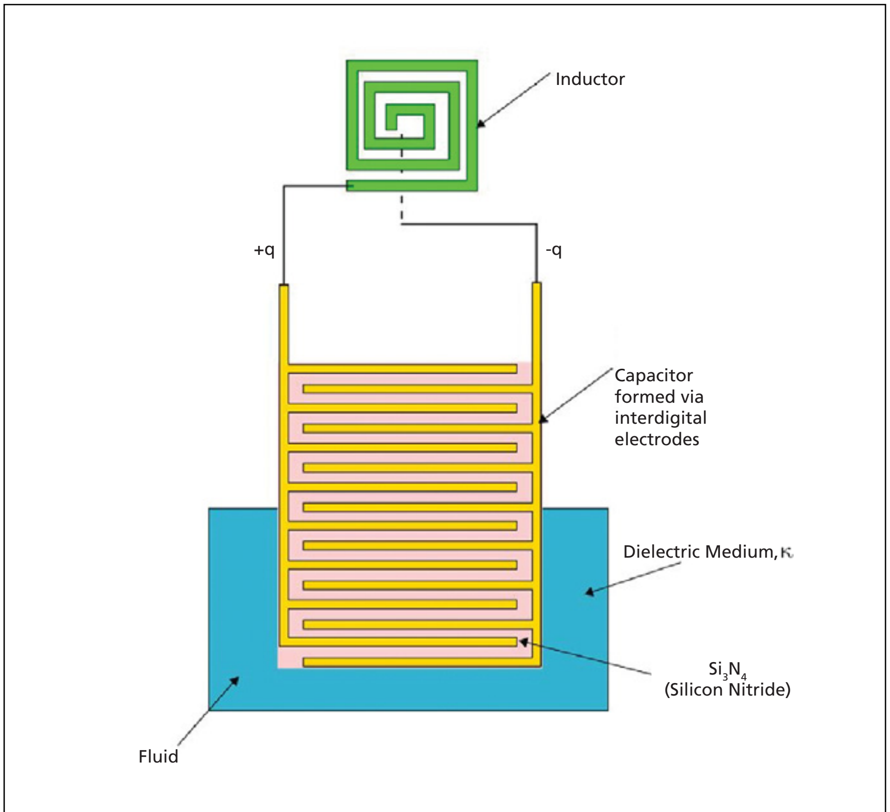


Figure 2: **Part of Capacitance** (fluid sensor) is immersed in fluid.

The capacitance value of the sensor increases as the amount of fluid that the sensor is exposed to increases. When the energy is in the inductor, the harmonic magnetic field produced can be interrogated. The response recorder interrogates the sensor response and correlates the response frequency to fluid level.

A thin layer of silicon nitride film is deposited on interdigital electrodes as shown in Figure 2 to electrically insulate the sensor's capacitor. Silicon nitride also can be placed on the inductor. The fluid-level sensor uses interdigital electrodes for the capacitor that are electrically connected in parallel to a spiral trace inductor. The advantage of this design is that the entire sensor can be embodied as a thin film, and can be directly deposited to the inner wall of a nonconductive container for measuring non-viscous fluids.

In Figure 2, a fluid having dielectric constant, κ, is in contact with *m* pairs of electrodes (e.g., placed in a fluid such that *m* electrode pairs are submersed). Each electrode pair has a capacitance of C_{free} when not immersed in the fluid and $C_{immersed} = \kappa C_{free}$. The advantage of this method is that it serves as a lightweight, thin-film method of measuring fluids that are non-viscous. Another advantage is that the level measurements are discretized. The sensor capacitance, $C(m)$, for a sensor having n electrode pairs increases as the number of electrode pairs, m, in contact with the dielectric increases.

$$\begin{aligned} C(m) &= (n-m)C_{free} + mC_{immersed} \\ &= (n-m+\kappa m)C_{free} \\ &= [n+m(\kappa-1)]C_{free} \end{aligned}$$

When the electrodes are electrically connected to an inductor, a resonant circuit is formed having the resonant frequency of

$$\omega = \frac{1}{2\pi\sqrt{[n+m(\kappa-1)]LC_{free}}}$$

The sensor response frequency ranges from its maximum value when the capacitor is not immersed ($m = 0$)

$$\omega_{\max} = \frac{1}{2\pi\sqrt{nLC_{free}}}$$

to its minimum when the capacitor is completely immersed ($m = n$).

$$\omega_{\min} = \frac{1}{2\pi\sqrt{m\kappa LC_{free}}}$$

This work was done by Stanley E. Woodard, Qamar A. Shams, and Robert L. Fox of Langley Research Center and Mr. Bryant D. Taylor of SWALES Aerospace. For more information, contact the Langley Innovative Partnerships Office at (757) 864-8881. Refer to LAR-16614-1.

Progress in Development of Improved Ion-Channel Biosensors

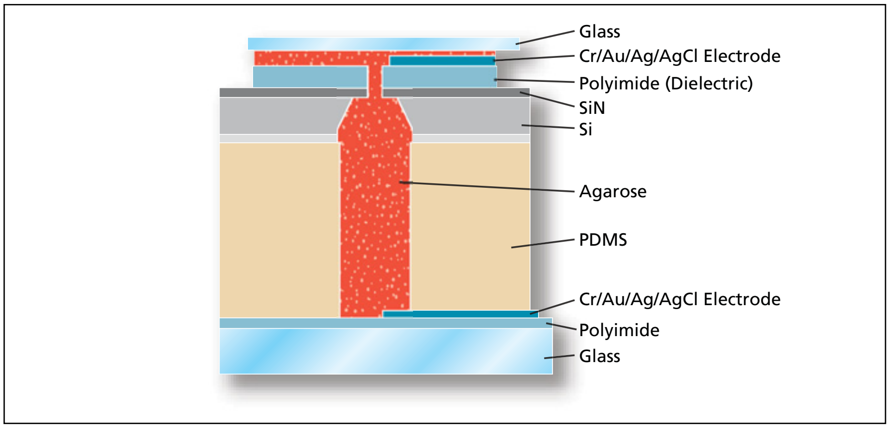
Improvements in design and fabrication have been made since a previous report.

NASA's Jet Propulsion Laboratory, Pasadena, California

Further improvements have recently been made in the development of the devices described in "Improved Ion-Channel Biosensors" (NPO-30710), *NASA Tech Briefs*, Vol. 28, No. 10 (October 2004), page 30. As discussed in more detail in that article, these sensors offer advantages of greater stability, greater lifetime, and individual electrical addressability, relative to prior ion-channel biosensors.

In order to give meaning to a brief description of the recent improvements, it is necessary to recapitulate a substantial portion of the text of the cited previous article. The figure depicts one sensor that incorporates the recent improvements, and can be helpful in understanding the recapitulated text, which follows:

These sensors are microfabricated from silicon and other materials compatible with silicon. Typically, the sensors are fabricated in arrays in silicon wafers on glass plates. Each sensor in the array can be individually electrically addressed, without interference with its neighbors. Each sensor includes a well covered by a thin layer of silicon nitride, in which is made a pinhole for the formation of a lipid bilayer membrane. In one stage of fabrication, the lower half of the well is



This **Simplified Cross Section**, which is not to scale, shows selected features of a sensor that incorporates recent improvements.

filled with agarose, which is allowed to harden. Then the upper half of the well is filled with a liquid electrolyte (which thereafter remains liquid) and a lipid bilayer is painted over the pinhole. The liquid contains a protein that forms an ion channel on top of the hardened agarose. The combination of enclosure in the well and support by the hardened agarose provides the stability needed to keep the membrane functional for times as long as days or even weeks.

An electrode above the well, another electrode below the well, and all the materials between the electrodes together constitute a capacitor. What is measured is the capacitive transient current in response to an applied voltage pulse. One notable feature of this sensor, in comparison with prior such sensors, is a relatively thick dielectric layer between the top of the well and the top electrode. This layer greatly reduces the capacitance of an aperture across which the ion channels are formed, thereby increasing the signal-to-noise ratio. The use of a relatively large aperture with agarose support makes it possible to form many ion channels instead of only one, thereby further increasing the signal-to-noise ratio and effectively increasing the size of the available ionic reservoir. The relatively large reservoir makes it possible to measure AC rather than DC. This concludes the recapitulation from the cited previous article.

The improvements include the following:

- The microfluidic channels through which agarose is wicked into the lower halves of the wells are fabricated in a reusable layer of polydimethylsiloxane [PDMS (commonly known as silicone rubber)]. This layer of PDMS forms a hermetic seal with the underlying glass plate and the overlying silicon chip, but can be removed and washed, making the array reusable.
- Before forming the lipid bilayer over the pinholes in the silicon nitride layer, the silicon nitride is coated with a self-assembled monolayer, which serves to stabilize the lipid bilayer, thereby making the array into an even more stable device.
- The lipid bilayer is formed rapidly by means of a spin-coating procedure that can be performed by a worker without special skill.

This work was done by Jay L. Nadeau, Victor E. White, Joshua A. Maurer, and Dennis A. Dougherty of Caltech for NASA's Jet Propulsion Laboratory.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-40560, volume and number of this NASA Tech Briefs *issue, and the page number.*

Simulating Operation of a Complex Sensor Network

NASA's Jet Propulsion Laboratory, Pasadena, California

Simulation Tool for ASCTA Microsensor Network Architecture (STAMiNA) ["ASCTA" denotes the Advanced Sensors Collaborative Technology Alliance.] is a computer program for evaluating conceptual sensor networks deployed over terrain to provide military situational awareness. This or a similar program is needed because of the complexity of interactions among such diverse phenomena as sensing and communication portions of a network, deployment of sensor nodes, effects of terrain, data-fusion algorithms, and threat characteristics.

STAMiNA is built upon a commercial network-simulator engine, with extensions to include both sensing and communication models in a discrete-event simulation environment. Users can define (1) a mission environment, including terrain features; (2) objects to be sensed; (3) placements and modalities of sensors, abilities of sensors to sense objects of various types, and sensor false-alarm rates; (4) trajectories of threatening objects; (5) means of dissemination and fusion of data; and (6) various network configurations. By use of STAMiNA, one can simulate detection of targets through sensing, dissemination of information by various wireless communication subsystems under various scenarios, and fusion of information, incorporating such metrics as target-detection probabilities, false-alarm rates, and communication loads, and capturing effects of terrain and threat.

This program was written by Esther Jennings, Loren Clare, and Simon Woo of Caltech for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-45213.