

## Promoted-Combustion Chamber With Induction Heating Coil

Tests can be done at temperature and pressure combinations not previously attainable.

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An improved promoted-combustion system has been developed for studying the effects of elevated temperatures on the flammability of metals in pure oxygen. In prior promoted-combustion chambers, initial temperatures of metal specimens in experiments have been limited to the temperatures of gas supplies, usually near room temperature. Although limited elevated temperature promoted-combustion chambers have been developed using water-cooled induction coils for preheating specimens, these designs have been limited to low-pressure operation due to the hollow induction coil. In contrast, the improved promoted-combustion chamber can sustain a pressure up to 10 kpsi (69 MPa) and, through utilization of a solid induction coil, is capable of preheating a metal specimen up to its melting point [potentially in excess of 2,000 °F ( $\approx$ 1,100 °C)]. Hence, the improved promoted-combustion chamber makes a greater range of physical conditions and material properties accessible for experimentation.

The chamber consists of a vertical cylindrical housing with an inner diameter of 8 in. (20.32 cm) and an inner

height of 20.4 in. (51.81 cm). A threaded, sealing cover at one end of the housing can be unscrewed to gain access for installing a specimen. Inlet and outlet ports for gases are provided. Six openings arranged in a helical pattern in the chamber wall contain sealed sapphire windows for viewing an experiment in progress.

The base of the chamber contains pressure-sealed electrical connectors for supplying power to the induction coil. The connectors feature a unique design that prevents induction heating of the housing and the pressure sealing surfaces; this is important because if such spurious induction heating were allowed to occur, chamber pressure could be lost.

The induction coil is 10 in. (25.4 cm) long and is fitted with a specimen holder at its upper end. At its lower end, the induction coil is mounted on a ceramic base, which affords thermal insulation to prevent heating of the base of the chamber during use. A sapphire cylinder protects the coil against slag generated during an experiment.

The induction coil is energized by a 6-kW water-cooled power supply operating

at a frequency of 400 kHz. The induction coil is part of a parallel-tuned circuit, the tuning of which is used to adjust the coupling of power to the specimen.

The chamber is mounted on a test stand along with pumps, valves, and plumbing for transferring pressurized gas into and out of the chamber. In addition to multiple video cameras aimed through the windows encircling the chamber, the chamber is instrumented with gauges for monitoring the progress of an experiment. One of the gauges is a dual-frequency infrared temperature transducer aimed at the specimen through one window. Chamber operation is achieved via a console that contains a computer running apparatus-specific software, a video recorder, and real-time video monitors. For safety, a blast wall separates the console from the test stand.

*This work was done by Erin Richardson, Richard Hagood, and Freida Lowery of Marshall Space Flight Center, Stephen Herald of Integrated Concepts & Research Corp., and Dean Byess of Qualis Corp. Further information is contained in a TSP (see page 1). MFS-32036*

## Miniature Ion-Mobility Spectrometer

Advantages would include robustness, simplicity, and extreme miniaturization.

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The figure depicts a proposed miniature ion-mobility spectrometer that would be fabricated by micromachining. Unlike prior ion-mobility spectrometers, the proposed instrument would not be based on a time-of-flight principle and, consequently, would not have some of the disadvantageous characteristics of prior time-of-flight ion-mobility spectrometers. For example, one of these characteristics is the need for a bulky carrier-gas-feeding subsystem that includes a shutter gate to provide short pulses of gas in order to generate short pulses of ions. For another example, there is need for a complex device to generate pulses of ions from the pulses of gas and the device is capable of ionizing only a fraction of the incoming gas molecules; these characteristics preclude miniaturization. In contrast, the proposed instrument would not require

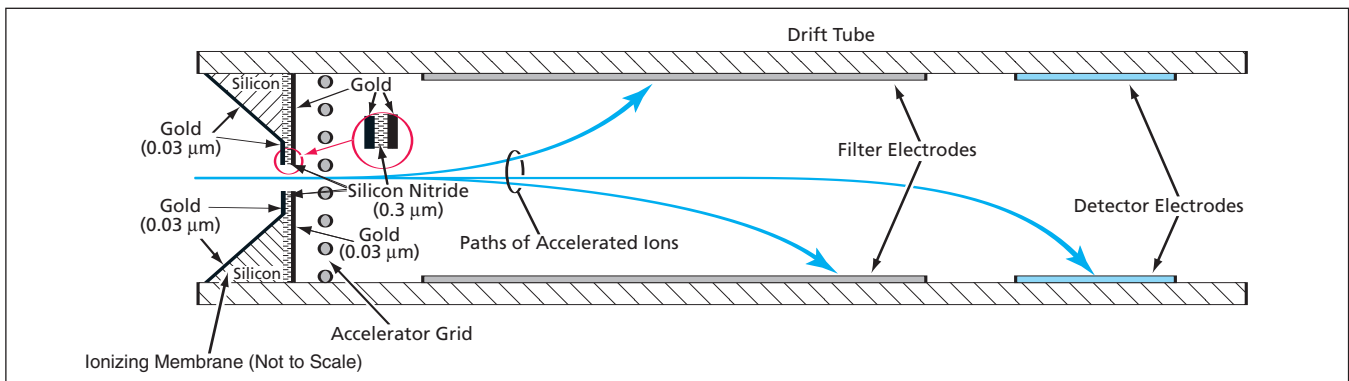
a carrier-gas-feeding subsystem and would include a simple, highly compact device that would ionize all the molecules passing through it.

The ionization device in the proposed instrument would be a 0.1-micron-thick dielectric membrane with metal electrodes on both sides. Small conical holes would be micromachined through the membrane and electrodes. An electric potential of the order of a volt applied between the membrane electrodes would give rise to an electric field of the order of several megavolts per meter in the submicron gap between the electrodes. An electric field of this magnitude would be sufficient to ionize all the molecules that enter the holes. Ionization (but not avalanche arcing) would occur because the distance between the ionizing electrodes would be less than the mean free path of gas molecules at

the operating pressure of instrument.

An accelerating grid would be located inside the instrument, downstream from the ionizing membrane. The electric potential applied to this grid would be negative relative to the potential on the inside electrode of the ionizing membrane and would be of a magnitude sufficient to generate a moderate electric field. Positive ions leaving the membrane holes would be accelerated in this electric field. The resulting flux of ions away from the ionization membrane would create a partial vacuum that would draw more of the gas medium through the membrane.

The figure depicts a filter electrode and detector electrodes located along the sides of a drift tube downstream from the accelerator electrode. These electrodes would apply a transverse AC electric field superimposed on a ramped DC electric



This Proposed Ion-Mobility Spectrometer would be made to sweep repeatedly through a spectrum of ionic species by applying a combination of AC and ramped DC voltages between the filter electrodes.

field. The AC field would effect differential transverse dispersal of ions. At a given instant of time, the trajectories of most of the ions would be bent toward the electrodes, causing most of the ions to collide with the electrodes and thereby become neutralized. The DC field would partly counteract the dispersive effect of the AC field, straightening the trajectories of a selected species of ions; the selection would

vary with the magnitude of the applied DC field. The straightening of the trajectories of the selected ions would enable them to pass into the region between the detector electrodes. Depending on the polarity of the voltage applied to the detector electrodes, the electric field between the detector electrodes would draw the selected ions to one of these electrodes. Hence, the current collected by

one of the detector electrodes would be a measure of the abundance of ions of the selected species. The ramping of the filter-electrode DC voltage would sweep the selection of ions through the spectrum of ionic species.

*This work was done by Frank T. Hartley of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-21109*

## Mixed-Salt/Ester Electrolytes for Low-Temperature Li<sup>+</sup> Cells

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Electrolytes comprising, variously, LiPF<sub>6</sub> or LiPF<sub>6</sub> plus LiBF<sub>4</sub> dissolved at various concentrations in mixtures of alkyl carbonates and alkyl esters have been found to afford improved low-temperature performance in rechargeable lithium-ion electrochemical cells. These and other electrolytes have been investigated in a continuing effort to extend the lower limit of operating temperatures of such cells. This research at earlier stages, and the underlying physical and chemical principles, were reported in numerous previous *NASA Tech Briefs*

articles, the most recent being "Ester-Based Electrolytes for Low-Temperature Li-Ion Cells" (NPO-41097), *NASA Tech Briefs*, Vol. 29, No. 12 (December 2005), page 59. The ingredients of the solvent mixtures include ethylene carbonate (EC), ethyl methyl carbonate (EMC), methyl butyrate (MB), and methyl propionate (MP). The electrolytes were placed in Li-ion cells containing carbon anodes and LiNi<sub>0.8</sub>Co<sub>0.2</sub>O<sub>2</sub> cathodes, and the electrical performances of the cells were measured over a range of temperatures down to -60 °C. The elec-

trolytes that yielded the best low-temperature performances were found to consist, variously, of 1.0 M LiPF<sub>6</sub> + 0.4 M LiBF<sub>4</sub> or 1.4 LiPF<sub>6</sub> in 1EC + 1EMC + 8MP or 1EC + 1EMC + 8MB, where the concentrations of the salts are given in molar units and the proportions of the solvents are by relative volume.

*This work was done by Marshall Smart and Ratnakumar Bugga of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-42862*

## Miniature Free-Space Electrostatic Ion Thrusters

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A miniature electrostatic ion thruster is proposed for maneuvering small spacecraft. In a thruster based on this concept, one or more propellant gases would be introduced into an ionizer based on the same principles as those of the device described in the earlier article, "Miniature Bipolar Electrostatic Ion Thruster" (NPO-21057). On the front side, positive ions leaving an ionizer element would be accelerated to high momentum by an electric

field between the ionizer and an accelerator grid around the periphery of the concave laminate structure. On the front side, electrons leaving an ionizer element would be ejected into free space by a smaller accelerating field. The equality of the ion and electron currents would eliminate the need for an additional electron- or ion-emitting device to keep the spacecraft charge-neutral. In a thruster design consisting of multiple membrane ionizers in a

thin laminate structure with a peripheral accelerator grid, the direction of thrust could then be controlled (without need for moving parts in the thruster) by regulating the supply of gas to specific ionizer.

*This work was done by Frank T. Hartley and James B. Stephens of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-21059*