

NT11 and Satellite workshop held on metrology standardization for CNTs
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The 12th International Conference on the Science and Applications of Nanotubes (NT11) was held in Cambridge, UK on July 10–14, 2011, together with five satellite conferences, including one on Metrology Standardization and Industrial Quality of Graphene and Nanotubes. Alan Windle of the University of Cambridge chaired the local organization committee. The conference brought together leading researchers in the area of nanotube science and technology in order to evaluate the current state of the art and to identify current trends.

NT11, as in past years, emphasized the synthesis of nanotube materials most strongly. This year the emphasis was on the significant progress recently made in the separation of nanotubes by metallicity and specific chiralities and on the impact this has had scientifically. While Boris I. Yakobson (Rice University, USA) stressed the theory behind growth mechanisms, Annick Loiseau (CNRS-ONERA, France) underscored the importance of the quasi-perpendicular and tangential growth modes, while attention continued to be focused on the size and shape of the catalytic particle for promoting the growth process. The special roles of water and sulfur and aligned nanotube forest growth also attracted special attention for nanotube growth.

The audience was impressed by the many (13) different kinds of tube chirality (n,m) that can now be prepared (for example, by the Kataura agarose separation method). Increased attention was given to studying double-walled nanotubes which may be more attractive for reliable long-term service use because they are more robust than single-walled nanotubes. M. Endo reported results for both bundles and individual double-walled tubes and showed that the same techniques and strategies also worked for the synthesis, study, and application of triple-walled nanotubes in bundles and at the individual tube level. By starting from pea-pod precursors, significant diameter and chirality control is now achievable.

Results for detailed study of the relatively rare metallic inner and outer tube combination were shown by Martin Kalbac (Academy of Sciences of the Czech Republic). Both inorganic and organic dopants could produce very large charge-transfer effects. The impressive recent progress made with coherent phonon spectroscopy in carbon nanotubes was reported by Jun Kono (Rice University, USA), while Riichiro Saito (Tohoku University, Japan) explained the importance of considering not only the phonon frequency and wave vector, but also the phonon phase.

The NT11 conference highlighted a trend of using much of the science and technology developed in carbon nanotube studies to study nanotubes of other layered compounds, such as WS_2 , WSe_2 , MoS_2 , and $MoSe_2$, as was, for example, emphasized by C.N.R. Rao (Jawaharlal Nehru Centre for Advanced Scientific Research, India). NT11 also gave increased attention to graphene with several compelling presentations given on optical, Raman studies, and ultrafast emission from graphene, including harmonic and anharmonic decay processes.

This year's conference also saw increased emphasis on nanotube applications. Emphasis was given to electronic and biomedical applications and toxicology. As the number of graphene presentations increases, future conferences expect greater interaction in detailed subject matter between the nanotube and graphene systems building on both their similarities and differences.

The commercial adoption of nanotubes and graphene requires a level of consistency and quality that can only be assured by internationally agreed upon standards of measurement. The satellite workshop to NT11, Metrology Standardization and Industrial Quality of Graphene and Nanotubes 2011 (MSIGN11), held on July 15–16 at the University of Cambridge represents the fifth conference in the nanotube metrology series.

MSIGN11 provided good coverage of several measurement techniques, in-

cluding Raman, photoluminescence, and surface-enhanced Raman spectroscopy. The metrological issues covered included (1) measurements of nanotubes with and without water contained in the nanotube core; (2) measurements on nanotubes with and without defects; (3) property measurements in the presence of controlled strain on nanotubes; (4) determination of the number of carbon atoms in a given nanocarbon sample; and (5) the use of more than one measurement technique on the same sample, such as transmission electron microscopy and Raman, or transmission electron microscopy and atomic force microscopy, or Raman and photoluminescence, or Raman and graphene substrate-enhanced Raman scattering. Very few talks addressed graphene metrology.

For the future, participants identified these possible goals for MSIGN12, to be held in Australia:

- Progress in the development of a reference carbon nanomaterial should be reviewed.
- Progress in improving carbon nanomaterial homogeneity for making a reliable reference nanomaterial should be encouraged.
- Progress is needed with identifying measurement techniques and protocols for characterizing a standard reference nanomaterial.
- Standards and protocols should be developed for separating and sorting carbon nanotubes according to diameter, chiral angle, length, and metallicity.
- Attention should also be given to the metrology of graphene, and in particular to metrology issues relevant to the relation between graphene and carbon nanotubes.

Other satellite conferences included Computational Challenges and Tools for Nanotubes; Carbon Nanomaterial Biology, Toxicology and Medicine; Graphene Technology: Production, Assembly and Applications; and Nano Carbon Composites.

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