Worldwide R&D

Biomaterials System Engineering Laboratory, Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo

Ryo Yoshida, Associate Professor
http://www.bmw.t.u-tokyo.ac.jp/yoshida/

The Biomaterials System Engineering Laboratory is entering its fifth year since its launch in April 2001. The laboratory is currently staffed by three doctoral students (one working adult), four master's students, three undergraduate students, and one technical assistant.

Living organisms are perhaps the ultimate material system capable of transmitting data, transporting materials, and creating motion and force through cooperation at the molecular level. Using such organisms as a model, we are attempting to artificially design and construct materials and systems with polymer gels that can replace or imitate the functions of these living organisms.

Polymer gels can be broadly defined as a cross-linked polymer network inflated with a solvent such as water. In addition to foodstuffs, there are numerous gels that we use in our daily lives, such as the superabsorbent material in disposable diapers, and soft contact lenses. Polymer gels are used in a variety of fields. Many gel-like tissues can also be found in living organisms, including the cornea of our eye and vitreous bodies.

This type of gel can exhibit a very unusual phenomenon called volume phase transition in which the gel reversibly and discontinuously swells or shrinks in response to environmental changes, such as changes in the solvent composition, temperature, and pH, the application of an electric field, exposure to light, and the addition of specific molecules. Much research is now being conducted on this quality to find applications for these gels as functional materials. So far several “intelligent” gels having organism-like functions have been developed, including gels that function as artificial muscles and gels that release medicine only when heated.

While various stimuli-responsive gels are being created in this way, our laboratory is developing a “life-like” functional gel that produces spontaneous pulses under uniform conditions similar to myocardial cells. By developing a molecular design in the gel for inducing the BZ reaction, an oscillating reaction known as a chemical model of biological metabolic reactions (citric acid cycles), and converting the chemical changes to dynamic changes, we have succeeded in producing a periodic swelling and shrinking oscillation in the gel (Fig. 1). This led to the creation of a new biomimetic gel capable of inducing its own oscillations in a regular rhythm under fixed conditions, much like the pulsations of a cardiac muscle. Unlike conventional stimuli-responsive gels, this is the first gel in the world that produces swelling-shrinking oscillations without an external stimulus being turned on and off and is expected to have applications in molecular pacemakers, pulsating micropumps, and microactuators having peristalsis. New gels that imitate a cardiac muscle have also been developed recently. These gels are capable of self-induced pulsations in the presence of ATP.

Currently we are attempting to apply lithography and other micromachining technologies that have made remarkable advances in recent years to develop micromachines and nanomachines from these functional gels. For example, we are creating microactuators (artificial cilia) by arranging hundreds of microprotrusions on the surface of self-oscillating gel and generating wave propagation through a chemical reaction, spontaneously producing periodic fluctuations in the protrusions (Fig. 2). It is thought that such a microactuator may have applications in a microtransfer system for transporting minute particles and cells added to a surface.

We are also working on applications for medical chips. By providing a medicine storage section in a chip and forming a gel at the exit passage to this section through local photopolymerization, we can produce a drug release system that opens and closes a gate in response to abnormal signals (Fig. 3). We are designing a drug release chip for releasing insulin in response to changes in temperature and pH and glucose concentrations. Further, a pulsating gel embedded in a chip is anticipated to serve as the power source for a pulsating micropump designed to releasing drugs periodically. This chemical engine requires no electrical power and can be used as a completely independent drug release chip having no wires connected to an external power source. By fusing this gel with micromachining technology, we believe that new developments and applications for the gel as a functional material will continue to expand.

For more information on our research activities, please visit our Web site. Although our laboratory is relatively new, the students and I are conducting research round the clock.

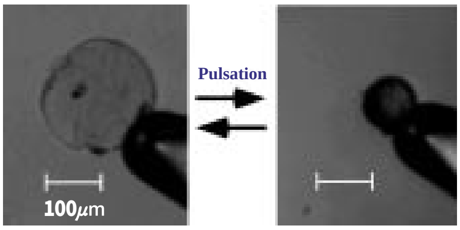

Fig. 1 Self-oscillating gel that pulses spontaneously pulsation

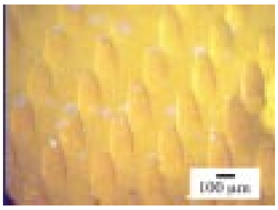

Fig. 2 Gel array created through micromachining (artificial cilia)

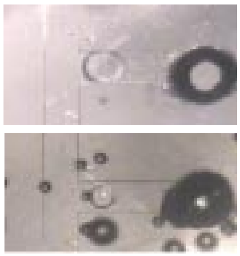

Fig. 3 Microvalve formed of gel in a microchannel for automatically controlling drug release (the valve is closed in the top photo and open in the bottom photo)

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Keiichi Aoyagi, Executive Director, Micromachine Center (MMC)
MBR99 Bldg., 6F., 67 Kanda Sakumagashi, Chiyoda-ku, Tokyo 101-0026, Japan
Tel : +81-3-5835-1870, Fax : +81-3-5835-1873
Internet Home Page http://www.mmc.or.jp/
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