



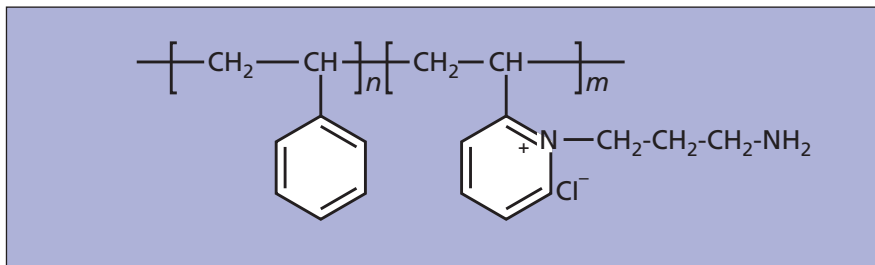
## Special Polymer/Carbon Composite Films for Detecting SO<sub>2</sub>

These films offer distinct advantages over prior SO<sub>2</sub>-sensor materials.

NASA's Jet Propulsion Laboratory, Pasadena, California

A family of polymer/carbon films has been developed for use as sensory films in electronic noses for detecting SO<sub>2</sub> gas at concentrations as low as 1 part per million (ppm). Most previously reported SO<sub>2</sub> sensors cannot detect SO<sub>2</sub> at concentrations below tens of ppm; only a few can detect SO<sub>2</sub> at 1 ppm. Most of the sensory materials used in those sensors (especially inorganic ones that include solid oxide electrolytes, metal oxides, and cadmium sulfide) must be used under relatively harsh conditions that include operation and regeneration at temperatures >100 °C. In contrast, the present films can be used to detect 1 ppm of SO<sub>2</sub> at typical operating temperatures between 28 and 32 °C and can be regenerated at temperatures between 36 and 40 °C.

The basic concept of making sensing films from polymer/carbon composites is not new. The novelty of the present family of polymer/carbon composites lies in formulating the polymer components of these composites specifically to optimize their properties for detecting SO<sub>2</sub>. First-principles quantum-mechanical calculations of the energies of binding of SO<sub>2</sub> molecules to various polymer functionalities are used as a guide for selecting polymers and understanding the role of polymer functionalities in sensing.



This Copolymer is a member of the family of polymers suitable for use as components of polymer/carbon composite films for sensing SO<sub>2</sub>. The integers  $m$  and  $n$  can be chosen by formulation to be in a desired ratio: a typical ratio for the molecular structure shown here is  $n/m = 3/7$ .

The polymer used in the polymer-carbon composite is a copolymer of styrene derivative units with vinyl pyridine or substituted vinyl pyridine derivative units (see figure). To make a substituted vinyl pyridine for use in synthesizing such a polymer, poly(2-vinyl pyridine) that has been dissolved in methanol is reacted with 3-chloropropylamine that has been dissolved in a solution of methanol. The methanol is then removed to obtain the copolymer. Later, the copolymer can be dissolved in an appropriate solvent with a suspension of carbon black to obtain a mixture that can be cast and then dried to obtain a sensory film.

This work was done by Margie Homer, Margaret Ryan, Shiao-Pin Yen, Adam Kisor, April

Jewell, Abhijit Shevade, Kenneth Manatt, Charles Taylor, Mario Blanco, and William Goddard of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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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## Nickel-Based Superalloy Resists Embrittlement by Hydrogen

This alloy also exhibits high strength and ductility.

Marshall Space Flight Center, Alabama

A nickel-based superalloy that resists embrittlement by hydrogen more strongly than does nickel alloy 718 has been developed. Nickel alloy 718 is the most widely used superalloy. It has excellent strength and resistance to corrosion as well as acceptably high ductility, and is recognized as the best alloy for many high-temperature applications. However, nickel alloy 718 is susceptible to embrittlement by hydrogen and to delayed failure and reduced tensile properties in gaseous hydrogen. The

greater resistance of the present nickel-based superalloy to adverse effects of hydrogen makes this alloy a superior alternative to nickel alloy 718 for applications that involve production, transfer, and storage of hydrogen, thereby potentially contributing to the commercial viability of hydrogen as a clean-burning fuel.

The table shows the composition of the present improved nickel-based superalloy in comparison with that of nickel alloy 718. This composition was

chosen to obtain high resistance to embrittlement by hydrogen while maintaining high strength and exceptional resistance to oxidation and corrosion. The alloy-design approach followed to arrive at this composition was based on accounting for the simultaneous effects of several additions. The approach included systematic modification of  $\gamma$ -matrix compositions for increased resistance to embrittlement by hydrogen, increasing the volume fraction of the