



## **Novel Materials Containing Single-Wall Carbon Nanotubes Wrapped in Polymer Molecules**

**Coating carbon nanotubes in polymer molecules creates a new class of materials with enhanced mechanical properties for printed circuit boards, antenna arrays, and optoelectronics.**

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In this design, single-wall carbon nanotubes (SWNTs) have been coated in polymer molecules to create a new type of material that has low electrical conductivity, but still contains individual nanotubes, and small ropes of individual nanotubes, which are themselves good electrical conductors and serve as small conducting rods immersed in an electrically insulating matrix. The polymer is attached through weak chemical forces that are primarily non-covalent in nature, caused primarily through polarization rather than the sharing of valence electrons. Therefore, the electronic structure of the SWNT involved is substantially the same as that of free, individual (and small ropes of) SWNT. Their high conductivity makes the individual nanotubes extremely electrically polarizable, and materials containing these individual, highly polarizable molecules exhibit novel electrical properties including a high dielectric constant.

The polymer coating, however, greatly inhibits the Van der Waals attraction normally observed between separate, or small ropes of, SWNT. The polymer coating also interacts with solvents. The combination of the Van der Waals inhibition and the polymer-solvent interaction causes the wrapped nanotubes to be more readily sus-

ended in solvents at high concentrations, which in turn substantially enables the manipulation of SWNT into many kinds of bulk materials including films, fibers, solids, and other types of composites. Also, the polymer-coated SWNT can be treated for the removal of the polymer molecules, restoring the SWNT to a pristine state.

Aggregations of the polymer-coated SWNT are substantially aligned and provide a new form of electrically-conducting rod composite, where the conducting rods have cross sectional dimensions on the nanometer scale and lengths of hundreds of nanometers or more. The electrical properties of the composite are highly anisotropic.

This innovation can be made compatible with matrices of other materials to facilitate fabrication of composites. Composite materials with polymer-coated SWNTs suspended in a polymer matrix have a novel structure of a suspended nanotube being smaller in its cross-sectional dimensions than the typical scale length of the individual polymer molecules in the matrix. This microscopic, dimensional compatibility minimizes the propensity of the composite to fail mechanically at the interface between the matrix and the SWNT, producing a composite material

with enhanced properties such as strain-to-failure, toughness, and resistance to mechanical fatigue. These materials also serve as the active element for a range of transducers because they can change their physical dimensions in response to applied electric and magnetic fields. If treated with certain chemicals, the material can also change dimensionally and electronically in response to adsorption of chemicals on the nanotube surface, and can serve as chemical sensors and transducers.

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*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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## **Light-Curing Adhesive Repair Tapes**

**Adhesive resins in tapes are rigidized in place by exposure to light.**

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Adhesive tapes, the adhesive resins of which can be cured (and thereby rigidized) by exposure to ultraviolet and/or visible light, are being developed as repair patch materials. The tapes, including their resin components, consist entirely of solid, low-outgassing, nonhazardous or minimally

hazardous materials. They can be used in air or in vacuum and can be cured rapidly, even at temperatures as low as  $-20^{\circ}\text{C}$ . Although these tapes were originally intended for use in repairing structures in outer space, they can also be used on Earth for quickly repairing a wide variety of structures. They can

be expected to be especially useful in situations in which it is necessary to rigidize tapes after wrapping them around or pressing them onto the parts to be repaired.

As now envisioned, when fully developed, the tapes would be tailored to specific applications and would be pack-