

Popular scientific introduction to the paper

*One-piece micropumps from liquid crystalline core-shell particles*

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Rubbers, or elastomers, are fascinating materials. You cannot really classify them as solids, because they are soft, incredibly elastic and easily deformable. On the other hand they do not flow so they seem not to be liquid either. If you investigate the dynamics of the long polymer chains that make up a normal rubber; however, you will find that they locally are in a state that is indeed liquid-like. What prevents them from flowing are so-called cross-links, network-like connections between chains that keep each molecule center of mass in about the same position, although the molecules can fluctuate substantially in shape. The average shape is spherically symmetric and referred to as a random coil.

In a select subcategory of rubbers the local dynamics of the molecules is a bit different. A quite large fraction of the molecules adopt a partially ordered state, which we call liquid crystalline. This is the state of the liquid you find inside your laptop or mobile phone display and it is characterized mainly by rod-shaped molecules (called mesogens) all being aligned in the same direction. This long-range orientational order gives rise to spectacular physical properties of such materials.

When such a state is combined with the crosslinked long molecules of rubber, the polymer network also becomes aligned: the random coil is stretched along a direction defined by the liquid crystal. This stretching however comes at the cost of reducing the freedom in adopting different molecule shapes, so without the orientational order the polymer would prefer a regular sphere-shaped random coil, where the fluctuations are maximum (the entropy is maximized). If we heat a liquid crystal there will normally be a temperature where the long-range orientational order is lost, turning the system into an ordinary liquid. This happens also in liquid crystalline elastomers, so if we heat this type of rubber, the polymers are free to adopt the normal random coil shape above this temperature. But they are still connected into a network by the crosslinks, so when this happens it is actually not just the shape of the molecule that changes, but in fact of the whole macroscopic piece of rubber! This has been used for making plastic actuators, or artificial muscles, by many researchers around the world.

In our work we have made thin shells of a liquid crystalline elastomer using a microfluidic processing technique, that produces about 100 elastomer shells of a few hundred micrometers (or tenths of a millimeter) diameter per minute. When they are heated to the point where the mesogens lose their orientational order, the shell changes shape dramatically, with the consequence that a pressure on the core material builds up inside the shell. By punctuating the shell and connecting it to a capillary we demonstrate that this (fully reversible) process can be used to eject 60% of the core liquid (see figure), and we can therefore use these shells as micropumps that require no assembly of different components. This can be very attractive for microfluidic systems, where small pumps that can pump out or suck in a certain fluid rapidly and dynamically are very useful. Moreover, because these pumps are not connected to any substrate and because the in- and outlets can be attached at any desired angle, we can realize three-dimensional microfluidic systems, something that is not easily achievable with alternative techniques.

