Physica E 44 (2012) 921–923

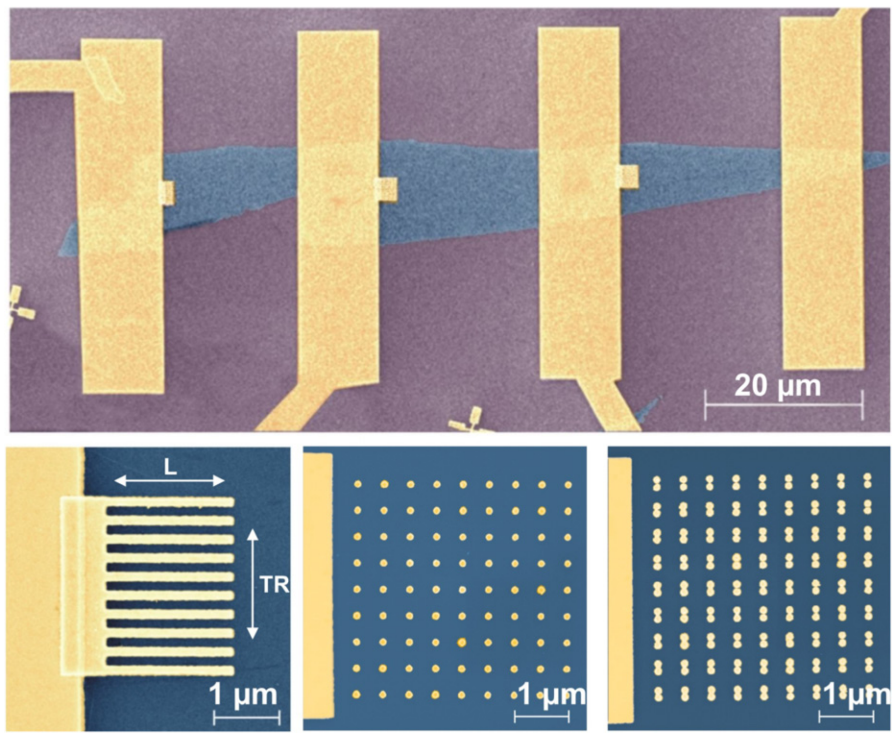
Contents lists available at SciVerse ScienceDirect

Physica E

journal homepage: www.elsevier.com/locate/physe

Preface

Science and technology of nanotubes, nanowires and graphene



Plasmonic-Enhanced Graphene Photodetector (adapted from T.J. Echtermeyer et al., Nature Communications 2:458 (2011)

Fundamental science plays a crucial role in underpinning and generating future technologies. The ability to manipulate the structure and composition at the nanoscale opens new horizons and huge opportunities to create novel materials with superior performance. The introduction of a wide range of new nanomaterials, including carbon nanotubes (CNTs), nanowires (NWs), graphene and related two dimensional crystals, will have disruptive impact on a variety of devices based on conventional inorganic semiconductors, not only because of cost/performance advantages, but also because they can be manufactured in more flexible ways, suitable for a growing range of applications.

The physical properties of nanomaterials strongly depend on their atomic-scale structure, size and chemistry, as well as their organisation and aggregation. To fully exploit the technological advantages offered by these self-assembled molecular structures it is essential to acquire the ability to select, control and manipulate individual or aggregated nanomaterials. There has been much progress in the synthesis and characterisation of nanostructures such as nanotubes, nano-crystals, atomic wires, organic and biological nanostructures, molecular junctions and graphene layers. However, challenges remain in understanding their properties and interactions with external probes to realise their potential for applications.

Carbon nanotubes are a unique platform for many fundamental studies of quantum physics in low-dimensional systems, and several unexpected physical phenomena have been discovered. Recent breakthroughs in the high-yield, structure-selective manufacturing and techniques for separating metallic and semiconducting nanotubes promise to make commercial applications of this material real. Large efforts in the area of chemical modification and manipulation have allowed the design and fabrication of well-controlled architectures. Substantial progress has also been made in fabricating electronic devices, sensors, field-emission displays, and nano-electro-mechanical systems using nanotubes and nanotube-based mesostructures.

1386-9477/$ - see front matter
doi:10.1016/j.physe.2012.02.005

One-dimensional nanowires are also receiving increasing attention because of their potential applications in electronics, photonics, energy storage and harvesting. Device performance typically depends on structure and crystallinity, but assembly is also a critical issue for applications. Fabrication of several types of one dimensional nanostructures, such as nanowires, nanorods, nanosaws and nanoribbons, has been successfully demonstrated by several growth methods for elemental semiconductors, such as Si and Ge, as well as for III–V and II–VI compounds. Nanotubes of various non-carbon materials have been produced and characterised. Theoretical modelling of these structures continues to reveal fascinating attributes. The electronic functionality of these materials, based on the directional transport of charges or energy, makes them promising building blocks for interconnecting individual quantum systems in supramolecular architectures, field effect transistors or photonic wires. The large surface to volume ratio results in a pronounced sensitivity to environmental conditions making them suitable as sensors in nanoscale devices.

Graphene is a one-atom-thick sheet of carbon whose strength, flexibility, and electrical conductivity have opened new horizons for fundamental physics, together with technological innovations in electronic, optical, and energy sectors. The production of high quality graphene remains one of the greatest challenges, in particular when it comes to maintaining the material properties and performance upon up-scaling, which includes mass production for material/energy-oriented applications and wafer-scale integration. Potential electronic applications of graphene include high-frequency devices and RF communications, touch screens, flexible and wearable electronics, as well as ultrasensitive sensors, NEMS, super-dense data storage, or photonic devices. In the energy field, potential applications include batteries and supercapacitors to store and transit electrical power, and highly efficient solar cells. In the medium term, some of graphene's most appealing potential lies in its ability to transmit light as well as electricity, offering improved performances of light emitting diodes and aid in the production of next-generation devices like flexible touch screens, photodetectors, and ultrafast lasers. New horizons have also been opened from the demonstration of high-speed graphene circuits offering high-bandwidth suitable for the next generation of low-cost smart phone and television displays. Graphene is promising as addictive for composite materials, thin films and conducting inks.

This volume contains the proceedings of the European Materials Research Symposium on Science and Technology of Nanotubes, Nanowires and Graphene held June 7–11, 2010 in Strasbourg, France

The symposium was chaired by Andrea Ferrari, Liberato Manna, Manish Chhowalla, Kostya Novoselov and Andreia Luisa da Rosa.

The invited speakers were Ralph Krupke (Karlsruher Institut für Technologie, Germany), Alain Penicaud (CNRs Bordeaux), Alexander Tzalenchuk (National Physical Laboratory, UK), Christoph Stampfer (RWTH, Aachen, Germany), Vasili Perebeinos (IBM Watson Research Centre, USA), Francisco Guinea (CSIC, Madrid, Spain), Volodya Falko (Lancaster University, UK), Achim Hartschuh (University of Munich, Germany), Mikhail Katsnelson (Radbound University, Nijmegen, Netherlands), Stephan Roche (CSIC-ICN, Barcelona, Spain), Kirill Boloton (Vanderbilt University), Andre Geim (University of Manchester, UK), Byung Hee Hong (Seoul National University, Korea), Luigi Colombo (Texas Instruments, USA), Thomas Seyller (University of Erlangen, Germany), Alexey B. Kuzmenko (University of Geneva, Switzerland), Irina Grigorieva (University of Manchester, UK), Brian Korgel (The University of Texas at Austin, USA), Lars Samuelson (Lund University, Sweden), Maurizio Prato (University of Trieste, Italy), Zhipei Sun (University of Cambridge, UK), Jannik Meyer (University of Vienna, Austria), Ado Jorio (UFMG, Belo Horizonte, Brazil), John Rogers (University of Illinois, USA), and Annick Loiseau (ONERA-CNRS, France).

The symposium covered the progress in design, manufacturing and characterisation of nanotubes, nanowires, graphene and related two dimensional crystals, and new developments leading to possible commercial applications of these materials.

In particular, the key sessions focussed on

- Nanotube optics
- Solution processing of graphene
- Graphene electro-opto-mechanics
- Graphene quantum dots and nanoribbons
- Graphene transport
- Graphene optoelectronics
- Graphene growth and characterisation
- Magnetism in nanotubes nanowires and graphene
- Nanowires growth and characterisation
- Applications of nanotubes, nanowires and graphene
- Defects and disorder in nanotubes, nanowires and graphene

We hope that these proceedings will provide the readers with a survey of recent developments in these exciting fields of nanotechnology.

The Symposium was sponsored by

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