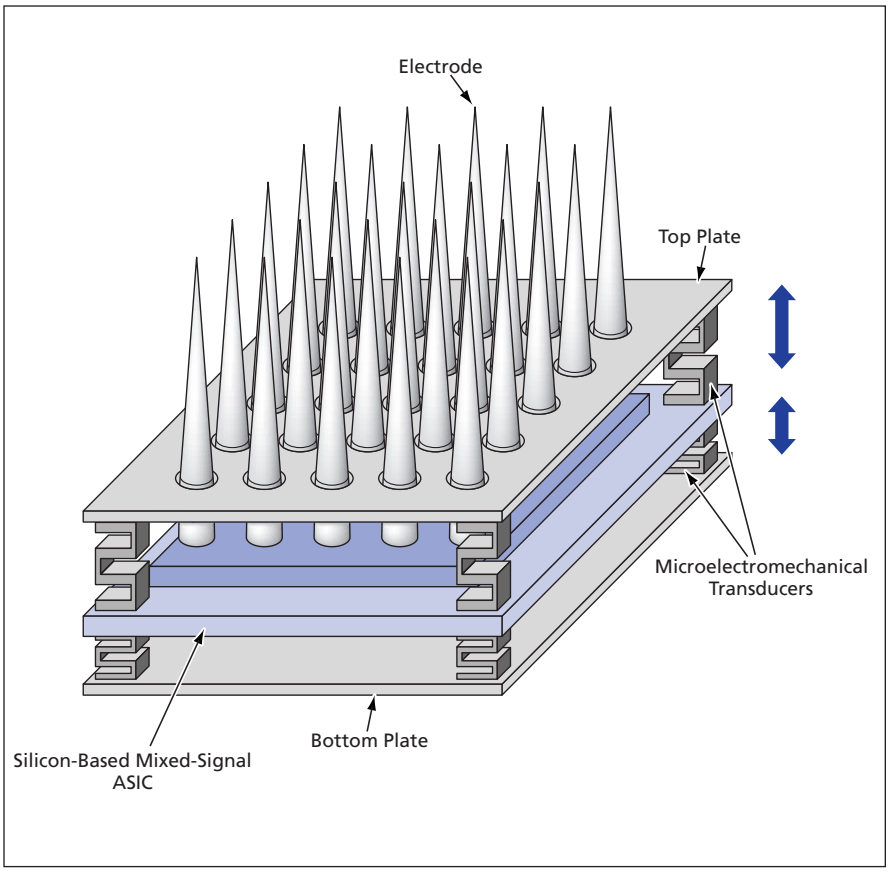
Neuro-Prosthetic Implants With Adjustable Electrode Arrays

Depths of penetration of electrodes would be adjusted to maximize received signals.

NASA's Jet Propulsion Laboratory, Pasadena, California

Brushlike arrays of electrodes packaged with application-specific integrated circuits (ASICs) are undergoing development for use as electronic implants — especially as neuro-prosthetic devices that might be implanted in brains to detect weak electrical signals generated by neurons. These implants partly resemble the ones reported in "Integrated Electrode Arrays for Neuro-Prosthetic Implants" (NPO-21198), *NASA Tech Briefs*, Vol. 27, No. 2 (February 2003), page 48. The basic idea underlying both the present and previously reported implants is that the electrodes would pick up signals from neurons and the ASICs would amplify and otherwise preprocess the signals for monitoring by external equipment.

The figure presents a simplified and partly schematic view of an implant according to the present concept. Whereas the electrodes in an implant according to the previously reported concept would be microscopic wires, the electrodes according to the present concept are in the form of microscopic needles. An even more important difference would be that, unlike the previously reported concept, the present concept calls for the inclusion of microelectromechanical actuators for adjusting the depth of penetration of the electrodes into brain tissue.



The **Thickness of the Implant Package** and/or the length of protrusion of the electrodes would be adjusted by use of the microelectromechanical actuators.

The prototype implant now under construction includes an array of 100 electrodes and corresponding array of electrode contact pads formed on opposite faces of a plate fabricated by techniques that are established in the art of microelectromechanical systems (MEMS). A mixed-signal ASIC under construction at the time of reporting the information for this article will include 100 analog amplifier channels (one amplifier per electrode). On one face of the mixed-signal ASIC there will be a solder-bump/micro-pad array that will have the same pitch as that of the electrode array, and that will be used to make the electrical and mechanical connections between the electrode array and the ASIC. Once the electrode array and the ASIC are soldered together, the remaining empty space between them will be filled with a biocompatible epoxy, the remaining exposed portions of the ASIC will be covered with micromachined plates for protection against corrosive bodily fluids, and then the ASIC and its covering micromachined plates will be coated with parylene.

The implant includes a top plate, into which through-holes of the same pitch as that of the electrodes have been micromachined. The plate is mounted so that the electrodes protrude through the holes. The implant also includes a bottom plate without through-holes. The depth of penetration of the electrodes into brain tissue (more precisely, the thickness of, and the length of protrusion of the electrodes from, the implant package) would be controlled by use of microelectromechanical actuators that would move the top and bottom plates toward or away from the MEMS electrode-supporting plate.

The microelectromechanical actuators would be controlled by electrical signals from the ASIC. According to one concept under consideration at press time, the actuators could be microfabricated electrochemical cells containing solid electrolytes that expand by large amounts (increase in thickness of the order of 50 percent) when charged to potentials of the order of 3 V. The control signals for the transducers could originate in external equipment or could be gener-

ated by an on-chip servocontrol subsystem that would strive to adjust the depth of penetration to maximize the strength of signals picked up by the electrodes. The ASIC will include a section for induction and/or radio reception of power and control signals from, and for transmission of electrode readout signals to, external equipment. A simple wire dipole antenna or a printed spiral coil on a flexible substrate could be used to couple the signals between the implant and external equipment, without need for wire connections.

This work was done by Jay Whitacre, Linda Y. Del Castillo, Mohammad Mojarradi, Travis Johnson, William West, and Richard Andersen of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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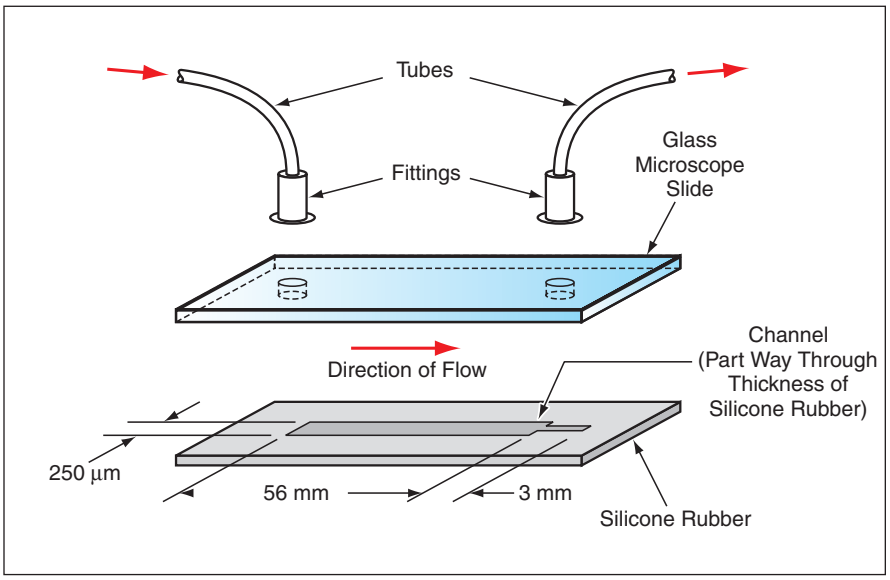
Microfluidic Devices for Studying Biomolecular Interactions

These devices can be fabricated rapidly and inexpensively.

Marshall Space Flight Center, Alabama

Microfluidic devices for monitoring biomolecular interactions have been invented. These devices are basically highly miniaturized liquid-chromatography columns. They are intended to be prototypes of miniature analytical devices of the "laboratory on a chip" type that could be fabricated rapidly and inexpensively and that, because of their small sizes, would yield analytical results from very small amounts of expensive analytes (typically, proteins). Other advantages to be gained by this scaling down of liquid-chromatography columns may include increases in resolution and speed, decreases in the consumption of reagents, and the possibility of performing multiple simultaneous and highly integrated analyses by use of multiple devices of this type, each possibly containing multiple parallel analytical microchannels.

The principle of operation is the same as that of a macroscopic liquid-chromatography column: The column is a channel packed with particles, upon which are immobilized molecules of the protein of interest (or one of the proteins of interest if there are more than one). Starting at a known time, a solution or suspension containing molecules of the protein or other substance of interest is pumped into the channel at its inlet. The liquid emerging from the outlet of the channel is monitored to detect the molecules of the dissolved or suspended substance(s). The time that it takes these molecules to flow from the inlet to the outlet is a measure of the degree of interaction between the immobilized and the dissolved or suspended molecules. Depending on the precise natures of the molecules, this measure can be used for diverse purposes: examples include screening for solution conditions that favor crystallization of proteins, screening for interactions between drugs and proteins, and determining the functions of biomolecules.



A **Basic Microfluidic Device** according to the invention includes a sheet of silicone rubber containing a molded channel that is exposed at its upper surface. The sheet is sealed to a glass microscope slide, thereby enclosing the channel.

The figure presents a schematic exploded view of a basic microfluidic device according to the invention. The device includes a sheet of polydimethylsiloxane (silicone rubber) that contains the channel and that is sealed to a glass microscope slide. In order to make this sheet, one first makes a mold that comprises a flat surface from which protrudes a ridge having the dimensions of the channel. The mold can be fabricated photolithographically on an oxidized silicon substrate. The silicone-rubber sheet is formed by casting the mixture of silicone-rubber ingredients on the mold.

Prior to assembly, a diamond-tipped drill is used to make holes in the microscope slide at the locations assigned to the inlet and outlet ends of the channel. After cleaning and oxidizing in an air plasma cleaner, the silicone-rubber sheet and the microscope slide are pressed together, taking care to align the holes with the ends of the channels. No adhesive is needed; an irreversible seal is formed spontaneously between the glass and the silicone rubber.

Fittings for tubes to carry the liquid are attached to the edges of the holes in the microscope slide. Particles coated with the substance to be immobilized in the column are suspended in a slurry,