Prototype Space Propulsion System Runs on Microwave-Powered Thruster

Using parts from a 1,000 W kitchen microwave oven, Michael M. Micci, associate professor of aerospace engineering at The Pennsylvania State University, has built a prototype propulsion system that shows promise as a thruster for positioning and maneuvering satellites in space.

He said that the thruster concept is based on the fact that microwaves can be used to create and maintain a free-floating plasma within a cavity. If a cold "fuel" gas is passed through or around the plasma in the cavity, the cold gas will become heated and create thrust when allowed to flow out through a nozzle and heat energy is converted to kinetic energy.

Micci said, since the plasma creates temperatures higher than those possible by chemical combustion, the plasma creates more thrust from the same amount of cold "fuel" gas than chemical combustion. In addition to being more fuel-efficient than chemical systems, the microwave-powered thruster is inherently safer as well, he said. The thruster operates only when the magnetron is generating microwaves. If the magnetron is turned off, so is the plasma that heats the fuel.

In Micci's prototype the electrical hardware and microwave source, or magnetron, came from a conventional 1,000 W kitchen microwave oven. The system has been operated using hydrogen, nitrogen, and ammonia fuel gases. To date, the research has shown that the device can be successfully operated with a number of propellants and easily creates and maintains plasmas from them.

According to Micci, the thruster can potentially be operated with water as fuel. Water is heavier than ammonia but lighter than nitrogen. Micci has achieved his best performance with hydrogen; however, hydrogen is difficult to store in space. Ammonia was closest in performance to hydrogen. Nitrogen's performance came in third.

Micci has presented the device and research results in a paper, "Current Status of the Microwave Arcjet Thruster," at the 31st American Institute of Aeronautical and Astronautics/American Society of Mechanical Engineering/Society of Automotive Engineering/American Society of Electrical Engineering Joint Propulsion Conference and Exhibit in San Diego, California. He said, "Existing chemical positioning and maneuvering systems for communications satellites account, with their fuel, for a very large fraction of the total launch mass. Though less commonly acknowledged, these existing systems are also responsible for the majority of satellite failures."

The microwave-powered thruster has the potential to reduce the amount of propellant needed by up to 50%. The fuel savings can be used to install more payload on the satellite or can be taken in launch cost savings.

"In addition, since many commercial communication satellites in orbit today were still operational when they ran out of maneuvering fuel, the increased capacity could extend satellite life by a number of years," he said.

Plasma Process Used to Deposit Alumina and Mullite Coatings

A plasma-based process for depositing high-temperature protective coatings improves the efficiency and reduces the wear and tear of devices ranging from engines and turbines to hip joints. The process, developed at Ernest Orlando Lawrence Berkeley National Laboratory, involves two types of ceramic films, alumina and mullite, because they have a strong tolerance for high temperatures. Mullite is a particularly good coating for silicon carbide, a ceramic material with high-temperature applications. According to Ian Brown, leader of the Plasma Applications group that developed the process, the coating makes advanced heat engines more efficient because the engine parts can run at higher temperatures and the smooth surface of the coating minimizes the wear of moving parts.

Using a powerful electrical current in a plasma gun, the scientists turn solid aluminum, silicon, or other material into plasma. The particles shoot out of the gun and into a curved metal coil. The magnetized coil helps filter and purify the plasma stream by deflecting only the charged particles of aluminum or silicon through the coil. Oxygen is added to produce the right amount of oxide. The plasma stream hits the substrate, coating it. In the laboratory, the substrate is often a 1 cm^2 of a material like silicon carbide.

One advantage of plasma deposition with energetic ion bombardment is its ability to create a good bond between coating and substrate. "These films have an ion beam-mixed interface...and the adhesion is very strong," said Brown.

Another benefit of the process is its ability to produce a very smooth coating. "By adjusting the ion energy," said Brown, "we can get films that are very dense: no voids—very smooth and uniform." In other processes such as sputtering, the particles of coating material are not charged, causing difficulty in controlling the characteristics of the film.

The researchers have also used plasma deposition to form high-quality films of diamondlike carbon (DLC). They are creating and studying multilayer films. Using the plasma process they can deposit a coat of, for example, silicon carbide, and then a coat of DLC, followed by more alternating layers of the two. Multilayer coats may adhere to their substrates better, or combine the best features of two or more coatings in one.

DOE Announces Recipients of Innovative Concepts Program for Aluminum Technology Ideas

The Department of Energy (DOE) staff was looking for the best and the brightest developers of solutions to the aluminum industry's current technology barriers. They found them in the 1996 recipients of their Innovative Concepts Program. Eleven developers have received an award of $22,000 each for their technology ideas related to the aluminum industry. The recipients also will be given technical and marketing assistance to move their concepts closer to the marketplace. DOE's evaluations were based upon technical merit, novelty, commercial potential, work plan, appropriateness of the proposer's experience, and the cost proposal.

The recipients and their proposals are:

- Chon L. Tsai, Ohio State University, Technology Advancements in Resistance Welding of Aluminum for Automotive Applications;
- Glenn Freitas, Aztex Inc., Joining Aluminum Materials Using Ultrasonic Impactors;
- Guy Davis, DACCO SCI Inc., Thermal Spraying of Aluminum as an Adhesive Bond Pretreatment;
- Jiann-Yang (Jim) Hwang, Michigan Technological University, Utilization of Recycled and Unrecoverable Aluminum Scraps in Manufacturing Cellular Concrete;
- Ralph Tapphorn and Howard Gabel, Innovative Technology Inc., Solid-State Spray Forming of Aluminum Near-Net Shapes;
- L.S. Fan and Robert A. Rapp, Ohio State University, Closed-Loop Nitrogen-Chlorine Degassing/Fluxing of Liquid Aluminum Alloys;

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■ Robert A. Rapp, L.S. Fan, Ohio State University, Degassing Liquid Aluminum Alloys by Argon in Closed Circuit;
■ David A. Larsen, Blasch Precision Ceramics Inc., Energy and Other Cost Savings Through Novel, Static Degassing in Recycled Aluminum Production;
■ Thomas J. Mroz, Advanced Refractory Technologies Inc., Evaluation of a New Material for Hall-Heroult Cell Cathodes;
■ J.R. Divine, ChemMet Ltd., Disposal of Hall-Heroult Cell Pot-Lining; and
■ James Oxley, Oxley Research Inc., An Alumina Concentration Sensor.

The concepts will be presented at the annual meeting and exhibition of The Minerals, Metals and Materials Society (TMS), February 9–13, 1997, in Orlando, Florida. At this meeting, program representatives will try to match the technology concepts with investors and program managers who express interest in commercializing the ideas. During concurrent sessions, technical presentations will be made describing the concepts. Interested parties also will have a chance to talk one-on-one with the developers at a trade booth (#130) where the concepts will be showcased.

For more information about the winning aluminum concepts, the TMS meeting or the Innovative Concepts Program, contact Robin Conger, Pacific Northwest National Laboratory, PO Box 999, K8-11, Richland, Washington 99352; 509-372-4328.

Scientists Encase 6-Å-Thick Wires in Polymer Matrix

Wires that are 6–20-Å thick in diameter encased in a polymer matrix have been developed at Cornell University. The wires can be as long as 50–100 nm. According to a report published in the August 9 issue of *Science*, the researchers took atoms of the metallic substances molybdenum and selenium separated by lithium. By putting them in a solvent of ethylene carbonate—which polymerizes into polyvinylene carbonate—the lithium was separated out, leaving long strings of the metals. They then added an agent to make the polymer. By doing so quickly, the organic polymers gelled before the wires had a chance to clump together. The end result was a plastic block laced with subnanometer-sized wires.

"We polymerize it very quickly using light. It freezes the wires in whatever orientation they are in," said Jean M.J. Frechet, a polymer chemist.

Images from scanning transmission electron microscopy (STEM) confirmed that the wires were in place. The microscopists

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used an imaging technique in which the atomic number of the metallic ions are distinguished from the polymer's organic materials, which have lower atomic numbers. The images showed single wires from 6-Å diameter, and double wires of about twice that size, and groups of wires, or cables, up to 40-Å diameter. Through an optical method, the scientists determined the conductivity of the multiwire cables.

Er-Doped Optical Amplifier Operates at 1.54 μm, Dimension at 1 mm^2

A research team from the Netherlands has developed an erbium-doped optical waveguide amplifier operating at 1.54 μm with dimensions as small as 1 mm^2. It shows an optical gain of nearly a factor of two for a pump power of only 10 mW.

Er-doped optical fiber amplifiers are being used in the telecommunication network for the amplification of optical signals at 1.5 μm. A disadvantage of these fiber amplifers is that they are large, and cannot be easily integrated with other optical devices. The Netherland team—a collaboration between the FOM Institute AMOLF in Amsterdam and the Technical University in Delft—has deposited 600-nm-thick aluminum oxide films onto an oxidized silicon wafer, and implanted them with Er ions. Two-micron-wide channel waveguides were then defined using lithographical techniques. A spiral geometry was made in which a 4-cm-long Er-doped waveguide was rolled up within 1 mm^2. Wavelength division multiplexers to combine pump and signal wavelengths were added on the same chip. The device shows a net gain of 2.3 dB (nearly a factor of two amplification) at a 1.48 μm pump power of 10 mW. Other existing planar Er-doped amplifiers require much higher pump powers (> 50 mW) and take up several cm^2 on the chip.

"The real challenge in this work was to optimize the Er concentration," said Albert Polman, the project leader for this work at the FOM Institute in Amsterdam. "High gain in a short distance requires high Er concentrations. But if the Er ions are too closely spaced, interactions will take place which create emission at undesired wavelengths, and which will reduce the optical gain." Calculations show that by lengthening the waveguide and further optimizing the waveguide design, an optical gain of 20 dB can be achieved. The planar amplifier can be integrated with splitters, gratings, multiplexers, and other devices on the same chip.

Silcox Named Microscopist of the Year

John Silcox, the David E. Burr Professor of Engineering and director of the Materials Science Center at Cornell University, has

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received the 1996 Distinguished Scientist Award in the Physical Sciences from the Microscopy Society of America. He has been cited for "internationally recognized research accomplishments and distinguished contributions to microscopy." Given annually since 1975, it is the highest honor given by the Society. Silcox received the award August 12 in Minneapolis.

Silcox's research interests include electron microscopy, microspectroscopy, and microdiffraction of materials by field-emission gun scanning transmission electron microscopy. The aim of his research is to establish quantitative procedures at the atomic or subatomic length scale that can be applied to materials science problems.

A Fellow of the American Physical Society, Silcox came to Cornell in 1961 after holding a research fellowship at Cambridge University for electron microscopy studies of magnetic materials. He spent sabbatical leaves in France and Great Britain in 1967–1968 as a Guggenheim Fellow, at Bell Laboratories in 1974–1975, and at Arizona State University in 1983. Silcox earned an undergraduate degree from Bristol University in 1957 and a doctorate from Cambridge University in 1961, both in physics.

At Cornell since 1961, he has twice served as director of the School of Applied and Engineering Physics. In 1985 he earned the Tau Beta Pi Excellence in Engineering Teaching Award, and he has been director of the Materials Science Center since 1989.

A past president and member of the Electron Microscopy Society of America, Silcox has served on the Solid State Sciences Committee of the National Academy of Sciences/National Research Council. He has been a member and past chair of the National Science Foundation's Materials Advisory Committee and serves on the advisory committee for the Electron Microscopy Center for Materials Science at Argonne National Laboratory. □

National Research Council (NRC)
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For information and application materials, contact the Office for Central Europe and Eurasia, National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418; 202-334-3680; fax 202-334-2614; e-mail OCEE@NAS.EDU; URL http://www.nas.edu/oia/22da.html.

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MRS MATERIALS RESEARCH SOCIETY

1996 FALL MEETING
DECEMBER 2-6
BOSTON
MASSACHUSETTS

ICEM-96

INCLUDING

The 1996 ICEM Meeting

International Conference on Electronic Materials

MRS EXHIBIT

Boston Marriott Hotel and Westin Hotel/Copley Place

The MRS Exhibit, held in conjunction with the 1996 MRS Fall Meeting, will encompass the full spectrum of equipment, instrumentation, products, software, publications and services for materials research. As always, the exhibit will closely parallel the nature of the technical symposia. The technical program has been arranged to allow meeting participants ample opportunity to visit the exhibit, and MRS encourages attendees to visit the exhibit by scheduling coffee breaks, deli-style lunches, and a meeting-wide reception in University Hall.

EXHIBIT HOURS

	Marriott Hotel University Hall & Atrium Lounge	Westin Hotel 3rd & 4th Floors
Tuesday, December 3	Noon - 6:30 p.m.	9:30 a.m. - 5:00 p.m.
Complimentary Reception will be held at the Marriott on Tuesday evening from 5:00 p.m. - 6:30 p.m.		
Wednesday, December 4	9:30 a.m. - 5:00 p.m.	9:30 a.m. - 12:30 p.m. 7:30 p.m. - 10:00 p.m.
Thursday, December 5	9:30 a.m. - 1:00 p.m.	9:30 a.m. - 12:30 p.m.

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