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

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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

materials: (1) The lack of chemical reactivity between the PFPE and the glass makes it impossible to form a lasting bond between them; and (2) such conventional membrane-fabrication techniques as spin coating yield membranes that are not sufficiently flat and not sufficiently resistant to curling upon themselves. The present process overcomes these obstacles.

The process consists mainly of the following steps:

1. A fluorocarbon-based polymer is formed on the glass plates by means of a plasma deposition subprocess.
2. The polymer is patterned by use of a photoresist and conventional photolithography.
3. The polymer is removed in the pattern by use of an O_2/Ar plasma.
4. The remaining polymer surface areas are cleaned and modified by use of a low-energy O_2 plasma.
5. The glass plates are spin-coated with a lift-off material, which is then cured by heating to a temperature of 150 °C for 5 minutes.
6. The liquid (uncured) PFPE material is pressed between the two lift-off-layer-coated glass plates, along with 250-µm-thick shims to define the desired thickness of the PFPE membrane.
7. The liquid PFPE is cured to a solid by exposure to ultraviolet light for 5 minutes.
8. The PFPE membrane is released from the glass plates by submersion in a developer solution and/or acetone.
9. The glass plates and the PFPE membrane are cleaned and activated for bonding by exposure to an O_2 plasma.
10. The glass plates and the membrane are aligned and sandwiched together at a temperature ≤100 °C and a pressure of 3 bar (0.3 MPa) for one hour. This combination of pressure and temperature is sufficient to cause a chemical reaction that results in bonding of the PFPE membrane to the polymer coats on the glass plates.