films of Poly(styrene-b-dimethylsiloxane), *Angewandte Chemie International Edition* 2006, 45, No. 38, doi: 10.1002/anie.200602274

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