

dition to determining the error signal (the first derivative of absorption with respect to frequency), the system also determines the derivative of the error signal with respect to time. The system can readily identify the locking zone because the derivative of the error signal is positive and reaches its highest value in the locking zone and is negative just outside the locking zone. Once the laser frequency is inside the locking zone, the frequency sweep is halted and the frequency-stabilization circuitry that implements the locking scheme described above is activated. In a test, the system was demonstrated to be capable of maintaining the frequency of a diode laser at the middle of a 944-nm-wavelength water-vapor absorption peak, with an error of no more than 3 percent of the full width at half maximum of the peak.

*This work was done by Grady J. Koch of Langley Research Center. Further information is contained in a TSP (see page 1). LAR-16394-1*

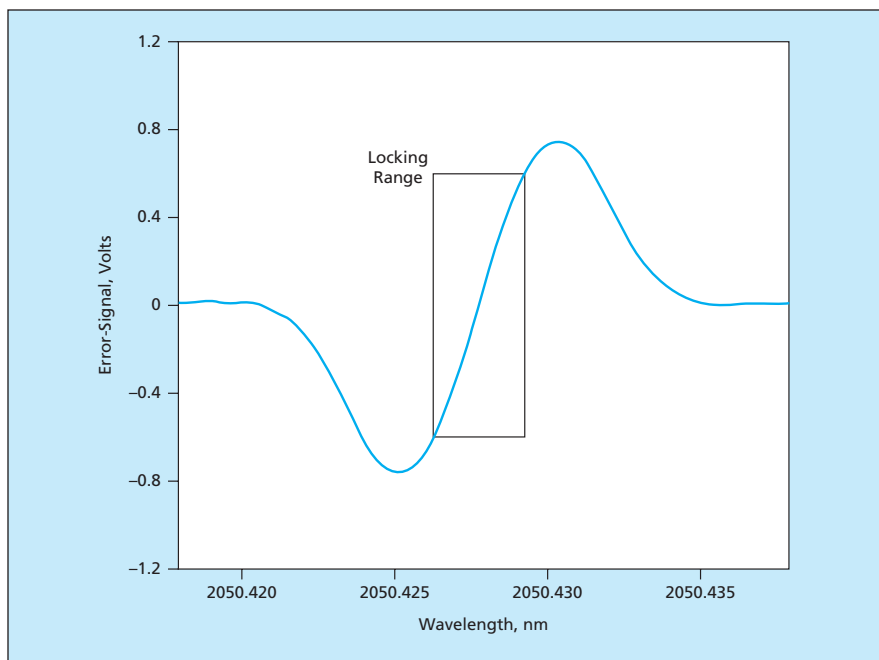


Figure 2. The Error Signal and its derivative are used in finding the locking range and then maintaining lock. This error signal was obtained in operation using a CO<sub>2</sub> absorption peak centered at a wavelength of 2,050.428 nm.

## Self-Passivating Lithium/Solid Electrolyte/Iodine Cells

Passivating lithium iodide films of optimum or nearly optimum thickness form spontaneously.

NASA's Jet Propulsion Laboratory, Pasadena, California

Robust lithium/solid electrolyte/iodine electrochemical cells that offer significant advantages over commercial lithium/iodine cells have been developed. At room temperature, these cells can be discharged at current densities 10 to 30 times those of commercial lithium/iodine cells. Moreover, from room temperature up to 80 °C, the maximum discharge-current densities of these cells exceed those of all other solid-electrolyte-based cells.

A cell of this type includes a metallic lithium anode in contact with a commercial flexible solid electrolyte film that, in turn, is in contact with an iodine/graphite cathode. The solid electrolyte (the chemical composition of which has not been reported) offers the high ionic conductivity needed for high cell performance. However, the solid electrolyte exhibits an undesirable chemical reactivity to lithium that, if not mitigated, would render the solid electrolyte unsuitable for use in a lithium cell. In this cell, such mitigation is affected by the formation of a thin passivating layer of lithium iodide at the anode/electrolyte interface.

Test cells of this type were fabricated from iodine/graphite cathode pellets, free-standing solid-electrolyte films, and

lithium-foil anodes. The cathode mixtures were made by grinding together blends of nominally 10 weight percent graphite and 90 weight percent iodine. The cathode mixtures were then pressed into pellets at 36 kpsi (248 MPa) and inserted into coin-shaped stainless-steel cell cases that were coated with graphite paste to minimize corrosion. The solid-electrolyte film material was stamped to form circular pieces to fit in the coin cell cases, inserted in the cases, and pressed against the cathode pellets with polyethylene gaskets. Lithium-foil anodes were placed directly onto the electrolyte films. The layers described thus far were pressed and held together by stainless-steel shims, wave springs, and coin cell caps. The assembled cells were then crimped to form hermetic seals.

It was found that the solid electrolyte films became discolored within seconds after they were placed in contact with the cathodes — a result of facile diffusion of iodine through the solid electrolyte material (see figure). This is fortuitous for the following reasons:

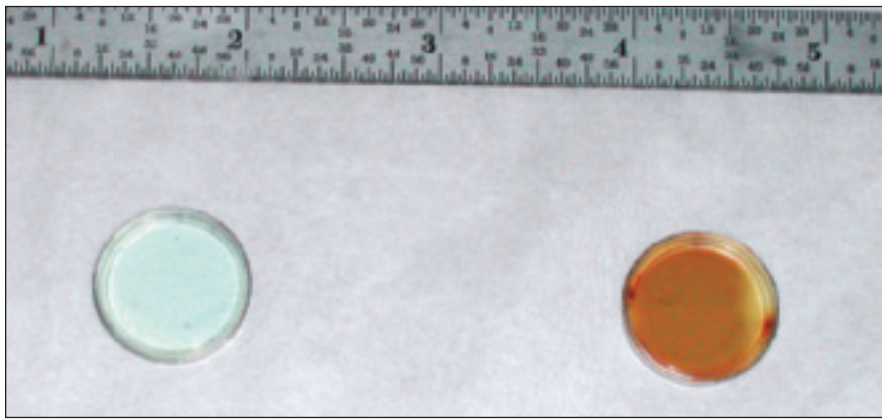
- Upon reaching the anode side, the iodine reacts with lithium from the anode to form lithium iodide, which is known as both a solid electrolyte and an effec-

tive passivating-film material for solid electrolytes in contact with lithium.

- Heretofore, it has been necessary to vacuum-deposit LiI onto a solid electrolyte to form a passivating film. The vacuum-deposition process is expensive, time-consuming, and difficult. If the thickness of the deposited LiI film is  $\approx 1$  mm or more, the high electrical resistivity of LiI limits the cell discharge rates. If the film is too thin, it likely contains pinholes, which act as corrosion sites and thereby degrade cell performance.
- In the present case, the LiI is neither thick enough to introduce excessive electrical resistance nor too thin to prevent formation of pinholes: The formation of LiI film is self-limiting because iodine diffuses very slowly through LiI.

Commercial lithium/iodine cells are primary cells (that is, they are not rechargeable, as opposed to secondary cells, which are rechargeable). Thus far, lithium/solid-electrolyte/iodine cells have been demonstrated in primary form only. However, in principle, the present approach to passivation should be applicable to secondary cells also.

*This work was done by Ratnakumar Bugga, Jay Whitacre, Sekharipuram Narayanan, and*



The Half Cell on the left contains a graphite cathode pellet behind a solid-electrolyte film. The half cell on the right contains a graphite/iodine pellet behind a solid-electrolyte film; the darkening of this cell was caused by diffusion of iodine through the solid electrolyte.

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## Four-Quadrant Analog Multipliers Using $G^4$ -FETs

Devices with independently biased multiple inputs are exploited to simplify multiplier circuits.

NASA's Jet Propulsion Laboratory, Pasadena, California

Theoretical analysis and some experiments have shown that the silicon-on-insulator (SOI) 4-gate transistors known as  $G^4$ -FETs can be used as building blocks of four-quadrant analog voltage multiplier circuits. Whereas a typical prior analog voltage multiplier contains between six and 10 transistors, it is possible to construct a superior voltage multiplier using only four  $G^4$ -FETs.

A  $G^4$ -FET is a combination of a junction field-effect transistor (JFET) and a metal oxide/semiconductor field-effect transistor (MOSFET). It can be regarded as a single transistor having four gates, which are parts of a structure that affords high functionality by enabling the utilization of independently biased multiple inputs. The structure of a  $G^4$ -FET of the type of interest here (see Figure 1) is that of a

partially-depleted SOI MOSFET with two independent body contacts, one on each side of the channel. The drain current comprises of majority charge carriers flowing from one body contact to the other — that is, what would otherwise be the side body contacts of the SOI MOSFET are used here as the end contacts [the drain (D) and the source (S)] of the  $G^4$ -FET. What would otherwise be the

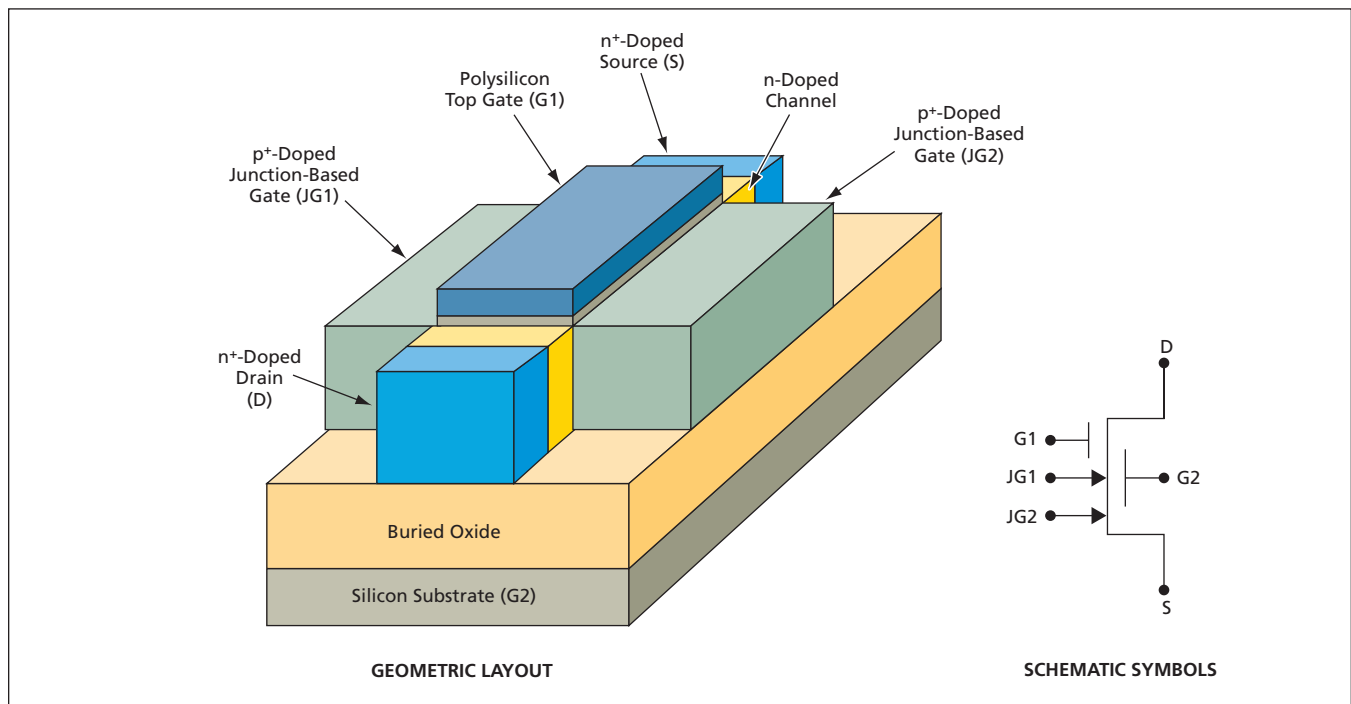


Figure 1. In this  $G^4$ -FET, the top gate plays the same role as does the sole gate in a conventional accumulation-mode MOSFET. The side gates (JG1 and JG2) provide additional degrees of freedom for design and operation, beyond those of a conventional MOSFET.