Packaging for Miniature Immersible Diagnostic Systems

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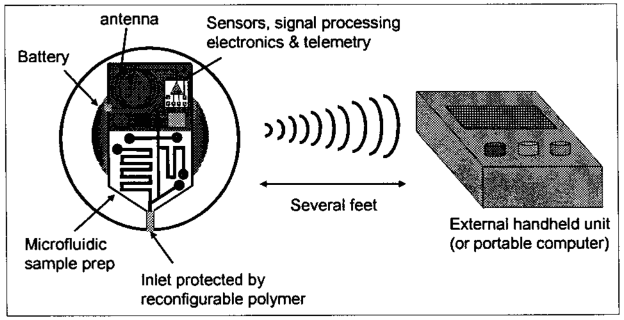
ABSTRACT

Miniature biosensor systems are at the forefront of modern technology. Biomedical sensors that can assess the in-situ health of an individual or the in-situ quality of the environment will be invaluable to humans in hospitals, in the battlefield, and in outer space. Through Microelectromechanical Systems (MEMS) technology, micro scale biosensing systems are being realized.

Although progress has been made in biosensing technology, relatively little progress has been made in biosensor packaging. Chemical biosensors require direct contact between the active surface area of the sensor and the analyte. In applications that present complex and hostile environments such as insertion into the human body or in wastewater streams, packaging is a significant challenge. The sensor may need to be protected for hours, days, or weeks before a reading is taken.

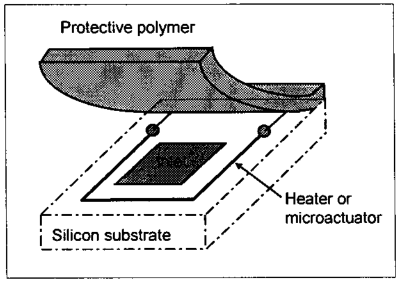
We describe research that focuses on the development of a Miniature Immersible Diagnostic System (MIDS) that senses the condition of its liquid environment and reports its findings remotely. To address packaging issues, biocompatible polymers will be utilized as protective coatings. Selective manipulation/movement of this coating allows biosensor interaction with its environment. External signals can initiate polymer reconfiguration in order to obtain a reading when needed. This, coupled with microfluidic handling techniques, is a versatile, interactive package that can be used with a variety of biosensors. This type of packaging will allow MEMS biosensors to be an integral component of NASA's advanced life support systems and astrobiological studies that will require a host of environmental, chemical, and microbial direct sensing capability.

SYSTEM DIAGRAM



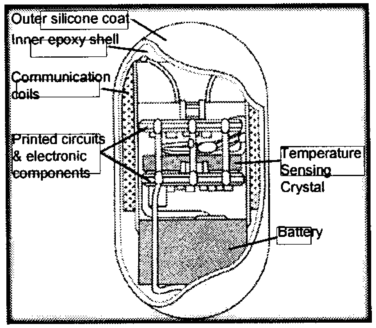
Schematic overview of the Miniature Immersible Diagnostic System (MIDS). The sampling hardware is anticipated to be no larger than a golf ball. It can be fully immersed in liquid and will be capable of transmitting data across the liquid/air interface to the external unit (diagram not drawn to scale).

RECONFIGURABLE PACKAGING

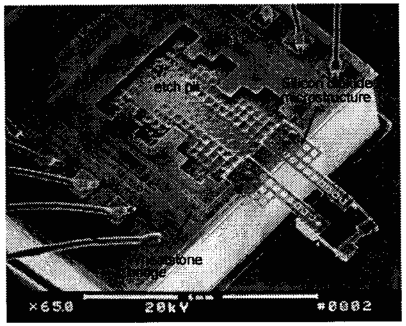


A protective polymer covers the inlet until the underlying heater or actuator is activated. Upon activation the polymer can be moved either by mechanical, thermal, or chemical means. The inlet leads to a microfluidic circuit containing the sensors. Microactuation methods currently under consideration include shape memory alloys, magnetic microactuation, piezoelectric actuation, and electroactive polymers. Protective polymers under consideration include teflon and viton.

ENCAPSULATION PACKAGING EXAMPLES



Swallowable temperature sensor. [1]



MEMS heart cell force transducer. [2]

Complete encapsulation is a proven effective method of biosensor packaging, as illustrated in these two examples.

Example #1: The CoreTemp ™ pill by HTI Technologies, Inc. is a wireless, swallowable temperature sensor. It entirely coated in silcone rubber and epoxy which enables it to withstand the acidity and toxicity of the GI tract.
Example #2: The force generated by an individual heart cell was measured using a completely encapsulated MEMS device. The packaging required for the chip and supporting electrical interconnects required complete encapsulation using silicon dioxide, epoxy, silicone rubber sealant, and enamel.

1. CoreTemp ™, HTI Technologies, Inc. http://www.htitech.com/med.htm
2. Developed by G. Lin, K. S. J. Pister, and K. P. Roos at the UCLA School of Engineering and Applied Science, Los Angeles, California USA. Work sponsored by the American Heart Association, Greater Los Angeles Affiliate, Grant-in-Aid #1059 GI-3, and the National Institute of Health, #HL-47065.

ACKNOWLEDGMENT:

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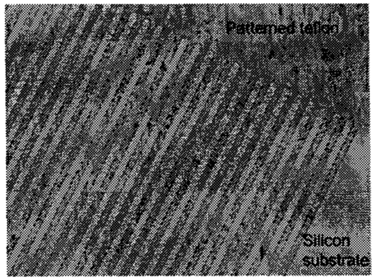
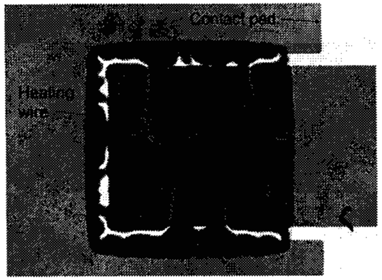
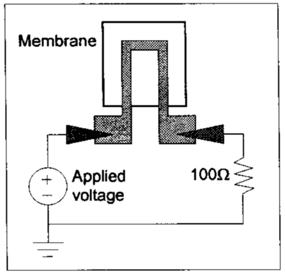
RECONFIGURABLE PACKAGING: PRELIMINARY RESULTS



Patterned teflon microchannels



Teflon membrane test structure



Test circuit

- To date we have routinely spun thin films of Teflon AF (Dupont) onto silicon substrates. Typically the films are spun for 15 seconds at 2000 RPM. The films are roughly 0.8μm thick after curing at 200°C for 2 hours.
- The films did not degrade when immersed in solvents. If not properly cured, the films would delaminate when exposed to solvents. If the film delaminates, it comes off as a single sheet. In addition to proper curing, exposing the substrate to HMDS vapor prior to spinning increased the teflon film adhesion.
- Photoresist will not adhere to teflon unless the teflon surface is first roughened. Teflon surface roughening is achieved via an oxygen plasma at 200W for 5 minutes.
- Teflon is patterned using a photoresist mask and an argon plasma. 250W for 30 minutes was needed to pattern a 0.8μm-thick teflon film. Patterned teflon microchannels 35mm wide are shown in the left photograph.
- In a separate experiment we attempted to break teflon-coated membranes using metal heating wires. 300Å chromium and 2000Å gold were evaporated onto 1μm of thermally grown silicon dioxide (see middle photograph - membrane shown is 500 μm x 500μm. The heating wire is 30μm wide.). Membrane size varies from 200μm square to 1mm square. All membranes were coated with an unpatterned 0.8μm film of teflon.
- The test structure was incorporated into a circuit (right diagram). Preliminary results indicate that hundreds of milliamps are required to initiate oxide cracking. The tensile stress in the oxide film caused the attached teflon film to lift out of the plane of the wafer, but the amount of force was not sufficient to tear the teflon.
- Films with higher tensile stress are needed. Alternatively, patterning the teflon into "doors" may facilitate lifting of the teflon during actuation. Other methods of polymer actuation are also being considered.

CONCLUSION:

At NASA/JPL we are developing a new reconfigurable biosensor package that will operate in liquid and allow sensors direct access to their environment. Packaging is a critical component towards the development of a Miniature Immersible Diagnostic System (MIDS). To date we have patterned protective films of Teflon AF using a photoresist mask. Breaking or lifting a teflon-coated membrane has proven to be more challenging, and preliminary tests indicate that more force needs to be generated.