New Technology Uses "Cold" Plasma to Break Down Pollutants, Produce Cleaner Air

NASA is supporting the development of a potentially breakthrough technology that could preserve spacecraft air quality on long-duration missions and bring about cleaner air on Earth by destroying chemicals that contribute to smog and global warming.

In high school chemistry class, we learned about the three "ordinary" states of matter that exist on Earth—solid, liquid, and gas—but we learned less about plasma, which is often referred to as the fourth state of matter.

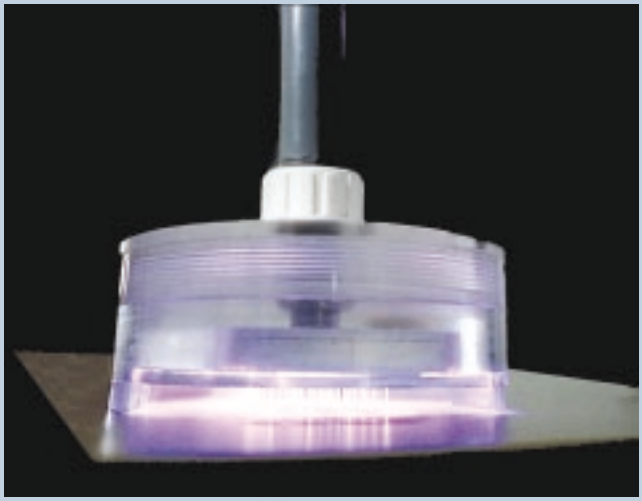
Plasma is a high-energy, electrically charged mixture of free-moving electrons and ions (charged atomic particles). It is by far the most abundant form of matter in the visible universe—the stuff of stars, quasars, supernovas, and interstellar space. Lightning bolts and the aurora borealis or "Northern lights" are manifestations of plasma.

In Earth's atmosphere, natural plasma exists only at extremely high temperatures. Low-temperature or "cold" plasma is found naturally only in a vacuum. However, artificial plasma can be created by applying an electrical charge to a gas, producing such familiar technologies as neon signs and fluorescent lights. Plasmas also are used in flat-panel computer monitors and to etch the tiny circuits on computer microprocessor chips.

Outside a vacuum—that is, under normal atmospheric pressure—low-temperature plasma is highly chemically reactive, a feature that makes it extremely useful but also, until recently, difficult to generate. That could change with the development of a novel, potentially breakthrough technology for producing low-temperature plasma to destroy environmental contaminants.

Applications in Space and on Earth

The technology, known as capillary discharge non-thermal plasma, can be used to break down polluting organic chemicals by bombarding them with high-energy electrons, converting the contaminants into carbon dioxide and water. The technology already shows promise as a self-sufficient, energy-efficient system for destroying airborne trace contaminants and preserving air quality on board a spacecraft. It also has many potentially valuable pollution-control applications on Earth—for example, in the reduction of automobile and smokestack emissions.



The non-thermal capillary plasma generator emits a "purple glow."

"NASA has initiated the funding of a technology that has an extraordinary number of applications both in space and on Earth," says George P. Korfiatis, Ph.D., professor of environmental engineering and director of the Center for Environmental Engineering at Stevens Institute of Technology in Hoboken, New Jersey.

Two of Korfiatis's colleagues at the Stevens Institute, physicists Erich Kunhardt and Kurt Becker, devised a reactor for generating large quantities of non-thermal plasma at normal atmospheric pressure. With funding from NASA, they collaborated with Korfiatis to demonstrate

the technology's potential for destroying volatile organic compounds (VOCs), contaminants that readily evaporate. The researchers have now demonstrated that the non-thermal plasma reactor can destroy high concentrations of VOCs such as benzene, iso-octane, and methanol at up to 99% efficiency with very low power consumption.

Low Energy Use, Low Cost, No Consumables

On a long-duration human space mission, maintaining air quality within the confined environment of a spacecraft is a major challenge. Current technologies use carbon to remove airborne contaminants. However, existing carbon adsorption systems are ill suited for use on long-duration space missions because of their bulk and weight, says Korfiatis. An additional problem is that the adsorption medium becomes depleted and must be regenerated or replaced. High energy consumption is a further disadvantage of current technologies.

"A low-energy, low-cost technology that does not rely on expendable materials for continuous operation is highly desirable for maintaining a contaminant-free breathable atmosphere, especially during long-duration space flights when material resupply is not feasible or cost-effective," says Korfiatis.

Further research is required to identify the most efficient and effective ways of using non-thermal plasma technology to destroy airborne contaminants aboard spacecraft, Korfiatis notes. For example, non-thermal plasma might be used in combination with a carbon adsorption system to remove contaminant buildup from depleted carbon, making it possible to reuse rather than replace the adsorption medium.

Non-thermal plasma might also be used to destroy contaminants such as ethylene gas that are produced in plant growth chambers. Astronauts on long-duration space missions will need to generate at least some of their own food by growing plants. Other NASA-supported research has shown that air contamination with ethylene (a VOC) reduces plant seed formation in microgravity, and care must be taken to ensure that plant growth chambers remain free of ethylene during the development of seeds.

NASA is currently supporting other research to determine whether non-thermal plasma could be used for pre-flight decontamination of instruments intended for use in planetary exploration. Pre-flight decontamination is essential to assure, for example, that any microbes or chemical substances found on a probe returning from a mission to Mars were indeed acquired on the red planet and were not present on Earth before the mission.

Korfiatis and his associates have formed a company, PlasmaSol Corp., to develop applications of non-thermal plasma technology on Earth. The company's first product is a plasma reactor to eliminate VOCs from contaminated soil and groundwater. Also being explored is the use of the technology to clean aluminum surfaces, potentially eliminating the use of environmentally hazardous solvents, and to sterilize medical equipment. In 2000, PlasmaSol was named Environmental Company of the Year by the New Jersey Technology Council.

In the future, Korfiatis predicts, devices based on non-thermal plasma technology could be retrofitted to automobiles to eliminate emissions of hydrocarbons, nitrous oxides, and sulfur oxides, which are important contributors to smog and global warming.

References

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