RESEARCH BRIEF

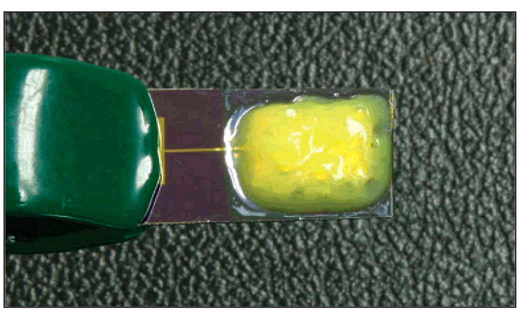
BIOMEMS DEVICES FOR PATTERNING AND SENSING BIOMOLECULES

The need

In the aftermath of the terrorist attacks of 9.11.2001, there has been an exponential increase in research that will provide better preventative surveillance. One of the areas of need is for a new generation of sensors that can detect minute quantities of explosives, bioagents, chemicals, and other dangerous materials in air and water. Strategically placed, such sensors could be part of better security at airports, hospitals, and other public locations. In addition to security, the sensors have many other potential uses, including monitoring the air in industrial plants, screening drugs and diagnosing diseases.

A potential solution

One promising area of research is chitosan-based microelectromechanical sensor systems (MEMS sensors). Chitosan is a substance derived from chitin, one of nature's most abundant biological compounds. Chitin makes up the shells of crabs and other crustaceans, insects, zooplankton and even the cell walls of mushrooms. It is both a polymer (a large molecule composed of repeating units) and produced by living things (biological). Chitin and its derivative chitosan are known as biopolymers.

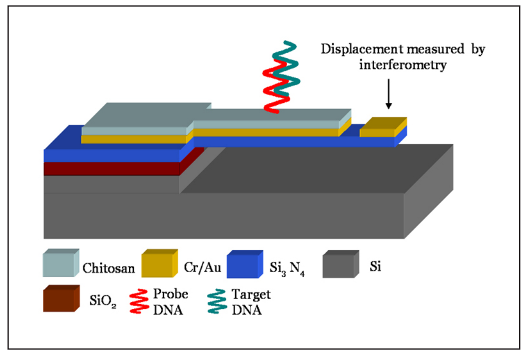


Chitosan hydrogel electrodeposited on microfabricated electrode.

Chitosan is the key component in MEMS sensors being developed by Associate Professor Reza Ghodssi (ISR/ECE), his students and a multidisciplinary group that includes Maryland NanoCenter Director Gary Rubloff (ISR/MSE), Bill Bentley from the Fischell Department of Bioengineering and Greg Payne from the University of Maryland Biotechnology Institute (UMBI).

"Chitosan is interesting because it's a biological compound that can interact with a wide variety of substances, and also work well in a complex, sensitive microsystem device," Ghodssi says.

Ghodssi's graduate students are helping to develop a MEMS "system on a chip." It employs multiple miniature vibrating cantilevers, similar to diving boards, which are coated with chitosan, plus optical sensing technology that can see when the cantilevers' vibrations change.



Schematic of micro cantilever sensor coated with chitosan and used for the detection of DNA molecules.

Different cantilevers can detect different substances and concentrations. When a targeted substance enters the device from the air or water, the chitosan on a specific cantilever interacts with the substance and causes that cantilever's vibration to change its characteristics. The optical sensing system sees the vibration change and indicates that the substance has been detected.

"This is an exciting and complex microsystem that bridges biotechnology and nanotechnology to address critical needs of homeland security applications. My colleagues and I are expecting this work to become a product in the near future," says Ghodssi.

The research

Microfabrication enables patterned surfaces and three-dimensional structures to be constructed with precise spatial selectivity. Biomolecules (proteins and nucleic acids) offer exquisite capabilities for molecular recognition and sensing. Together, microfabrication and biotechnology offer the potential

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for creating miniaturized sensor devices. A current limitation is the integration of the biological system with the inorganic surface of typical devices. The researchers are exploring how chitosan can be used as an interface material templated onto patterned surfaces and covalently coupled with sensing biomolecules.

The group has developed a means to spatially localize biofunctional surfaces in specific locations by chitosan electrodeposition. Specifically, spatial control of the deposition is based on where electrodes are patterned on the surface while temporal control of deposition is achieved according to when voltage is applied.

This approach was combined with conventional MEMS fabrication to create photonic and micromechanical biosensors. The photonic sensors analyze localized biomolecules by optical excitation and collecting the emitted light. The micromechanical sensors detect the attachment of biomolecules to specific locations by means of their physical interaction with microfabricated structures.

These demonstrations have shown that chitosan is a novel biomaterial that can serve to marry microfabrication with biotechnology. We hope this interface material will provide new opportunities for the creation of robust and reusable biosensors.

Collaborators

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Funding

The technology was developed and initially tested at the Laboratory for Physical Sciences (LPS) in College Park, Md. It is currently sponsored by LPS, the National Science Foundation (NSF) and the R.W. Deutsch Foundation.

Patents pending

Six patents have been filed related to this technology.

Web links

Dr. Ghodssi's home page
www.ece.umd.edu/~ghodssi/

The MEMS Sensors and Actuators Lab (MSAL)
www.ece.umd.edu/MEMS/

Project overview at the MSAL site
www.ece.umd.edu/MEMS/projects/bio.html

Clark School of Engineering press release
www.eng.umd.edu/media/pressreleases/pr072506_crab-detector.html

ISR news story
www.isr.umd.edu/news/news_story.php?id=675

Links to press coverage of the nanosensors
www.isr.umd.edu/news/news_story.php?id=855

View a bioMEMS actuator device in action
www.eng.umd.edu/media/pressreleases/images/MSAL_InP_Actuator.wmv