SiO_2/TiO_2 Composite for Removing Hg From Combustion Exhaust

This material could remove mercury from exhaust streams of coal-burning power plants.

Lyndon B. Johnson Space Center, Houston, Texas

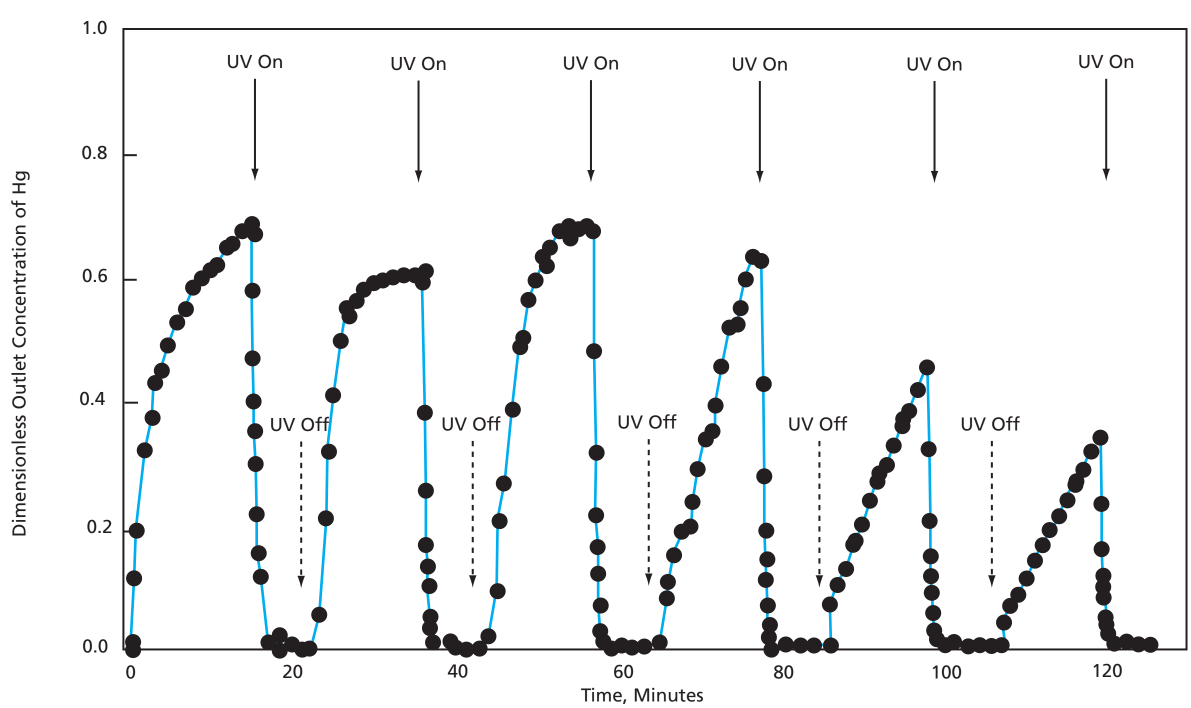
Pellets made of a high-surface-area composite of silica and titania have shown promise as means of removing elemental mercury from flue gases. With further technical development and commercialization, this material could become economically attractive as a more-effective, less-expensive alternative to activated carbons for removing mercury from exhaust streams of coal-burning power plants, which are the sources of more than 90 percent of all anthropogenic airborne mercury.

The silica/titania composite is made from a silica precursor and titania, starting with a sol-gel process in which water, a solvent, and acids are used to promote the hydrolysis and condensation reactions. After gelation, the reaction mixtures are aged, rinsed, and then dried in a series of heat treatments. The resulting composite pellets are about 5 mm long and 3 mm wide. Each pellet comprises TiO_2 nanoparticles distributed in a porous SiO_2 matrix. The pores are of the order of 15 nm wide. The pellets are characterized by specific surface area of about 300 m^2/g.

This composite material removes elemental mercury from air or a flue-gas mixture through a synergistic combination of (1) adsorption on the surfaces of the composite pellets and (2) photocatalytic oxidation in the presence of ultraviolet light. The mercury oxide remains on the surfaces of the pellets as a solid deposit. From time to time, the mercury oxide can be extracted from the pellets — thereby both regenerating the pellets and making the mercury available for recycling — for example, by rinsing the pellets with acid.

The adsorptive capacity of the composite material is great enough to enable continuous concentration of mercury onto the pellets without continuous use of ultraviolet light (see figure). Intermittent ultraviolet irradiation suffices to ensure oxidation of adsorbed mercury and mercury vapor and to regenerate the adsorbent. The efficiency of removal of Hg can easily be made as high as 99 percent or greater while ultraviolet light is on. Moreover, the photocatalytic oxidation can be said to activate the adsorbent in that it increases the subsequent adsorption capacity in the absence of ultraviolet light.

The mercury-adsorption capacity of the pellets is high although at the 3-mm



The **Dimensionless Outlet Concentration of Hg Vapor** (that is, the outlet concentration ÷ inlet concentration) was measured in an experiment in which air laden with Hg vapor was pumped through a bed of SiO_2/TiO_2 pellets under periodic exposure to ultraviolet (UV) light. This curve shows that adsorption continued (albeit at a diminishing rate) when the UV light was turned off and that oxidation removed most of the Hg from the outlet stream within about 2 minutes of turning the UV light on.

pellet width, only a thin outer layer is utilized effectively. A TiO_2 loading of 13 weight percent has been found to result in the best removal of Hg, both with and without ultraviolet light. Humidity has been found to impede adsorption, thereby reducing the overall Hg-removal efficiency. An examination of the effects of flow velocity revealed that adsorption is the rate-limiting step, suggesting a need to improve mass-transfer characteristics to obtain better performance.

This work was done by David Mazyck, Danielle Londeree, Chang-Yu Wu, Kevin Powers, and Erik Pitoniak of the University of Florida for Johnson Space Center.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to MSC-23624, volume and number of this NASA Tech Briefs *issue, and the page number.*

Lightweight Tanks for Storing Liquefied Natural Gas

These tanks are also relatively inexpensive.

Marshall Space Flight Center, Alabama

Single-walled, jacketed aluminum tanks have been conceived for storing liquefied natural gas (LNG) in LNG-fueled motor vehicles. Heretofore, double-wall steel tanks with vacuum between the inner and outer walls have been used for storing LNG. In comparison with the vacuum-insulated steel tanks, the jacketed aluminum tanks weigh less and can be manufactured at lower cost. Costs of using the jacketed aluminum tanks are further reduced in that there is no need for the vacuum pumps heretofore needed to maintain vacuum in the vacuum-insulated tanks.

The single-walled, jacketed aluminum tanks are members of the class of composite overwrapped pressure vessels; that is, they comprise basically, seamless aluminum tank liners overwrapped in composite (matrix/fiber) materials. On each such tank, the composite overwrap is further encapsulated in a layer of insulating foam, which, in turn, is coated with a flexible sealant that protects the foam against abrasion, ultraviolet light, and other adverse environmental phenomena.

The innovative tank concept admits to a number of variations. For example, the aluminum tank liner can be a common, commercially available aluminum tank liner that is already certified by the United States Department of Transportation for use at pressure up to 3,000 psi (≈20.7 MPa). The composite-material overwrap can be made by winding high-strength-carbon-fiber/poly(phenylene benzobisoxazole)-fiber hybrid filaments with an epoxy matrix material. The insulating layer can be made by spraying polyurethane foam, waiting for the foam to cure to rigidity, then machining the foam to final size and shape. The protective outer layer can be formed by brush application of a ductile epoxy or spray application of a truck-bed-liner material.

Of course, if the tank liner is a pressure vessel as in the example above, then the tank can be used to store a high-pressure gaseous fuel. Moreover, in the case of storage of LNG, the high-pressure capability of the tank helps to conserve stored fuel by reducing the need to vent gas to relieve pressure as heat leaks into the tank, causing slow vaporization of the LNG.

This work was done by Tom DeLay of Marshall Space Flight Center.

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy. a.nabors@nasa.gov. Refer to MFS-32024-1.

Hybrid Wound Filaments for Greater Resistance to Impacts

PBO fibers are used in addition to high-strength carbon fibers.

Marshall Space Flight Center, Alabama

The immediately preceding article includes an example in which a composite overwrap on a pressure vessel contains wound filaments made of a hybrid of high-strength carbon fibers and poly(phenylene benzobisoxazole) [PBO] fibers. This hybrid material is chosen in an effort to increase the ability of the pressure vessel to resist damage by low-speed impacts (e.g., dropping of tools on the vessel or bumping of the vessel against hard objects during installation and use) without significantly increasing the weight of the vessel. Heretofore, enhancement of the impact resistances of filament-wound pressure vessels has entailed increases in vessel weight associated, variously, with increases in wall thickness or addition of protective materials.

While the basic concept of hybridizing fibers in filament-wound structures is not new, the use of hybridization to increase resistance to impacts is an innovation, and can be expected to be of interest in the composite-pressure-vessel industry. The precise types and the proportions of the high-strength carbon fibers and the PBO fibers in the hybrid are chosen, along with the filament-winding pattern, to maximize the advantageous effects and minimize the disadvantageous effects of each material. In particular, one seeks to (1) take advantage of the ability of the carbon fibers to resist stress rupture while minimizing their contribution to vulnerability of the vessel to impact damage and (2) take advantage of the toughness of the PBO fibers while minimizing their contribution to vulnerability of the vessel to stress rupture.

Experiments on prototype vessels fabricated according to this concept have shown promising results. At the time of reporting the information for this article, research toward understanding and