Micro-scale actuators based on photo-responsive polymers

Have you ever imagined that we could build remotely controlled robots the size of ants? Or even smaller, the size of bacteria? They could explore the inside of our bodies to diagnose diseases, perform surgical procedures without the need of cutting through the skin or deliver precisely targeted therapies. In the environment, they could join forces to perform complex task and disperse afterwards, waiting unnoticed for the next job.

However, miniaturization of robots below the centimeter scale faces several problems. First, we do not have power sources small enough to be carried on a millimeter and sub-millimeter mechanisms. Second, we do not have the technology to either control them from a distance or program them to operate autonomously. And third, despite spectacular progress in miniaturization in electronics and micro-mechanics, we still have no motors and actuators, that could work on such small scales, allowing the robots to move around, change shape and apply forces.

In our project we will be exploring one of the recently discovered "smart material" – liquid crystal elastomers (LCEs) – that can change shape when illuminated with visible light. This shape transformation is reversible and can be fast if the element is small. We also have techniques that allow us to program how the element (actuator) will deform, by aligning the liquid crystal molecules in space before the material is polymerized. So far, we have demonstrated simple geometries: stripes of LCE film that can contract, bend and bulge. To go a step forward, we will be developing techniques for aligning the molecules into arbitrary patterns (defined by computer-generated images) and shaping the elements: laser cutting and 3D printing of LCE in the millimeter and micrometer scales.

Fig. 1 A natural scale caterpillar micro-robot made of liquid crystal elastomer with complex molecular orientation can crawl when illuminated with a laser beam.

The next step will be characterization of the LCE complex elements and structures: measuring their optical, mechanical and thermal properties. Especially measuring (with infrared imaging), numerical modeling and understanding the heat transfer dynamics in the aligned polymers may open up previously inaccessible ways to micro-mechanical devices and micro-robots with many degrees of freedom.

Perhaps soon a polymer micro robot will be taking photographs of the inside of your eye, repair your teeth and an army of millimeter-size artificial ants will be cleaning the remote corners of your house.