Microcapsules like it Hot and Salty

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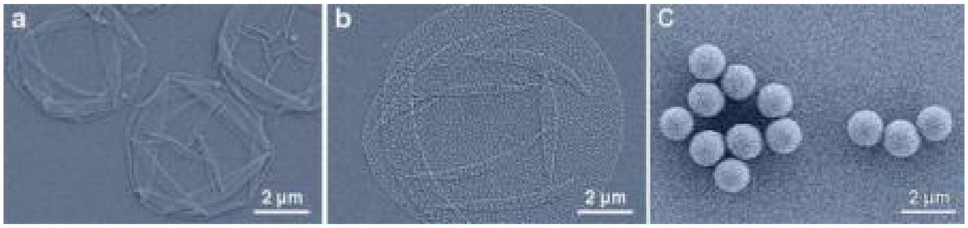

Electron microscopic images of capsules of different sizes. The hollow polymer spheres collapse when they are dry like deflated footballs: a) original size of the capsules; b) swollen capsules at high temperature; c) shrunken capsules following addition of salt. The capsule wall is thick enough to prevent collapse when salt is added. Image: Max Planck Institute of Colloids and Interfaces

Scientists at the Max Planck Institute of Colloids and Interfaces have presented a new method with which to precisely control the permeability of microcapsules using the salt content and the temperature of the solution. In order to accomplish this, the researchers developed a theoretical model which exactly describes the processes in the polymer shell of the capsules. This means that is possible to predict, without any experimental investigations, how the properties of the hollow spheres will change if the temperature and salt content are altered (*Physical Review Letters*, November 3, 2006).

This opens up new possibilities for using the capsules to transport active substances in the body, as components of self-repairing car paints or as microsensors and micropumps.

Ideally, medicines should only go to the sick regions of the body to prevent side-effects and to be as effective as possible. This requires intelligent transport systems which initially enclose the active substances and then release them at the location where they are to be effective given the presence of certain conditions. Scientists at the Max Planck Institute of Colloids and Interfaces in Potsdam are working on a microtransport system which meets these requirements exactly. Polymer capsules of just a few micrometres, i.e. thousandths of a millimetre, transport drugs through the organism. The walls of the microcapsules are constructed from alternate layers of positively and negatively charged polymer molecules so that molecules with very different properties can be used to make the capsules.

To maximize the usefulness of the capsules, it is important that the permeability of the capsule wall can be adjusted precisely. When the microcontainer is filled, the wall must initially allow the active substance through to the inside. Then the capsule shell must be sealed to enclose the contents so that they can be released at the location where they are to take effect. The scientists in Potsdam have now found out that the density and the thickness of the capsule wall, and hence its permeability, can be controlled with changes to the temperature and salt content.

If the temperature is only slightly raised the hollow spheres swell up or shrink and at the same time the wall becomes thinner or thicker. This depends on the composition and the electrical charge of the polymer shell:

-- If it shrinks, it is possible to encapsulate very small molecules. With the powerful supply of energy from raising the temperature, the bonds between the polymer molecules with opposite charges are loosened and as a result, the capsule wall becomes softer. The material of the shell can therefore flow closer together; the wall becomes thicker and denser. The molecules can no longer move through it and are enclosed inside.

-- If the hollow spheres shrink, the polymer walls also soften when heated. However, there are so many equivalent charges in the capsule wall that they repel each other. The whole structure expands considerably, the diameter increases and the wall becomes thinner. The result is significantly higher permeability compared to the original capsules at room temperature.

-- If salt is now added to the capsule solution, the electrical charges are neutralized and the capsules shrink again, the wall thickening as described in the first example above. "By combining simple materials available in any kitchen, we can vary the properties of the wall of the microtransport system in any way we wish," said Karen Kohler, a scientist working on this project at the Max Planck Institute of Colloids and Interfaces in Potsdam. The scope for change in capsules with an original diameter of 4.5 micrometers varies from 1.5 to 20 micrometres (see fig.).

However, it is not just in the laboratory that the size of the capsule can be adjusted precisely. The scientists also have a theoretical understanding of the processes in the capsule wall, which means that they can predict the diameter of the hollow spheres under any given circumstances without an experiment. The model they have developed contains the competition between two forces: the polymer/water surface tension, which attempts to make the capsule and its surface smaller on the one hand, and the electrostatic repelling force between like charges in the polymer shell which makes the capsule swell on the other. "Depending on the strength of the two competitors, the exact size of the capsule can be calculated in advance for a very specific salt concentration and temperature," explained Maarten Biesheuvel, another member of the team of researchers.

The theoretical model also predicts that it should be possible, by way of skilful adjustment of the conditions, to shrink initially swollen capsules and vice versa. This prediction was also confirmed in experiments.

This continuous switching between the two states of quite different capsule sizes expands the range of possible uses for the Potsdam microcapsules enormously. As well as being used as medicine transporters, conceivable applications include using the capsules as a component of car paint which releases a corrosion protection agent when damaged, thereby stopping the damaged section from becoming larger. As microsensors they could supply information about the concentration of certain molecules, such as glucose or calcium ions in cells or also work as micropumps.

Citation: Karen Köhler, P. Maarten Biesheuvel, Richard Weinkamer, Helmuth Möhwald and Gleb B. Sukhorukov, Salt-induced swelling-to-shrinking transition in polyelectrolyte multilayer microcapsules, *Physical Review Letters*, 3 November 2006

Source: Max Planck Institute of Colloids and Interfaces

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