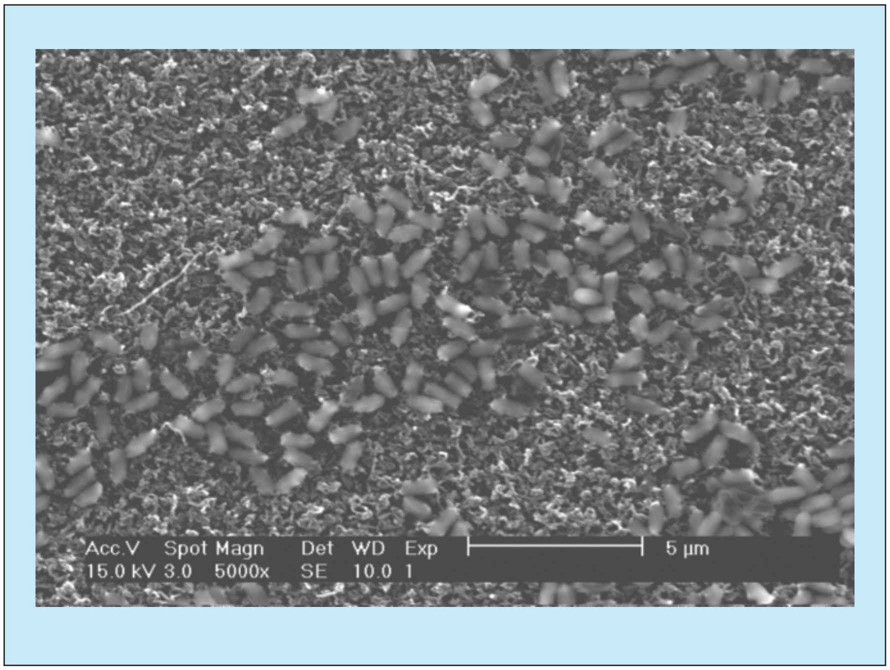
Nanocarpets for Trapping Microscopic Particles

Properties of nanocarpets can be tailored for selective trapping.

NASA's Jet Propulsion Laboratory, Pasadena, California

Nanocarpets — that is, carpets of carbon nanotubes — are undergoing development as means of trapping microscopic particles for scientific analysis. Examples of such particles include inorganic particles, pollen, bacteria, and spores. Nanocarpets can be characterized as scaled-down versions of ordinary macroscopic floor carpets, which trap dust and other particulate matter, albeit not purposefully. Nanocarpets can also be characterized as mimicking both the structure and the particle-trapping behavior of ciliated lung epithelia, the carbon nanotubes being analogous to cilia (see figure).



Microscopic Particles *(Bacillus pumilis spores)* were trapped on a nanocarpet by immersing the nanocarpet in a spore-containing solution, then drying the nanocarpet.

Carbon nanotubes can easily be chemically functionalized for selective trapping of specific particles of interest. One could, alternatively, use such other three-dimensionally-structured materials as aerogels and activated carbon for the purposeful trapping of microscopic particles. However, nanocarpets offer important advantages over these alternative materials:

- Nanocarpets are amenable to nonintrusive probing by optical means; and
- Nanocarpets offer greater surface-to-volume ratios.

This work was done by Flavio Noca, Fei Chen, Brian Hunt, Michael Bronikowski, Michael Hoenk, Robert Kowalczyk, and Daniel Choi of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

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Precious-Metal Salt Coatings for Detecting Hydrazines

Colors change upon exposure to hydrazines and perhaps other hazardous gases.

Lyndon B. Johnson Space Center, Houston, Texas

Substrates coated with a precious-metal salt $KAuCl_4$ have been found to be useful for detecting hydrazine vapors in air at and above a concentration of the order of 0.01 parts per million (ppm). Upon exposure to air containing a sufficient amount of hydrazine for a sufficient time, the coating material undergoes a visible change in color. Although the color change is only a qualitative indication, it can serve as an alarm of a hazardous concentration of hydrazine or as advice of the need for a quantitative measurement of concentration. Detection of hydrazine vapors by this technique costs much less and takes less time than does laboratory analysis of sorbent tubes using high-performance liquid chromatography, which is the technique used heretofore to detect hydrazines at concentrations down to 0.01 ppm.

A substrate for use in this technique should be made of a chemically inert material (e.g., fiberglass filter paper). The substrate is uniformly coated with 1 to 10 weight percent of the precious-metal salt in a solvent (e.g., dilute HCl) that does alter the physical characteristics of the substrate. After driving off the solvent by gentle heating and/or by use of a vacuum, the coated substrate is packed into an inert tube with openings at each end. (The dried precious-metal coating is somewhat sensitive to light; the dried coated substrate should be handled accordingly and stored in the dark.)

The coated substrate is held in place with small quantities of inert wadding (i.e., borosilicate glass wool). A gas suction pump is attached to one end of the tube, and the air or other gas suspected to contain hydrazine vapor is drawn through the tube at a specified pumping rate for an amount of time sufficient to obtain a sufficient chemical change (and thus an observable color change) in the coating material. A semiquantitative relationship between the degree of chemical change and the quantity of vapor sampled can be established from observations of intensities of color changes and/or areas of color change in tests on similarly prepared substrates and tubes using known concentrations of hydrazine vapors.

In experiments, tubes containing $KAuCl_4$-coated substrates prepared as described above were exposed to 40-liter flows of air containing, variously, hydrazine, monomethylhydrazine, or unsymmetrical dimethylhydrazine at concentrations of the order of 0.01 ppm. These exposures caused the colors of the substrates to change from yellow to various purplish colors and, in one case, to black.

No such color changes were observed upon exposure of the $KAuCl_4$-coated substrates to flows of air that contained other gases (ammonia, isopropyl alcohol, NO_2, and H_2). Whether or not other precious-metal coating materials could be used as color-change indicators of these or other nonhydrazine gases remains to be determined.

This work was done by Louis A. Dee and Benjamin Greene of Allied-Signal Aerospace Co. for **Johnson Space Center**. *For further information, contact the Johnson Commercial Technology Office at (281) 483-3809.*
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Amplifying Electrochemical Indicators

Reporter compounds can be formulated for high sensitivity and miniaturization of sensor units.

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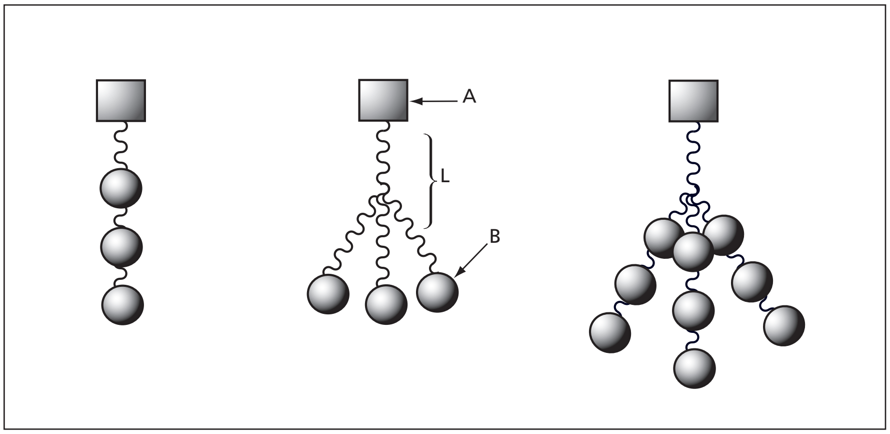
Dendrimeric reporter compounds have been invented for use in sensing and amplifying electrochemical signals from molecular recognition events that involve many chemical and biological entities. These reporter compounds can be formulated to target specific molecules or molecular recognition events. They can also be formulated to be, variously, hydrophilic or amphiphilic so that they are suitable for use at interfaces between (1) aqueous solutions and (2) electrodes connected to external signal-processing electronic circuits. The invention of these reporter compounds is expected to enable the development of highly miniaturized, low-power-consumption, relatively inexpensive, mass-producible sensor units for diverse applications, including diagnoses of infectious and genetic diseases, testing for environmental bacterial contamination, forensic investigations, and detection of biological warfare agents.

The multiple functionality of a reporter compound of this type is achieved through integration of a variety of chemical moieties into each molecule. The structure and composition of such a molecule is depicted schematically in the figure and represented by the general formula ALB_n. As used here, A signifies a targeting group, L signifies a linking group, and B signifies an active group.

The targeting group (A) can include nucleic-acid intercalators or other organic functional subgroups. It is designed to interact directly with a targeted molecule or molecular recognition event; that is to say, it is designed to bring itself and the rest of the reporter molecule into the vicinity of the target. Hence, the collective effect of the targeting groups of multiple reporter molecules is to concentrate the reporter compound in the region of the target compound or molecular recognition events that one seeks to detect.

An active group (B) is, more specifically, either (1) electroactive in a manner that enables detection of an electrochemical signal or (2) hydrophilic to enhance solubility. It is preferable that the number (n) of B groups exceed 1. The linking group (L) comprises two moieties: (1) a linker between the targeting (A) group and the B groups and (2) an amplifying moiety, through which the B groups are connected in series, parallel, or a combination of series and parallel connections in a dendritic structure.



A **Reporter Compound** according to the invention can have any of a wide variety of dendritic structures. The A, B, and L groups contribute synergistically to the overall effect of generating a highly amplified primary electrochemical sensory signal.

The active (B) groups can also be characterized as indicator groups because these are the ones that generate the desired electronic sensory signals. Because they are linked to the targeting group, the active groups are concentrated in the vicinity of the target, and the probability that each will generate a signal is correspondingly increased. The multiple active groups, connected together in the dendritic molecular structure, contribute to an aggregate signal much greater than that generated by a single-indicator reporter molecule. Depending upon the specific formulation of a reporter molecule according the invention, the primary signal could be as little as two