

Os, Pt being preferred); about 1 to 90 percent by weight of one or more oxides of reducible metals having multiple valence states (such as Sn, Ti, Mn, Cu, and Ce, with SnO<sub>2</sub> being preferred); and about 1 to 90 percent by weight of a compound that can bind water to its structure (such as silica gel, calcium chloride, magnesium sulfate, hydrated alumina, and magnesium perchlorate, with silica gel being preferred). Especially beneficial results are obtained when platinum is present in the catalyst composition in an amount of about 5 to 25 (especially 7) percent by weight, SnO<sub>2</sub> is present in an amount of about 30 to 40 (especially 40) percent by weight, and silica gel is present in an amount of 45 to 55 (especially 50) percent by weight.

The composition of this catalyst was suggested by preliminary experiments in which a Pt/SnO<sub>2</sub> catalyst was needed

for bound water to enhance its activity. These experimental results suggested that if the water were bound to the surface, this water would enhance and prolong catalyst activity for long time periods. Because the catalyst is to be exposed to a laser gas mixture, and because a CO<sub>2</sub> laser can tolerate only a very small amount of moisture, a hygroscopic support for the catalyst would provide the needed H<sub>2</sub>O into the gas. Silica gel is considered to be superior because of its property to chemisorb water on its surface over a wide range of moisture content.

The catalyst may be produced by first preparing a mixture of a commercially available, high-surface-area silica gel and an oxidizing agent. The second step is accomplished by preparing an aqueous mixture of the tin (IV) oxide coated silica gel and a soluble, chloride-free salt of

at least one platinum group metal. It is beneficial if the coated silica gel is first deaerated by boiling. The platinum group metal salt is adsorbed onto the high surface area and coats the surface. A chloride-free reducing agent is then added to the aqueous mixture whereby the platinum group metal is deposited onto the tin (IV) oxide coated silica gel. After the platinum group metal has been deposited onto the tin (IV) oxide coated silica gel, the solution is evaporated to dryness, whereby the desired catalyst is obtained.

*This work was done by Patricia Davis of Langley Research Center; Kenneth Brown, John Van Norman, and David Brown of Old Dominion University Research Foundation; and Billy Upchurch, David Schryer, and Irvin Miller of Science and Technology Corporation. Further information is contained in a TSP (see page 1). LAR-14155-1*

## Titanium Hydroxide — a Volatile Species at High Temperature

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Titanium hydroxide, TiO(OH)<sub>2</sub> (g), has been identified as the primary reaction product of TiO<sub>2</sub> (s) + H<sub>2</sub>O (g) at high temperatures (1,200–1,400 °C) through the use of the transpiration technique. This technique is a well-established method used to measure equilibrium pressures at 1 atm. Reactive O<sub>2</sub>/H<sub>2</sub>O mixtures of gases flow over the sample, and react to form volatile Ti hydroxides. The collected reaction gas condensate is analyzed to determine the vapor and dissociation pressures. From the amount of condensate and its relation to the partial pressures of the

reactive gases, the identity of the volatile hydroxide can be determined. From the relation of product pressure to temperature, thermodynamic enthalpy and entropy of formation can be calculated.

The reaction of the identified titanium hydroxide is useful to understanding the volatility of titanium-containing materials for high-temperature conditions that contain water vapor (i.e., combustion from hydrocarbon fuels, etc.). The identity of this molecule and thermodynamic data on this molecule contribute to the high-temperature materials database that

would directly impact future selection of refractory oxide materials for use in combustion environments. This will also aid in furthering the understanding of oxide stability with high-temperature water vapor.

*This work was done by QuynhGiao N. Nguyen of Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18482-1*

## Selective Functionalization of Carbon Nanotubes: Part II

**Different species are deposited at different distances.**

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An alternative method of low-temperature plasma functionalization of carbon nanotubes provides for the simultaneous attachment of molecular groups of multiple (typically two or three) different species or different mixtures of species to carbon nanotubes at different locations within the same apparatus. This method is based on similar principles, and involves the use of mostly the same basic apparatus, as those of the methods described in “Low-Temperature Plasma Func-

functionalization of Carbon Nanotubes” (ARC-14661-1), *NASA Tech Briefs*, Vol. 28, No. 5 (May 2004), page 45.

The figure schematically depicts the basic apparatus used in the aforementioned method, with emphasis on features that distinguish the present alternative method from the other. In this method, one exploits the fact that the composition of the deposition plasma changes as the plasma flows from its source in the precursor chamber toward

the nanotubes in the target chamber. As a result, carbon nanotubes mounted in the target chamber at different flow distances ( $d_1$ ,  $d_2$ ,  $d_3$  . . .) from the precursor chamber become functionalized with different species or different mixtures of species.

In one series of experiments to demonstrate this method, N<sub>2</sub> was used as the precursor gas. After the functionalization process, the carbon nanotubes from three different positions in the