Resistively Heated SiC Nozzle for Generating Molecular Beams

This nozzle is more durable and efficient relative to its predecessors.

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An improved nozzle has been developed to replace nozzles used previously in an apparatus that generates a substantially unidirectional beam of molecules passing through a vacuum at speeds of several kilometers per second. The need to replace the previous nozzles arose from a complex set of causes that can be summarized as follows:

(1) The previous nozzles had short operational lifetimes because it was necessary to fabricate them from components made of several different materials that, when used together, do not last long at the high operating temperatures needed to generate the requisite high molecular speeds and

(2) To protect the vacuum chamber from excessive heating, it was necessary to surround the operating nozzle with a cooling shroud that robbed the nozzle of reflected heater power and thereby contributed to energy inefficiency.

The basic principle of operation of the apparatus is the same for both the previous and the present nozzle designs. The main working part of the nozzle is essentially a cylinder that is closed except that there is an inlet for a pressurized gas and, at one end, the cylinder is closed by a disk that contains a narrow central hole that serves as an outlet. The cylinder is heated to increase the thermal speeds of the gas molecules into the desired high-speed range. Heated, pressurized gas escapes through the outlet into a portion of the vacuum chamber that is separated, by a wall, from the rest of the vacuum chamber. In this portion of the vacuum chamber, the gas undergoes a free jet expansion. Most of the expanded gas is evacuated and thus does not become part of the molecular beam. A small fraction of the expanded beam passes through a narrow central orifice in the wall and thereby becomes a needle-thin molecular beam in the portion of the vacuum on the downstream side of the wall.

In a nozzle of the previous design, the cylinder was made of molybdenum, and the disk with the outlet hole, also made of molybdenum, was welded onto the cylinder at one end. In the improved nozzle, the cylinder and the disk at one end containing the narrow outlet hole are made of a single piece of silicon carbide. In a nozzle of the previous design, the molybdenum cylinder was surrounded by an alumina electrical-insulation cylinder that was, in turn, surrounded by a silicon carbide cylinder that served as an electrical resistance heater. In the improved nozzle, the silicon carbide cylinder serves as its own electrical resistance heater.

In the improved nozzle, the silicon carbide cylinder is brazed to a molybdenum fitting that is brazed to a stainless-steel fitting that is electron-beam welded onto a length of stainless-steel tubing. Electrodes made of tungsten wire are attached to the ends of the silicon carbide cylinder by means of two-piece molybdenum hinge clamps, wherein the electrodes serve as the hinge pins. Sufficient clearance is provided between each molybdenum clamp and the SiC cylinder nozzle to accommodate a piece of graphite tape that both cushions and ensures a high degree of electrical contact. To reflect some heater power to the SiC cylinder and thereby both increase energy efficiency and reduce heating of the vacuum chamber, the nozzle as described thus far is surrounded by a radiation shield in the form of 12 concentric cylindrical layers of 50-μm-thick tungsten foil that are dimpled to maintain gaps between successive layers. The radiation shield is cooled by a circulation subsystem.

The nozzle has been tested using a gas mixture comprising 1 percent argon and 99 percent hydrogen at feed pressures up to 450 psi (≈3.1 MPa) and temperatures up to 2,000 °C. In one test at 1,600 °C, the speed of the argon fraction of the beam was observed to be 3.3 km/s. On the basis of performance data from the tests, it has been estimated that the nozzle would have unlimited operational lifetime at room temperature, could operate for many hundreds of hours at 1,000 °C, and could operate for at least 100 hours at 1,500 °C. At operating temperatures above 1,500 °C, the nozzle is vulnerable to clogging, though in the absence of oxygen, it may still be capable of operating for many hours.

This work was done by Steven Cagiano of Goddard Space Flight Center; Robert Abell of Swales Aerospace; Edward Patrick and Mirl Bendt of Honeywell Technical Services, Inc.; and Cynthia Gundersen of AMU Engineering, Inc. Further information is contained in a TSP (see page 1).
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Compact Packaging of Photonic Millimeter-Wave Receiver

Bulky positioning mechanisms are not needed.

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A carrier structure made from a single silicon substrate is the basis of a compact, lightweight, relatively inexpensive package that holds the main optical/electronic coupling components of a photonic millimeter-wave receiver based on a lithium niobate resonator disk. The design of the package is simple and provides for precise relative placement of optical components, eliminating the need for complex, bulky positioning mechanisms like those commonly used to align optical components to optimize focus and coupling. Although a prototype of the package was fabricated as a discrete unit, the design is amenable to integration of the package into a larger photonic and/or electronic receiver system.

The components (see figure) include a lithium niobate optical resonator disk of 5-mm diameter and ≈200-μm thickness, positioned adjacent to a millimeter-wave resonator electrode. Other components include input and output coupling prisms and input and output optical fibers tipped with ball lenses for focusing and collimation, respectively.