The National Research Council (NRC) is the Government of Canada's premier organization for research and development. NRC's integrated approach to creating next-generation materials provides a “One-Stop Shop” for the synthesis, characterization, metrology and the chemical integration of carbon nanotubes, through to the fabrication and prototyping of real-world applications. Through its quality assurance, NRC provides its clients with a single organization able to take carbon nanotubes from production, through regulatory approval, to product performance testing. These solutions are possible owing to the multidisciplinary and complementary expertise residing within 19 NRC Institutes across Canada.
SWCNT Production

Three unique processes have been developed for synthesizing SWCNT.

- NRC uses chemical vapour deposition (CVD) processes to produce unprocessed luminescent nanotubes, luminescent networks of nanotubes, and photo- and electroluminescent nanotube field effect transistors.

- A laser vaporization process is used to produce the highest purity and quality as-synthesized SWCNT yet reported at quantities up to a few grams per day.

- In collaboration with the Université de Sherbrooke, NRC has extrapolated the laser process to a new “Radio-Frequency (RF) Induction Plasma Process” capable of producing SWCNT material with the same properties of the laser material, but on a larger scale. The process is unique to the world and based on an industrially proven technology with a production capacity of one kilogram per day!

Large-scale SWCNT Production

NRC’s SWCNT Technology Accelerator Centre was recently launched to scale up SWCNT production using the RF induction plasma process – a first step along the chain of developing SWCNT composite materials from R&D to product.

Characterization

Characterization is central in the development of advanced materials based on nanotubes and NRC has all the necessary tools and expertise to characterize nanotubes, from their synthesis through to the final composites. These tools include TGA-MS-FTIR, UV-VIS-NIR, SEM, XRD, NMR, AFM and ICP-OES, particle sizing, conductivity measurements, PLE, PL, Raman, global Raman, and more, all geared for the full chemical and physical analysis and characterization of SWCNT and SWCNT-based materials.

For example, NRC-IMS discovered photoluminescence from air suspended SWCNT and demonstrated that such SWCNT have intrinsically high quantum efficiencies. They were also the first to produce hyperspectral photoluminescence images of ultralong nanotubes and explore many of the environmental effects on SWCNT spectra.

Standards and Metrology

NRC-INMS is producing reference materials for SWCNT which will be characterized for a number of physico-chemical properties. There is a critical need for credible reference materials for validation of measurement results and the ongoing evaluation of health and environmental concerns related to nanotechnology. Scientists are addressing this shortcoming by developing tools and techniques for accurate measurement and standardization. INMS has well-established expertise in the production and dissemination of Certified Reference Materials. Laboratories in Canada and around the world will benefit from these stable SWCNT references by using them as performance benchmarks for product quality and evaluation.
Chemistry
Chemistry allows researchers at the NRC-SIMS to control the final properties of matrices in SWCNT-modified composite materials. Shown here are SWCNT-loaded epoxy samples with the same final SWCNT loading but different interfacial bonding.

SIMS has developed various methods for adding active chemical functionalities to the SWCNT to tailor them for individual applications. In particular, SWCNT can be integrated in thermosets, thermoplastics and inorganic materials such as ceramics and metals with excellent transfer of properties. Processes for the preparation of neat SWCNT fibers, sheets and films have also been developed. Since some applications can be sensitive to the presence of the impurities that are inherently present in SWCNT, a number of rapid procedures were created to remove the impurities without modifying the structure or properties.

Just a few “SWCNT” Applications under Investigation at NRC
- Light-weight armour materials to protect soldiers and security personnel against improvised explosive devices (IEDs).
- Enhanced sporting equipment to strengthen hockey sticks and protective gear making them lighter or resistant to breakage
Performance & Testing
NRC has proven engineering expertise for materials design, pilot-scale formulation, fabrication and testing. Mechanical and physical properties of SWCNT-modified polymers and fibrous composites must be fully understood before practical application in components and structures can effectively be realized. For example, NRC-IAR has been working on mechanical and physical performance characterization of SWCNT-modified polymers and fibrous composites at multiple size scales including constituents, composite laminates and structural elements. Tests of fibre-reinforced composite laminates demonstrate that fracture toughness and low-speed impact behaviour of CRFP systems can be increased by adding only 0.1% (by wt.) of SWCNT.

MULTIWALL CARBON NANOTUBES (MWCNT)
Since MWCNT can have a significant cost advantage over SWCNT it is often considered a viable alternative for many materials and applications, NRC is involved in producing MWCNT in the purest and largest quantities possible.

Production
NRC-NINT uses a large-bore chemical vapour deposition (CVD) reactor for carbon nanotube growth to develop prototype scale synthesis of nanostructured materials, the supporting metrology, and the devices and intermediates based on these materials. Vertically aligned carbon nanotube (VACNT) films are among the morphologies of MWCNT with the most promise for technological exploitation. NINT has successfully synthesized VACNT films on a multi-wafer scale. The reactor used is capable of processing batches as large as fifty 150 mm wafers simultaneously with all steps between loading and unloading fully automated.

Applications
In collaboration with DRDC-Valcartier, NRC-IMI spins electric conducting triaxial fibres for the development of intelligent textiles. The technology produces the fibres with 2 conductive layers separated by an insulating layer, in a single step, using melt-state polymer processing techniques. IMI has fabricated a pilot-line of coaxial fibres with up to 3 layers of 3 different materials. In one example, coaxial fibres were fabricated containing 2 layers of polypropylene MWCNTs, separated by an insulation layer. The core and sheath layers are conductive enough to transport data (1S/cm) which is protected with electromagnetic shielding due to this innovative trilayer structure.

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