Physical Sciences

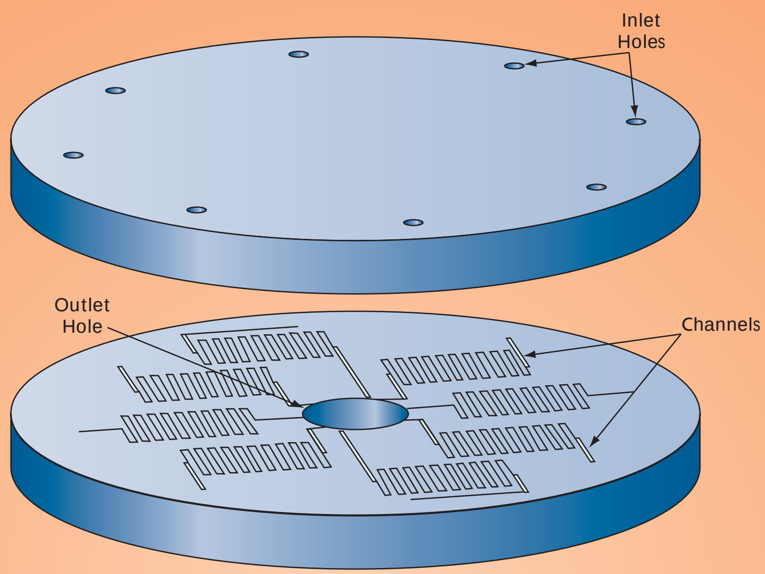
Silicon Microleaks for Inlets of Mass Spectrometers

These devices could contribute to feasibility of small, portable mass spectrometers.

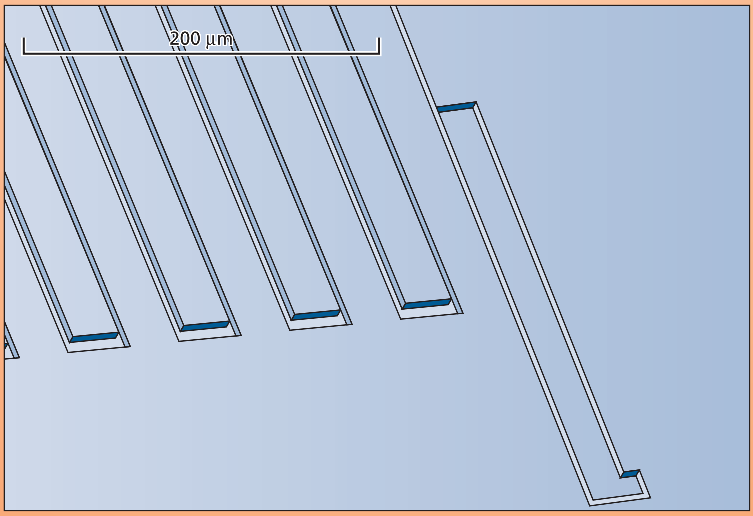
Goddard Space Flight Center, Greenbelt, Maryland

Microleaks for inlets of mass spectrometers used to analyze atmospheric gases can be fabricated in silicon wafers by means of photolithography, etching, and other techniques that are commonly used in the manufacture of integrated circuits and microelectromechanical systems. The microleaks serve to limit the flows of the gases into the mass-spectrometer vacuums to specified very small flow rates consistent with the capacities of the spectrometer vacuum pumps. There is a need to be able to precisely tailor the dimensions of each microleak so as to tailor its conductance to a precise low value. (As used here, "conductance" signifies the ratio between the rate of flow in the leak and the pressure drop from the upstream to the downstream end of the leak.) To date, microleaks have been made, variously, of crimped metal tubes, pulled glass tubes, or frits. Crimped-metal and pulled-glass-tube microleaks cannot readily be fabricated repeatably to precise dimensions and are susceptible to clogging with droplets or particles. Frits tend to be differentially chemically reactive with various gas constituents and, hence, to distort the gas mixtures to be analyzed. The present approach involving microfabrication in silicon largely overcomes the disadvantages of the prior approaches.

A silicon microleak comprises a silicon disk or plug containing channels that typically have cross-sectional dimensions of the order of microns and lengths from hundreds of microns to about a millimeter (see figure). Lithography enables precise tailoring of the lengths and cross-sectional dimensions of the channels, thereby enabling precise tailoring of conductances. A plug or disk can be fabricated to contain multiple channels that sustain parallel flows to reduce the adverse effect of clogging of a single channel with particles or droplets. The silicon and other materials incorporated during fabrication do not react chemically with most atmospheric gases to be sampled and,



EXPLODED VIEW OF SILICON MICROLEAK STRUCTURE



SCANNING ELECTRON MICROGRAPH SHOWING AN ETCHED CHANNEL PRIOR TO BONDING THE UPPER AND LOWER WAFERS

Serpentine Channels are photolithographically defined, then etched onto the surface of the lower silicon wafer. Next, the etched lower silicon wafer is fusion-bonded to the upper silicon wafer. Finally, inlet and outlet holes providing access to the ends of the channels are etched through the upper and lower wafers, respectively.

hence, do not distort samples in most cases. The techniques used in fabrication are amenable to fabrication in batches, thereby enabling production at relatively low cost.

Silicon microleaks have potential for additional device functionality. For example, resistance heaters could be integrated into silicon microleak structures to enable heating of inlets to vaporize droplets to prevent clogging. Thermistors could also be integrated into silicon microleak structures for monitoring their temperatures. Yet another device concept is that of a one-shot-closing valve: an integrated resistance heater would be used to momentarily melt a microscopic piece of a suitable metal positioned near a channel to cause the metal to flow into, and thus plug, the channel. If all of the multiple channels in a silicon microleak structure were equipped with one-shot-closing valves, then the valves could be actuated, one at a time, to effect stepped reductions in the overall conductance of the microleak.

Silicon microleaks could contribute to the feasibility of proposed small, field-deployable mass spectrometers for homeland-security and point-of-care medical diagnostic applications. Silicon microleaks might also be useful as very-low-conductance calibrated leaks that could enable different approaches to environmental gas sampling. Orifices that support leak rates ranging from 0.1 to 5 standard cubic centimeters per minute are currently available for use in environmental sampling. Silicon microleaks, which can be made to support flow rates many orders of magnitude lower, would enable gas sampling with much smaller volumes.

This work was done by Dan Harpold, Hasso Niemann, and Brian G Jamieson of Goddard Space Flight Center and Bernard A Lynch of MEI Technologies, Inc. Further information is contained in a TSP (see page 1). GSC-15341-1

CGH Figure Testing of Aspherical Mirrors in Cold Vacuums

Room-temperature and cryogenic tests yield complementary data on surface-figure errors.

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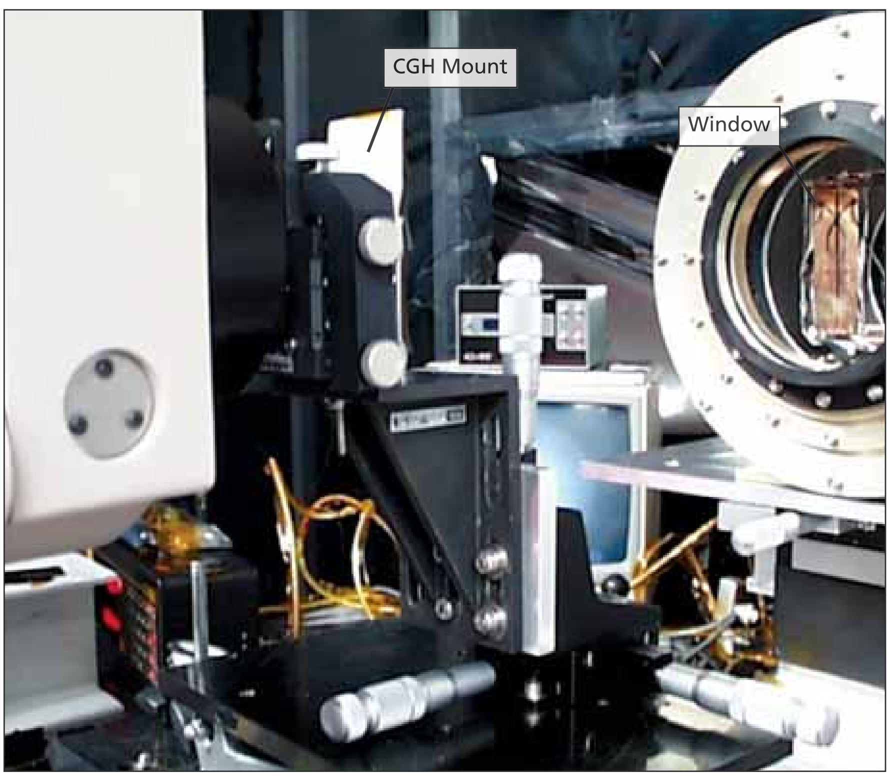
An established method of room-temperature interferometric null testing of mirrors having simple shapes (e.g., flat, spherical, or spheroidal) has been augmented to enable measurement of errors in the surface figures of off-axis, non-axisymmetric, aspherical mirrors when the mirrors are located inside cryogenic vacuum chambers. The established method involves the use of a computer-generated hologram (CGH), functionally equivalent to a traditional null lens, to modify the laser beam of an imaging interferometer to obtain a reference wavefront that matches the ideal surface figure of a mirror under test. The CGH is inserted at the appropriate position and orientation in the optical path of the imaging interferometer, which, in turn, is appropriately positioned and oriented with respect to the mirror under test. Deviations of the surface figure of the mirror from the ideal surface figure manifest themselves as interference fringes. Interferograms are recorded and analyzed to deduce figure errors.



A **CGH Is Positioned** to modify a test laser beam that travels, via a window, to and from a mirror under test inside a cryogenic vacuum chamber. The optical effects of the window, including the effects of any temperature gradient through the window, must be taken into account in analyzing test data.

The need for the present augmented method arises because testing an off-axis, non-axisymmetric, aspherical mirror in a cryogenic environment entails the following complications that are not present in room-temperature testing of simpler mirrors:

- There are commercial off-the-shelf CGHs for the simpler mirror shapes, but not for the more-complex aspherical, off-axis shapes.
- The wall of a typical cryogenic vacuum chamber blocks access to optomechanical alignment fiducial objects that are incorporated into or attached to the mirror.
- Thermal contraction from room temperature to the cryogenic test temperature changes gives rise to a change in the mirror surface, relative to the reference wavefront, that can be confused with a change in surface-figure error.
- The interferometer is located outside the cryogenic vacuum chamber and gains optical access to the mirror in the chamber via a window in the wall of the chamber (see figure). It is necessary to take account of the optical effects of the window, including any changes in these effects caused by imposition of