



## Green Design

### Carbon Dioxide Removal via Passive Thermal Approaches

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A paper describes a regenerable approach to separate carbon dioxide from other cabin gases by means of cooling until the carbon dioxide forms carbon dioxide ice on the walls of the physical device. Currently, NASA space vehicles remove carbon dioxide by reaction with lithium hydroxide (LiOH) or by adsorption to an amine, a zeolite, or other sorbent. Use of lithium hydroxide, though reliable and well-understood, requires significant mass for all but the shortest missions in the form of lithium hydroxide pellets, because the reaction of carbon dioxide with lithium hydroxide is

essentially irreversible. This approach is regenerable, uses less power than other historical approaches, and it is almost entirely passive, so it is more economical to operate and potentially maintenance-free for long-duration missions.

In carbon dioxide removal mode, this approach passes a “bone-dry” stream of crew cabin atmospheric gas through a metal channel in thermal contact with a radiator. The radiator is pointed to reject thermal loads only to space. Within the channel, the working stream is cooled to the sublimation temperature of carbon dioxide at the prevailing cabin

pressure, leading to formation of carbon dioxide ice on the channel walls. After a prescribed time or accumulation of carbon dioxide ice, for regeneration of the device, the channel is closed off from the crew cabin and the carbon dioxide ice is sublimed and either vented to the environment or accumulated for recovery of oxygen in a fully regenerative life support system.

*This work was done by Michael Lawson, Anthony Hanford, Bruce Conger, and Molly Anderson of Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24445-1*

### Polymer Electrolyte-Based Ambient Temperature Oxygen Microsensors for Environmental Monitoring

**This oxygen microsensor has extremely low power consumption, is small in size, and is simple to batch-fabricate.**

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An ambient temperature oxygen microsensor, based on a Nafion polymer electrolyte, has been developed and was microfabricated using thin-film technologies. A challenge in the operation of Nafion-based sensor systems is that the conductivity of Nafion film depends on the humidity in the film. Nafion film loses conductivity when the moisture content in the film is too low, which can affect sensor operation. The advancement here is the identification of a method to retain the operation of the Nafion films in lower humidity environments. Certain salts can hold water molecules in the Nafion film structure at room temperature. By mixing salts with the Nafion solution, water molecules can be homogeneously distributed in the Nafion film increasing the film's hydration to prevent Nafion film from being dried out in low-humidity environment. The presence of organics provides extra sites in the Nafion film to promote proton ( $H^+$ ) mobility and thus improving Nafion film conductivity and sensor performance.

The fabrication of ambient temperature oxygen microsensors includes depositing basic electrodes using noble metals, and metal oxides layer on one of the electrode as a reference electrode. The use of noble metals for electrodes is due to their strong catalytic properties for oxygen reduction. A conducting polymer Nafion, doped with water-retaining components and extra sites facilitating proton movement, was used as the electrolyte material, making the design adequate for low humidity environment applications. The Nafion solution was coated on the electrodes and air-dried. The sensor operates at room temperature in potentiometric mode, which measures voltage differences between working and reference electrodes in different gases. Repeatable responses to 21-percent oxygen in nitrogen were achieved using nitrogen as a baseline gas. Detection of oxygen from 7 to 21 percent has also been demonstrated.

The room-temperature oxygen microsensor developed has extremely

low power consumption (no heating for operation, no voltage applied to the sensor, only a voltmeter is needed to measure the output), is small in size, is simple to batch-fabricate, and is high in sensor yield. It is applicable in a wide humidity range, with improved operation in low humidity after the additives were added to the Nafion film. Through further improvement and development, the sensor can be used for aerospace applications such as fuel leak detection, fire detection, and environmental monitoring.

*This work was done by Gary W. Hunter and Jennifer C. Xu of Glenn Research Center and Chung-Chiun Liu of Case Western Reserve University. Further information is contained in a TSP (see page 1). LEW-18674-1*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18674-1.*