



## Fabricating PFPE Membranes for Capillary Electrophoresis

Precisely sized and positioned holes are defined by photomasks.

NASA's Jet Propulsion Laboratory, Pasadena, California

A process has been developed for fabricating perfluoropolyether (PFPE) membranes that contain microscopic holes of precise sizes at precise locations. The membranes are to be incorporated into "laboratory-on-a-chip" microfluidic devices to be used in performing capillary electrophoresis.

The present process is a modified version of part of the process, described in the immediately preceding article, that includes a step in which a liquid PFPE layer is cured into solid (membrane) form by use of ultraviolet light. In the present process, one exploits the fact that by masking some locations to prevent exposure to ultraviolet light, one

can prevent curing of the PFPE in those locations. The uncured PFPE can be washed away from those locations in the subsequent release and cleaning steps. Thus, holes are formed in the membrane in those locations.

The most straightforward way to implement the modification is to use, during the ultraviolet-curing step, an ultraviolet photomask similar to the photomasks used in fabricating microelectronic devices. In lieu of such a photomask, one could use a mask made of any patternable ultraviolet-absorbing material (for example, an ink or a photoresist).

This work was done by Michael C. Lee, Peter A. Willis, and Frank Greer of Caltech

and Jason Rolland of Liquidia Technologies Inc. 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:

Innovative Technology Assets Management  
JPL

Mail Stop 202-233

4800 Oak Grove Drive

Pasadena, CA 91109-8099

E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-45782, volume and number of this NASA Tech Briefs issue, and the page number.

## Linear Actuator Has Long Stroke and High Resolution

There are potential applications in precise measurement and precise fabrication.

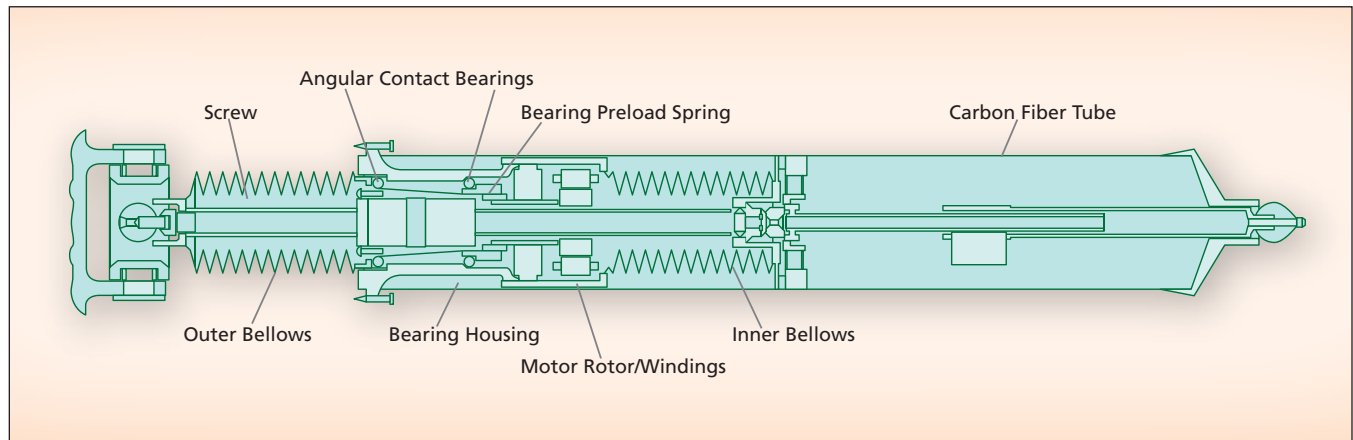
NASA's Jet Propulsion Laboratory, Pasadena, California

The term "precision linear actuator, direct drive" ("PLADD") refers to a robust linear actuator designed to be capable of repeatedly performing, over a lifetime of the order of 5 to 10 years, positioning maneuvers that include, variously, submicron increments or slews of the order of a centimeter. The PLADD is capable of both long stroke (120 mm) and high resolution (repeatable incre-

ments of 20 nm). Unlike precise linear actuators of prior design, the PLADD contains no gears, levers, or hydraulic converters. The PLADD, now at the prototype stage of development, is intended for original use as a coarse-positioning actuator in a spaceborne interferometer. The PLADD could also be adapted to terrestrial applications in which there are requirements for long stroke and

high resolution: potential applications include medical imaging and fabrication of semiconductor devices.

The PLADD (see figure) includes a commercially available ball-screw actuator driven directly by a commercially available three-phase brushless DC motor. The ball-screw actuator comprises a spring-preloaded ball nut on a ball screw that is restrained against rota-



This Partly Schematic Cross Section depicts some of the components of the PLADD.

tion as described below. The motor is coupled directly (that is, without an intervening gear train) to a drive link that, in turn, is coupled to the ball nut. By eliminating the gear train, the direct-drive design eliminates the complexity, backlash, and potential for misalignment associated with a gear train.

To prevent inadvertent movement, there is a brake that includes flexured levers compressed against the drive link by preload springs. This is a power-off brake: There are also piezoelectric stacks that can be activated to oppose the springs and push the levers away from the drive link. Hence, power must be applied to the piezoelectric stacks to release the drive link from braking.

To help ensure long operational life, all of the mechanical drive components are immersed in an oil bath within hermetically sealed bellows. The outer end of the bellows holds the outer end of the ball screw, thereby preventing rotation of the ball screw.

Positioning is controlled by an electronic control system that includes digital and analog subsystems that interact with the motor and brake and with two sensor/encoder units: a Hall-effect-sensor rotation encoder and a linear glass-scale encoder. This system implements a proportional + integral + derivative control algorithm that results in variation of voltage commands to each of the three pairs of windings of the brushless DC motor. In one of two alter-

native control modes, the voltages are applied to the windings in a trapezoidal commutation scheme on the basis of timing signals obtained from the Hall-effect sensors; this scheme yields relatively coarse positioning — 24 steps per motor revolution. The second control mode involves a sinusoidal commutation scheme in which the output of the linear glass-scale encoder is transposed to rotational increments to yield much finer position feedback — more than 400,000 steps per revolution.

*This work was done by Brant T. Cook, Donald M. Moore, David F. Braun, John S. Koenig, and Steve M. Hankins of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-45692*

---

## Installing a Test Tap on a Metal Battery Case

*Lyndon B. Johnson Space Center, Houston, Texas*

A mechanical fitting and relatively simple and safe method of installing it on the metal case of a battery have been devised to provide access to the interior of the battery to perform inspection and/or to measure such internal conditions as temperature and pressure. A metal boss or stud having an exterior thread is attached to the case by capacitor-discharge stud welding (CDSW), which takes only 3 to 6 milliseconds and in which the metallur-

gical bond (weld) and the heat-affected zone are limited to a depth of a few thousandths of an inch (a few hundredths of a millimeter).

These characteristics of CDSW prevent distortion of the case and localized internal heating that could damage the chemical components inside of the battery. An access hole is then drilled through the stud and case, into the interior of the battery. A mechanical fitting having a matching thread is in-

stalled on the stud and the interior end of the fitting is sealed with a pressure-sealing washer/gasket. The exterior end of the fitting is configured for attachment of whatever instrumentation is required for the selected inspection or measurement.

*This work was done by Daniel R. Mayes of Johnson Space Center and Daniel J. Rybicki of Lockheed Martin Corp. Further information is contained in a TSP (see page 1). MSC-23827-1*

---

## Fabricating PFPE Membranes for Microfluidic Valves and Pumps

**This process contributes to development of “laboratory-on-a-chip” devices.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A process has been developed for fabricating membranes of a perfluoropolyether (PFPE) and integrating them into valves and pumps in “laboratory-on-a-chip” microfluidic devices. Membranes of poly(tetrafluoroethylene) [PTFE] and poly(dimethylsilane) [PDMS] have been considered for this purpose and found wanting. By making it possible to use PFPE instead of PTFE or PDMS, the present process expands the array of options for further development of microfluidic devices for diverse applications that could include detection of biochemicals of interest, detection of toxins and biowarfare agents, synthesis

and analysis of proteins, medical diagnosis, and synthesis of fuels.

To be most useful, a membrane material for a microfluidic valve or pump should be a chemically inert elastomer. PTFE is highly chemically inert and is a thermoplastic and, therefore, subject to cold flow and creep. Also, procedures for fabricating PTFE membranes are excessively complex. PDMS is an elastomer that has been used in prior microfluidic devices but, undesirably, reacts chemically with some liquids (acetonitrile, acids, and fuels) that might be required to be handled by microfluidic devices in some applications. On the other hand,

the PFPE in question has elastomeric properties similar to those of PDMS and a degree of chemical inertness similar to that of PTFE.

The specific membrane material to which the present process applies is a commercially available, ultraviolet-curable PFPE. A microfluidic device of the type to which the process applies consists mainly of this PFPE sandwiched between two plates of a highly chemically resistant, low-thermal-expansion borosilicate glass manufactured by the float method. Heretofore, there have been two obstacles to fabrication of microfluidic devices from this combination of