news & features

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Getting to grips with smart materials

So-called intelligent or smart materials have to be able to sense an external stimulus and generate an appropriate and timely response. Now silica-based sol-gels have joined the ranks of materials that can change shape in response to their environment.

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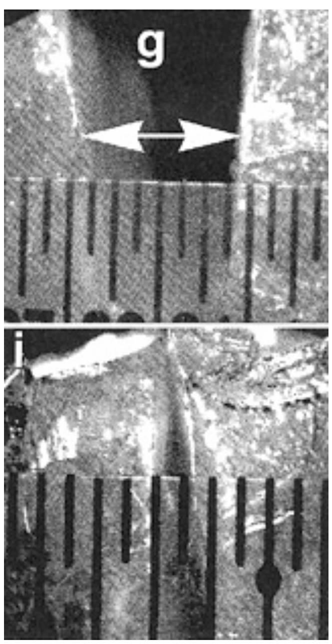

Side view of tweezer-shaped device made from organosilica sol–gel. In the first image, the tweezers are immersed in a solution at pH 4.5 and the distance between the tweezer arms (white arrow) is about 3 mm. In the second image, the tweezers have totally

To qualify as truly 'smart', a material has to sense changes in its environment and respond to them in an appropriate way. It must also do this reliably, over and over again. Mukti Rao and Bakul Dave have now created a silica-based material with such desirable properties using a sol–gel process. As they describe in *Advanced Materials*, their smart glass can be moulded into 'tweezers' that open and close in response to changes in temperature, pH and electrical potential.

In the sol–gel process, a colloidal suspension of precursor molecules (the 'sol') is converted by hydrolysis and condensation into a porous matrix filled with solvent (the 'gel'). Once the gel is formed, the solvent can be removed and the gel aged to produce a solid and highly porous matrix. Such silica sol–gel networks have been used to make sensors and optical fibres, but they cannot usually change shape in response to their environment. Some of the best studied 'shape changers' are polymer hydrogels, which swell or shrink when changes in pH or temperature cause them to absorb or lose water. Unfortunately, these crosslinked polymer networks are often slow to respond to environmental stimuli and are mechanically weak.

The silica-based gel designed by Rao and Dave

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tweezers have totally closed after immersion for 4 hours in a solution with neutral pH. The closure of the tweezers is caused by swelling of the sol–gel as the material takes in water to minimize the effects of a changing pH environment. Figure reprinted in part with permission from Advanced Materials . © 2002 Wiley-VCH.

undergoes smaller, but quicker, structural changes than a conventional polymer hydrogel. By creating a tweezer-shaped device from the sol–gel, the authors can observe the effect of volume changes on the distance between the arms of the tweezers, initially 3 mm apart. When placed in a water bath, the tweezers open by about 0.5 mm when the temperature is increased from 20 to 80 °C. Such changes are fairly rapid, reversible and reproducible. When the pH of the bath solution was increased from 4.5 to 7, the effect on the tweezers was more dramatic, but slower, causing them to close completely after several hours. Small reversible changes are also seen when an electrical potential is applied to the tweezers immersed in an ion-rich solution.

To turn unresponsive silica into a smart material, the authors had to organically modify the silica precursor molecules with a bis(propyl)ethylenediamine group. The organic modifier was carefully chosen to improve both the elasticity and responsiveness of the material. In particular, the introduction of hydrophobic and hydrophilic side groups generates a response to temperature, pH and ion concentration. As with the polymer hydrogels, the observed volume changes are caused by the changing affinity for water of the porous material.

Although the bulk volume changes generated in these experiments are small, Rao and Dave have succeeded in providing a general strategy for designing organosilica sol–gels from selectively tailored molecules. With suitable modifications, such smart materials could find potential applications in micromechanical and prosthetic devices.

"Smart" Glasses: Molecular Programming of Rapid Dynamic Responses in Organosilica Sol-Gels
Rao & Dave *Advanced Materials* **14** , 443 – 447 (18 March 2002).
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