Unidym
Carbon for Electronics

CARBON NANOTUBE FILM | Product Overview

Unidym produces electronic materials comprising interconnected networks of carbon nanotubes (CNTs) deposited on various flexible or rigid substrates. Unidym's first product is a CNT-based transparent electrode for use in such applications as touch screens, flat panel displays, solar cells, smart windows and solid state lighting. Unidym is also developing thin film transistors (TFTs) intended to form the backbone of the burgeoning printable electronics industry, and fuel cell electrodes to meet both near-term needs for powering portable electronics and long-term needs associated with a hydrogen-based energy economy.

CNTs are allotropes of carbon (others include graphite and diamond). CNTs can be single-wall carbon nanotubes (SWNTs), comprising individual, one-atom thick sheets of graphite (called graphene) rolled into seamless cylinders with diameters of about one nanometer and length-to-diameter ratios that can exceed 10,000. CNTs can also be multi-wall carbon nanotubes (MWNTs), comprising multiple, nested SWNTs rolled into concentric cylinders such that an outer tube diameter is between several and hundreds of nanometers. Both SWNTs and MWNTs have exhibited extraordinary strength, efficient heat-conduction and unique electrical properties (e.g., CNTs have displayed both extraordinary metallic characteristics, conducting approximately 1000 times more current per unit area than the copper that currently dominates the electronics industry; as well as extraordinary semiconducting characteristics, having an electron mobility roughly 70 times larger than that of the silicon used in modern integrated circuits).

Unidym synthesizes SWNTs and small-diameter MWNTs in its Houston, TX facility using commercial-scale gas phase and chemical vapor deposition (CVD) processes. Unidym's primary gas-phase process is a high-pressure carbon monoxide (HiPco) process, which selectively produces 100% SWNTs. Unidym's primary CVD process produces a wide variety of high-quality CNTs, including SWNTs and small-diameter MWNTs, through modified process conditions.

In order to make electronic materials, Unidym employs a number of application-enabling technologies to purify, disperse and coat the CNTs. For example, amorphous carbon and residual catalyst particles are removed from raw CNT batches using oxidation and acid treatments. The resulting purified CNTs are then solubilized and dispersed to form a proprietary ink. This ink may be coated onto a variety of rigid or flexible substrates (e.g., glass, plastic, metal, silicon) using one of a variety of low-impact, solution-based deposition methods (e.g., spray coating, slot-die coating, micro-gravure coating, inkjet printing, transfer stamping[1]). Flexible substrates can be advantageous as being compatible with roll-to-roll processing. As compared to a batch process, which handles only one component at a time, a roll-to-roll process represents a dramatic deviation from current manufacturing practices, and can reduce capital equipment and product costs, while significantly increasing throughput.

Where the density of CNTs on the substrate is above a percolation threshold (i.e., the density at which conductive pathways form in various dimensions across the film), the CNTs form interconnected CNT networks, such that a film comprised thereof is electrically conductive.[2] At relatively low levels of CNT loading, which are nonetheless above the percolation threshold, CNT films are optically transparent (e.g., in the visual and infrared spectrums) as well.[3] Generally, CNT films suitable for transparent electrode applications are less than 100 nm thick.

In addition to their distinguished optoelectronic properties, CNT-based transparent electrodes are very mechanically robust, flexible, offers substantially low reflection in comparison to ITO film and therefore ideal for applications in touch screens (e.g., 4-wire resistive, 5-wire resistive, surface capacitive, projected capacitive, etc.) and flexible displays and solar cells. Moreover, because of their compatibility with low-impact fabrication and patterning processes, such electrodes provide numerous advantages in rigid display devices, both as pixel and common electrodes.

Unidym also employs CNT films, as described above, in TFT and fuel cell applications. Film properties can be tailored for these applications by, for example, adjusting the film-thickness, CNT loading-level and CNT grades employed. In TFTs, CNT films are used as both electrode and semiconducting channel components, thereby enabling fully-printable and cost-effective electronic devices. In fuel cells, CNT films are used as electrodes, the porous structures of which minimize conventional device inefficiencies arising from kinetic, resistive and mass-transfer losses.

Footnotes

1. Y. Zhou, L. Hu, G. Grüner, *"A Method of Printing Carbon Nanotube Thin Films"*, Applied Physics Letters, 88, 123109 (2006).
2. L. Hu, D.S. Hecht and G. Grüner, *"Percolation in Transparent and Conducting Carbon Nanotube Networks"*, Nano Letters, 2004, Vol. 4, No. 12, 2513-2517.
3. Id.