Indo-Brazil

Discussion Meeting on Advances in Graphene and Nanotubes

Foz do Iguaçu, August 26th to 28th, 2011

ACADEMIA BRASILEIRA DE CIÊNCIAS
MCMXVI

Summary

Programme

August 26th, 2011

9:00 - 10:00	**Rao** - *"Fascination for nanocarbons"*
10:00 - 10:30	**Galvão** - *"Multi-million Atomistic Simulations of Carbon-Based Nanostructures"*
10:30 - 11:00	Coffee Break
11:00 - 11:30	**Ferlauto** - *"Carbon Nanomaterials Research at the Laboratorio de Nanomateriais"*
11:30 - 12:00	**Vijaymohanan** - *"Electrochemical transformation of carbon nanotubes to graphene"*
12:00 - 12:30	**Furtado** - *"Chemical Manipulation of Carbon Nanotubes and Graphenes"*
12:30 - 13:00	**Neves** - *"Characterization and manipulation of carbon nanostructures via scanning probe microscopy techniques"*
13:00 - 14:30	Lunch
14:30 - 15:00	**Bhattacharya** -*"Solubilization of various Nanocarbons in Self-assembled Molecular Networks and the Properties of the resulting systems"*
15:00 - 15:30	**Zarbin** - *"Carbon Nanotubes- and Graphene-Based Nanocomposites"*
15:30 - 16:00	**Misra** - *"Electrical transport in individual multiwall carbon nanotubes and graphene-Pt nanocomposites as counter electrodes in solar cells"*
16:00 - 16:30	Coffee Break
16:30 - 17:00	**Rappoport** - *"Spin-related properties of graphene with adatoms"*
17:00 - 17:30	**Dattagupta** - *"Dissipative Dynamics of Dirac Fermions in Graphene in a Magnetic Field"*
17:30 - 18:00	**Bechara Muniz** -*"Theoretical description of electronic and transport properties of carbon-basedmaterials"*

August 27th, 2011

8:30 - 13:00	**Water Falls visit**
13:00 - 14:30	Lunch
14:30 - 15:00	**Waghmare** - *"Theory of Defects in Graphene and Related Materials"*
15:00 - 15:30	**Nunes** - *"Strain-induced topological defect clustering and one-dimensional electronic states in graphene"*
15:30 - 16:00	**Roque da Silva**- *"First principle studies of Graphenes"*
16:00 - 16:30	Coffee Break
16:30 - 17:00	**Plentz** - *Fabrication and Electric Transport Investigation of Grafene Devices Ghosh - "Exploring New Phenomena in Graphene with Noise"*
17:00 - 17:30	**Ghosh** - *"Exploring New Phenomena in Graphene with Noise"*
17:30 - 18:00	**Fagan** - *"Carbon nanostructure functionalization: an ab initio approach"*
18:00 - 18:30	**Capaz** - *"Graphene Explorations: Reports from Experimental/Theoretical Endeavors"*

August 28th, 2011

8:30 - 9:00	**Sood** - *"Physics issues in FET and Resistive Switching Devices of Graphene"*
9:00 - 9:30	**Pimenta** - *Characterizing Graphene by Resonance Raman Scattering*
9:30 - 10:00	**Souza Filho** - *"Filling and intercalation effects on the mechanical stability of double walled carbon nanotubes: resonance Raman scattering studies"*
10:00 - 10:30	**Cançado** - *"Raman characterization of nanocarbons"*
10:30 - 11:00	Coffee Break
11:00 - 11:30	**Kopelevich** - *"High-Temperature Interface Superconductivity in Graphite/Si Sandwiches"*
11:30 - 12:00	**Deshmukh** - *"Suspended graphene electromechanics in quantum Hall regime"*
12:00 - 12:30	**Granado** - *"Raman spectroscopy in graphene and graphite under magnetic fields"*
12:30 - 13:00	**Moshkalev** - *"Gas sensors and reactors with decorated multi-walled carbon nanotubes and few-layer graphene*
13:00 - 14:30	Lunch
14:30 - 18:00	**Hotel Check out**

Participantes biographical notes and abstracts

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Santanu Bhattacharya obtained his Ph.D. degree from Rutgers University, New Brunswick, NJ under the supervision of Prof. Robert A. Moss. He then had a three year stint as a NIH postdoctoral fellow at the Massachusetts Institute of Technology under the tutelage of Nobel laureate, Prof. H. Gobind Khorana. He is currently a full Professor at the Indian Institute of Science and an honorary faculty member of the Chemical Biology Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore. He has authored more than 160 research articles in international refereed journals. He is a recipient of several awards and has been chosen to receive the TWAS prize in Chemistry for 2011. He is a member of the editorial advisory boards of the ACS journals, Langmuir and Bioconjugate Chemistry. His research interests include chemical biology, gene delivery, supramolecular chemistry, small molecular sensors, physical gels, self-assembly, nanostructures, and chemistry of nanomaterials.

SOLUBILIZATION OF VARIOUS NANOCARBONS IN SELF-ASSEMBLED MOLECULAR NETWORKS AND THE PROPERTIES OF THE RESULTING SYSTEMS

Carbon nanomaterials (CNMs) such as exfoliated graphene (EG), long-chain functionalized EG, single-walled carbon nanotubes (SWNT) and fullerene (C_{60}) have been investigated for their interaction with two structurally different gelator molecules based on all-trans tri(*p*-phenylene vinylene) bis-aldoxime **(1)** and *n*-lauroyl-L-alanine **(2)** both in solution and in supramolecular organogels derived from **1** and **2**. Gelation occurs in toluene medium through hydrogen bonding and van der Waals interactions for gelator **1** and **2** in addition to π-π stacking specifically in case of **1**. The

resulting gel-CNM composites, prepared using either gelator, have been characterized using a number of physical methods. Presence of densely wrapped CNMs encapsulated fibrous network in the resulting composites is evident from various microscopic studies indicating the presence of supramolecular interactions. Concentration- and temperature-dependent UV-vis and fluorescence spectra show that CNMs promote aggregation of the gelator molecules leading to the hypochromism and quenching of the fluorescence intensity. Thermotropic mesophases of **1** are altered by the inclusion of a small amount of CNMs. The gel-CNM composites show enhanced electrical conductivity compared to that of the native organogel. Thermogravimetric analysis shows thermal stabilization of EG in the gel-CNM composites. Rheological studies of the composites demonstrate the formation of rigid and viscoelastic solid-like assembly due to reinforced aggregation of the gelators on CNMs doping in the nano-composite. The mechanical flow of the resulting materials becomes resistant to applied stress upon incorporation of even a very small amount of CNMs (0.83 wt-%). A synergistic behavior is observed in case of the composite gel of **1** containing a mixture of EG and SWNT when compared with other mixtures of CNMs in all combinations with EG. This affords new composites with interesting optical, thermal, electrical and mechanical properties.

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Assistant Professor of Physics at the Federal University of Minas Gerais. The master's and doctoral degrees were obtained at the same University, in the area of Raman spectroscopy nanographites. Worked at The Institute of Optics, University of Rochester, as a postdoctoral fellow. The postdoc program was based on the experimental acquisition of spectroscopic images with high-spatial resolution by means of near-field Raman scattering. His current research topics are confocal Raman scattering and near-field Raman scattering applied on graphene and carbon nanotubes.

RAMAN CHARACTERIZATION OF NANOCARBONS

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This talk presents an overview on the characterization of nanocarbons using Raman spectroscopy. The first part shows some developments of technique applied on nanopgraphite and graphene. For nanographites, Raman spectroscopy delivers fast information about crystallite size and degree of stacking order. The Raman spectrum of graphene probes defect density, number of graphene layers, and doping level. In both cases, the Raman signal obtained from edges provides information about crystalline orientations (zigzag and armchair). We also extract the coherence length L of photo-excited electrons from the spatial confinement of the defect-induced Raman D band near the edges of graphene. Temperature dependent measurements in the range of 1.55K to 300K yield L proportional to $T^{1/2}$.

The second part of the talk shows theoretical and experimental results on the near-field Raman enhancement of 1D and 2D systems. The theory explains the dependency of the near-field Raman intensity on the tip-sample distance, and also on the geometrical parameters of the experiment (e.g. polarization of the incident field, and tip-sample orientation). Supporting the theory, experimental results of near-field Raman measurements performed on distinct serpentines carbon nanotubes (with different chiralities) is presented.

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Rodrigo B. Capaz is Associate Professor at the Physics Institute of the Federal University of Rio de Janeiro (UFRJ), Brazil. He holds a Ph.D. degree in Physics from the Massachusetts Institute of Technology (1996). Prof. Capaz has been a Visiting Scholar at U. C. Berkeley for two periods (2003-2005 and 2010). His research interests

are mainly in the electronic, optical and vibrational properties of graphene, carbon nanotubes, surfaces, OLEDs and semiconductors using first-principles and empirical theoretical methods. Prof. Capaz is the author of 81 papers, with 1,331 citations and H=21. He is a CNPq Research Fellow 1C, Guggenheim Fellow (2003) and he has won the TWAS-Rolac Young Scientist Prize (Physics) in 2009.

GRAPHENE EXPLORATIONS: REPORTS FROM EXPERIMENTAL-THEORETICAL ENDEAVORS

Graphene, a single atomic sheet of carbon atoms, is one of the most interesting materials ever studied, combining rich and fascinating fundamental physics with great promises of applications. In this talk, I'll review my recent work on the electronic, magnetic and optical properties of graphene-related systems, in which the main underlying theme is the close collaboration between theory and experiment. In particular, I'll focus on two distinct subjects: (1) the experimental observation and theory of magnetic edge states in chiral graphene nanoribbons, and (2) the most comprehensive study of the optical transitions of carbon nanotubes to date, providing surprising insights about the electronic structure of graphene.

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Sushanta Dattagupta is a condensed matter theorist whose work is marked by close relation to phenomena and active collaboration with experimentalists. Dattagupta is also deeply committed to develop science education in India, and has been involved with institution-building activities. He is the Founder-Director of the Indian Institute of Science Education and Research, Kolkata.

DISSIPATIVE DYNAMICS OF DIRAC FERMIONS IN GRAPHENE IN A MAGNETIC FIELD

Graphene has the extraordinary property that its electrons are Dirac Fermions with linear energy-momentum relation like in relativistic quantum mechanics. However, in contrast to relativity the electrons do not move with the speed of light but with the Fermi velocity! This gives rise to remarkable phenomena in the realm of condensed matter physics. Of particular interest is the behaviour of these electrons in the presence of an external magnetic field. The latter have consequence for Quantum Hall Effect, Diamagnetism as well as low-temperature Thermodynamics itself. Because nanoscale samples of graphene are in inevitable contact with their environment, dissipation plays an important role in observable properties. We shall present our preliminary theoretical results on such properties based on a Caldeira-Leggett coupling of the Dirac Hamiltonian of graphene. As dissipation is viewed to occur due to electron-hole excitations near the Fermi surface, the much-used Ohmic spectral density for describing bath excitations finds relevance in this context.

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I have been a faculty member at TIFR since January 2006 in the Department of Condensed Matter Physics and Materials Science. Before coming to TIFR I was a postdoctoral researcher in group of Hongkun Park at Harvard. My graduate research was in the group of Dan Ralph at Cornell.

The focus of our research is to look at nanoscale phenomenon in a variety of nanostructructures like nanowires and graphene. We also use nanoscale electromechanical devices to probe mesoscopic physics. More details of our work at www.tifr.res.in/~deshmukh.

As a postdoctoral researcher at Harvard University I worked on projects using the break junction technique to fabricate single

molecule transistors and also to study mesoscopic superconducting devices. My PhD thesis research at Cornell University work focused on exploring nanoscale magnetism using metallic quantum dots. Using the spin-split levels of a normal quantum dot we probed spin-dependent tunneling from a ferromagnetic electrode into the quantum dot.

SUSPENDED GRAPHENE ELECTROMECHANICS IN QUANTUM HALL REGIME

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There has been a keen interest in the NEMS community in probing the coupling between charge and mechanical degrees in NEMS resonators. These experiments show that electron transport and mechanical motion of the resonator influence each other. Motivated by this, we have probed the electron transport in the ultra clean graphene devices in quantum Hall regime at low temperature while it is mechanically perturbed. There can be several mechanisms that can lead to the resistance change due to mechanical vibrations like, by strain due to deformation of the flake, redistribution of the carrier density etc, electron scattering within the flake due to changes in the energy landscape. In our study we find that upon mechanical vibrations the resistance of the device changes. We try to understand these changes caused by the non-linear dependence of resistance on carrier density.examples of such materials for use as molecular electronics devices. Prof. de Melo has published more than 100 papers on different aspects of the physics of conducting polymers and has supervised the work of more than 30 graduate students. A member of the Brazilian Academy of Sciences, at the moment he is President of Brazilian Physical Society. Recently he has been appointed as the first physicist to hold the Juan Giambiagi's Chair at the Universidade da América Latina (UNILA) in Foz do Iguaçu (Brazil). He has occupied different academic and administrative positions such as a Scientific Directorship in the Brazilian Agency CNPq, Graduate and Research Dean at UFPE, and served a term as Vice-President of the Brazilian Society for the Advancement of Science (SBPC).

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Solange Binotto Fagan is graduate at Física from Universidade Federal de Santa Maria (1998), master's at Physic from Universidade Federal de Santa Maria (2000) and PhD at Physic from Universidade Federal de Santa Maria (2003). She is, currently, Associate Professor at the Franciscan University Center (UNIFRA) and Director of Research and Extension at UNIFRA. She is a CNPq fellow in research productivity level 1D. Has experience in Physics, focusing on Electronic States, acting on the following subjects: carbon nanostructures, density functional theory, and learning objects. She has approximately 60 papers published, more than 700 citations and H factor 15. In 2006 she won the Brazilian L´oreal prize for Young Woman in Science in Physics field.

CARBON NANOSTRUCTURE FUNCTIONALIZATION: AN AB INITIO APPROACH

The functionalization of carbon nanostructures is a major focus of current research which aims incorporate new properties on the pristine nanomaterials looking for improvement of their technological applications. This talk will be addressed to the main forms of functionalization of carbon nanostructures such as graphene, nanotubes and fullerenes. The functionalization of the nanostructures will be demonstrated by relating the results of computer simulation from first principles calculation, based on density functional theory, with experimental results of development and characterization of these systems. The ab initio simulations can show the structural, electronic and magnetic properties of the studied pristine and functionalized nanostructures. During the talk it will be evident the qualitative correlation between the theoretical and experimental results of the nanosystems evaluated. More specifically, we detail the interaction of nanotubes, fullerenes and graphene systems interacting with molecules that can be donors and acceptors of electronic charge, toxic molecules, and molecules of biological interest, as addressed in recent works of our group cited below.

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Andre S Ferlauto (October 9th 1972) is a Brazilian physicist. Since 2006 he is Professor of the Department of Physics at the Federal University of Minas Gerais in Belo Horizonte - MG, Brazil. He has more than 40 articles published in refereed journals and those articles were cited more than 700 times (h-index = 15). His research has a materials science focus, mainly in the following areas: nanomaterials (growth and characterization), thin films, ellipsometry, photovoltaic cells, and instrumentation.

CARBON NANOMATERIALS RESEARCH AT LAB DE NANOMATERIAIS

André S. Ferlauto, Rodrigo G. Lacerda, and Luiz O. Ladeira
Laboratório De Nanomateriais – Departamento de Física – UFMG

In this seminar I will present an overview of the research being conducted in the Laboratório de Nanomaterials -- UFMG. In our modus operandi, we attempt to cover a broad range of activities to promote the effective application of carbon nanomaterials (nanotubes and graphenes) in Brasil . These activities range from fundamental studies of their production to application studies of carbon nanomaterials. We have also a current focus on pilot scale production of CNTs

Our efforts on the production and application of carbon nanomaterials include:

(i) Plasma-enhanced chemical vapor deposition of vertically aligned multi-walled carbon nanotubes over several substrates including carbon cloth metals, and ceramics. With this approach we are able to develop functional electrode materials that can be applied in proton-exchange membrane solid oxide fuel cells.

(ii) Chemical vapor deposition of graphene on copper and silicon carbon substrates.

(iii) Synthesis of hybrids of carbon nanotubes and metallic and semiconductor nanoparticles, including CNT/Au, CNT/Pd, CNT/CdS, and CNT/Fe2O3. The CNT/NP hybrid materials are being studied in applications such as catalysis and photoelectrochemical water splitting.

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Clascídia Aparecida Furtado is Researcher and Professor at Nuclear Technology Development Center – CDTN/CNEN (Belo Horizonte-MG-BRAZIL) and leader of the research group "Chemical Manipulation of Carbon Nanotubes" (CNPq). She is graduated (1993) and Ph.D (1998) in chemistry from the Universidade Federal de Minas Gerais (UFMG). She has experience in materials science and is member

of the Brazilian Nanocarbon Institute and the Brazilian Network on Carbon Nanotube Research, acting on the following topics: chemical manipulation of carbon nanotubes and graphenes (purification, functionalization, dispersion/exfoliation and separation by type); controlled deposition of carbon nanostructures on substrates for fabrication of nanodevices; and preparation of composite materials for energy and aerospace area. Other areas of interest are polymer electrolytes and diblock copolymer systems.

CHEMICAL MANIPULATION OF CARBON NANOTUBES AND GRAPHENES

Clascídia A. Furtado[1], Adelina P. Santos[1], Max P. Ferreira[1], Daniel M. Andrada1, Sirlaine D. F. Brandão[1], Anderson F. Mesquita1, Jefferson P. Nascimento[1], Matheus L. Ângelo[1], Charles B. Sweeney[1], Fernanda Vieira[2], Cristiano Fantini[3], Luiz G. Cançado[3], Marcos A. Pimenta[3]
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The chemical manipulation of carbon nanotubes (purification, dispersion, functionalization and type separation) and wet routes towards graphene flakes and ribbons remain crucial for obtaining sufficient quantity of pure, isolated and selective species to understand and explore their superlative mechanical and conducting properties in fundamental studies and several applications. Systematic studies that explore an intimate knowledge of the carbon nanostructures surface and their reactivity and selectivity are greatly required to the easier manipulation of isolated and selected species, besides their broad characterization and integration with different (organic, inorganic and biological) environments. In this talking, we will initially focus on recent efforts from our group on carefully obtaining functionalized single walled carbon nanotubes (SWNT) and then understanding 1) the role of the oxidized surface composition on the interaction/dispersion of SWNT in amide solvents; and 2) the appearance of resonantly enhanced Raman signal of octadecylamine molecules bonded to SWNT. We will also show preliminary results on chemical exfoliation of natural graphite for obtaining graphene flakes in liquid medium. The various rotes described in the literature for graphite sonication show that the quantity and characteristics of the material obtained in

the final dispersion are totally dependent on experimental parameters, such as power ultrasound and centrifugation force. Hence, we have carried out a systematical work to optimize the preparation of stable suspensions in aqueous solution of surfactant.

This research has been supported by NGL, the Brazilian Agencies CNEN, CNPq, FAPEMIG, CAPES, the Brazilian Nanocarbon Institute and the Brazilian Network on Carbon Nanotube Research.

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Douglas S. Galvão is a Full Professor at the Applied Physics Department in the State University of Campinas, Campinas, Brazil. Prof. Galvão has worked in a variety of areas such as conducting polymers, biopolymers, drug design, metallic and carbon-based nanostructures, He is an expert in the area of computer simulations of electronic, structural and mechanical properties of nanostructures. His current interests include carbon-based nanostructures, metallic nanowires and molecularly imprinted polymer for sensor applications.

MULTI-MILLION ATOMISTIC SIMULATIONS OF CARBON-BASED NANOSTRUCTURES

The study of nanostructures has been object of intense experimental and theoretical investigations in the last years. The advent of sophisticated experimental tools such as atomic force, scanning tunneling, and transmission electron microscopes has opened new and exciting fields of investigations, leading to the discovery of new physical phenomena at the nanoscale, such as, new allotrope forms of carbon, quantized conductance, atomic suspended chains, etc.

Recent advances in hardware and software techniques have also allowed the developing of new and effective computer tools to simulate these nanostructures. Among these techniques classical and quantum molecular dynamics (MD) simulations have been proved to be

very effective to address structural, mechanical and electronic properties of nanostructures. Large classes of materials can be studied with these techniques. Especially for organic nanostructures MD simulations are in many aspects very close to real experiments.

Using some of these techniques it is possible now to investigate the structural properties of systems containing millions of atoms. In this presentation we will review and discuss some applications of these methodologies. In particular, we will present recent results obtained in our group for the formation of carbon nanotube serpentines and graphene membranes.

Work supported in part by the Brazilian Agencies FAPESP, CAPES and CNPq.

Arindam Ghosh

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Dr. Arindam Ghosh is an experimental physicist with research interest extending over several fields in classical and quantum solid state physics. He completed his PhD research from the Indian Institute of Science in 2000. During his PhD he worked on the effect of Coulomb interaction on the electrical properties of semiconductor and metals close to metal-insulator transition. Following PhD, he held the position of Research Associate at the Cavendish Laboratory, University of Cambridge, United Kingdom, till Nov 2005. During this period his research activities expanded to semiconductor nanostructures, effects of Coulomb interaction in mesoscopic systems, and spontaneous spin effects in semiconductors. At the Indian Institute of Science, Bangalore, where he is currently employed as an Assistant Professor, Dr. Ghosh researches on nanoelectronics with carbon and metallic nanosystems, quantum information processing with semiconductor nanostructures, and sensing with micro and nano-electromechanical devices. He has published over 50 international papers, and registered as a recognized researcher at the Engineering and Physical Sciences Research Council (EPSRC), UK, in 2005. He has also received the UK-India Education and Research Initiative

award in 2006, the IBM Nanotechnology Fellowship in 2008, and the Swarnajayanti Fellowship from the Government of India in 2009.

EXPLORING NEW PHENOMENA IN GRAPHENE WITH NOISE

The flicker noise in electrical transport is ubiquitous, and generally a nuisance in the operation of a field-effect device. This noise, also known as the '1/f noise', manifests in slow fluctuations in the drain-source current due to the fluctuations in the channel conductivity. The flicker noise often sets the limit of performance in both active and passive electronic components, but if appropriately analyzed, it can also provide information that cannot be gleaned from standard time-averaged current-voltage measurements. Here I shall demonstrate how noise experiments in graphene-based field transistors can act as an extremely versatile probe to several structural and electronic properties of graphene. This will involve exploitation of noise in determination of layer number in multilayer graphene, probing bandgap in bilayer graphene, and also novel quantum statistical aspects of graphene at very low temperatures.

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Presently works as an Associate Professor of the Institute of Physics of the Campinas State University (Unicamp), Brazil, holding the position of Chair of the Quantum Electronics Department. He got his Physics Major at Unicamp (1994), PhD also at Unicamp (2000), and performed a post-doc at the NIST Center for Neutron Research, Maryland, USA (2000-2002). He was a researcher at the Brazilian Synchrotron Light Laboratory (2002-2003). He has experience in Condensed Matter Physics, with emphasis in the interaction between electromagnetic or nuclear radiation with matter. Most of his papers employ Raman scattering, x-ray and neutron diffraction, and x-ray absorption as the main experimental tools to solve relevant problems

on a diversity of materials. He has published 59 articles that received 793 citations, corresponding to an h-factor=16 (source: Web of Science, June 2011).

RAMAN SPECTROSCOPY IN GRAPHENE AND GRAPHITE UNDER MAGNETIC FIELDS

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Graphite has been a widely used material since the invention of the pencil in the sixteenth century. Although its physical properties had been thoroughly investigated throughout the times, it has attracted renewed interest since the recognition that much in its physics was missed in the past [1]. In addition, the unexpected discovery of isolated graphene from exfoliated graphite in 2004 attracted enormous interest in the novel quantum phenomena revealed by graphene [2], and also related phenomena found in graphite [1]. Perhaps the most widespread technique to study and characterize graphitic materials in general and graphene in particular is Raman spectroscopy. Nonetheless, it was only very recently that the properties of graphene and graphite under applied magnetic fields started to be explored by this technique [3]. This is surprising, since much of the new physics brought by these materials is only exposed under applied magnetic fields. In this talk, we will show how this technique is now being employed to observe directly the unique Landau level quantization in graphite and how the unique electronic structure and instabilities of graphene under magnetic fields couple with its lattice vibrations. Experiments have been perfomed in bulk highly oriented pyrolitic graphite (HOPG) as well as single layer graphene over SiO_2 substrates, using micro and macro Raman techniques and optical magnets capable of generating fields up to 17 tesla.

Keywords: Graphene, graphite, Raman spectroscopy, Landau levels, magnetic fields.

Work supported by FAPESP and CNPq.

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HIGH-TEMPERATURE INTERFACE SUPERCONDUCTIVITY IN GRAPHITE/SI SANDWICHES

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In recent years, experiments performed on graphitic materials revealed localized superconductivity that may occur even at room temperature [1]. In the present work we discovered that the graphite-silicon (Si) interface is able to support dissipationless transport at room temperature. A number of samples have been tested demonstrating the same qualitative behavior. The possibility of room temperature superconductivity in graphite has been also analyzed theoretically [2-4]. However, the role of an interface with a semiconductor has not been envisaged. We measured four-probe magnetoresistance R(T, B) and current-voltage (I-V) characteristics in graphite/Si sandwiches in the temperature interval 2 K $\leq$ T $\leq$ 400 K and applied magnetic field up to B = 9 T. The measurements were performed with the current flowing through both Si substrate and graphite, and the voltage drop has been recorded along the graphite layer. In particular, we observed superconducting-type resistive transition at the transition temperature T_c ranging from 19 K to 250 K. For T < T_c we detected low ("zero") - and high-resistance two metastable states as well as the intermittent switching between them which we studied as a function of magnetic field, current and temperature. Overall the results resemble the behavior known for low-dimensional superconducting nanostructures. Irrespectively of the origin of the zero-resistance state (the genuine superconductivity or a new phenomenon), this finding may open up the major bottleneck in modern electronics towards new generation of high-performance devices with ultimate energy efficiency.

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ELECTRICAL TRANSPORT IN INDIVIDUAL MULTIWALL CARBON NANOTUBES AND GRAPHENE-PT NANOCOMPOSITES AS COUNTER ELECTRODES IN SOLAR CELLS

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Our laboratory at Physics Department of Indian Institute of Technology Bombay has focused on fabricating nanostructures and devices based on carbon nanotubes and grapehene. We have, in particular, concentrated on forming field emitters, bucky papers and grapehen-Pt NP composites. We have made bucky paper using SWNT as well as MWNTs and have shown its utility as an energy storage device[1]. We also find that the Bucky paper made with SWNTs is almost completely impermeable and does not allow solvents to pass through. This implies that the pores in the SWNT bucky paper are less than that of the solvents molecules. This might find applications in forming completely non-porous medium for water and similar solvents. In contrast, the MWNT based Bucky paper

can be used for the filtration of Nanoparticles of the sizes less than <10 nm. Our work demonstrate the formation of nm size defects on the walls of MWNT structures with the low energy ions produced in microwave discharge cavity and show exceptionally high field emission from CNTs[2].

Individual multiwall carbon nanotubes are selected and positioned on a ebeam prefabricated gold micro-grids with the separation between the gold electrodes 2 microns. The individual multiwall nanotubes of length more than 2 microns are suspended between the electrodes like a cantilever. The multiwall tubes without top contact shows the conductance values at zero bias of the order 0.5 G_0 (where G_0 is $2e^2/\hbar$). With the deposition of the top contacts on the tubes, the conductance of the tubes increase by about 23 % and becomes 0.7 G_0. These values indicate the diffusive nature of transport through the individual nanotubes. When platinum metal is deposited on the ends of the tube lying between the gold contacts, the conductance increases significantly to 1.2 G_0 indicating an increase in density of states available for the electrons to tunnel through[3,4]. We also report the switching of the electrical transport of between the layers of the multiwall tubes and find that the time between the switching is of the order 10-15 ms. In addition, we have exploited the high mobility of electrons in graphene to enhance the efficiency of dye sensitized solar cells. We have loaded the multilayer graphene (2-3 layers) with the Pt nanoparticles of sizes 2-3 nm using the laser ablation; as the nanoparticles are formed during their flight path, the loading of graphene with the nanoparticles is dense. We find that the efficiency of the solar cells fabricated with graphene –Pt NP is enhanced by 45 %. Some of the above results will be reported in the meeting.

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GAS SENSORS AND REACTORS WITH DECORATED MULTI-WALLED CARBON NANOTUBES AND FEW-LAYER GRAPHENE

Multi-wall carbon nanotubes (CNT) and few-layer graphene have been employed to fabricate gas micro-sensors and reactors with very low power consumption. The technologies of sensors fabrication were

established first for nanotubes. To provide selective sensitivity to different gases, the nanotubes were decorated by various metal or metal oxide (Ti, Sn, Ni, TiO_2, SnO_2, CePrOx, etc.) nanoparticles (NP) using several chemical or physical processes. Then, nanotubes were deposited from liquid solutions over metal (Ti, W, Au) electrodes with micron-scale gaps using ac di-electrophoresis, to form a chemical resistor configuration. Both suspended and supported (over SiO2 substrate) nanotubes were tested. To obtain suspended nanotubes, FIB milling was used to make deep trenches between electrodes, before nanotubes deposition. The samples were characterized using various microscopy techniques (SEM, TEM, EDX, EELS, confocal Raman, Raman imaging, AFM). Electrical measurements were carried out to evaluate performance of CNT/NP based sensors in the presence of various gases (Ar, N_2, O_2, H_2S, CH_4). Two different effects during CNT/NP-gas interaction were observed: (i) electrothermal (change of the nanotube resistance due to cooling by gas, as nanotubes can be heated up strongly by current - Joule effect), and (ii) chemical interaction between nanoparticles and the injected gas.

Self-heating of nanotubes by current was found to increase strongly the reactivity of nanoparticles towards reactive gases. The self-heating due to Joule effect was found to heat up suspended nanotubes up to 300-400 C at applied biases as low as 0.5 V (microwatt power consumption), while much smaller heating was observed for supported CNTs, due to unexpectedly high heat dissipation to the SiO2 substrate.

The self-heating effect allowed obtaining high sensitivity in detection of oxygen by Ti decorated nanotubes at room temperature, which is impossible for conventional thin film sensors. For comparison, for supported nanotubes, measurable signals were obtained only with a substrate heated to 150-200 C.

Similar technologies have been applied also to fabricate few-layer graphene based gas sensors. Finally, the concept of a new class of micro-reactors for study of catalytic reactions using the same fabrication procedures will be described.

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Roberto Bechara Muniz was born in 1951. He studied at the Pontifiícia Universidade Católica do Rio de Janeiro, where he graduated with a B.Sc. in Physics in 1973, and obtained his M.Sc. in Physics in 1977. He went on to the Department of Mathematics of the Imperial College of Science, Technology and Medicine of the University of London, and received his Ph.D. degree in Mathematical Physics in 1983. He joined the Universidade Federal Fluminense (UFF) in 1985. He developed postdoctoral research activities at the City University in London, at the Imperial College, and at the University of California, Irvine. Currently, he is the Director of the Instituto de Física of the Universidade Federal Fluminense. His main area of interest is Condensed Matter Physics, particularly magnetic and transport properties of metallic nanostructures. He has 87 papers published, and was recently appointed Commander of the National Order of the Scientific Merit, Brazil.

Theoretical description of electronic and transport properties of carbon-basedmaterials

The work being developed by the Group of Nanostructured Systems of the Fluminense Federal University is briefly reviewed. In general terms it involves calculations of electronic structure and transport properties of carbon-based systems. Several aspects have been investigated, such as:

propagation of spin currents and spin disturbances in carbon-based nanostructures; magnetic properties of zigzag nanoribbons; transport properties of strained graphene; electric transport properties of carbon nanotubes in the presence of external magnetic fields; effects of timedependent potential on carbon nanotube interferometers; electronic properties of graphene bilayer, Kondo effect in disordered graphene, and theory of double-resonant Raman spectra in graphene.

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Bernardo Neves got a Bachelor degree in Physics from Universidade Federal de Minas Gerais - UFMG (1990), where he also got his M.Sc. (1992) and Ph.D. (1996) in Physics investigating Transport Properties of Semiconductor Devices. His PhD program included a two-year exchange scholarship at the University of Nottingham, England (1994-1995), where most of the experimental work was carried out. After finishing his thesis, he started working with Scanning Probe Microscopy (SPM) at a state-owned technological center (CETEC-MG). Then, he got a post-doc position at North Carolina State University between 1998/1999, after which he got a permanent position at the Physics Department of UFMG, where he currently is an Associate Professor. He was Visiting Professor at Indiana University between 2009-2010 working with the SPM investigation of viruses and bacteria. He has published more than 50 papers in international journals and his current research projects focus on the SPM investigation of carbon nanostructures, self-assembled monolayers and nanolithography.

Characterization and manipulation of carbon nanostructures via scanning probe microscopy techniques

Scanning probe microscopy (SPM) is largely recognized for its morphological characterization capabilities, with AFM and STM being the most well-known techniques. Due to their extremely high resolution, these two techniques have been routinely employed in the characterization of many different nanostructures (nanotubes, DNA and, more recently, graphene). Nevertheless, the SPM techniques allow a much more comprehensive analysis of materials and, in addition to the plane morphological characterization, the extraction of local mechanical, electrical and magnetic properties is within reach. Moreover, the manipulation (modification) of such properties is also feasible. Therefore, this presentation summarizes recent studies (finished and ongoing) carried out in our labs where different SPM techniques are applied to

reveal, and even modify, several properties of carbon nanostructures (nanotubes and graphene). Initially, applications of SPM on the nano-electromechanical manipulation of carbon nanotubes will be presented. We will show a semiconductor-metal transition in a deformed nanotube. We will also analyse the universal behaviour of single-walled nanotubes upon radial compression and, in addition, will show a simple SPM-based methodology to identify metallic and semiconducting nanotubes. Switching to graphene, on the first study, we present theoretical and experimental evidences of compression-induced surface diamondization of few-layer graphene, which originates a new 2D material without a bulk counterpart – the *diamondol*. The Electric Force Microscopy (EFM) data show a compression-induced charging inhibition of bilayer and multi-layer graphene, which is reversible and water-dependent, and is absent in single-layer graphene, providing experimental evidence for such diamondization.

On a second study, we report the synthesis and characterization of two-dimensional (2D) molecular crystals from long and linear phosphonic acids atop graphene. These crystals are oriented along the graphene armchair direction only. They also provide a hole doping of graphene with carrier concentration of 1013cm-2 as demonstrated by Raman spectroscopy.

Finally, we will present some ongoing studies of graphene: initially, we investigate the metastable phase formation and structural evolution of epitaxial graphene. The 6H-SiC(0001) substrate was submitted to a temperature gradient during the process of formation of single/multi-layer epitaxial graphene under UHV conditions. Scanning tunnelling microscopy and X-ray diffraction were used to characterize the structure and morphology of the surface, from which the formation of a metastable phase was inferred. This metastable phase occurs in regions where the domains are quite small and disordered regions coexist with epitaxial graphene and Si sublimation is incomplete. The stability of this Si-doped metastable phase is confirmed via density functional theory. Finally, some studies on the decoration of graphene with phosphonic acids with different chain lengths and even the anomalous dielectric response of h-BN will be briefly discussed.

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TOPOLOGICAL DEFECTS IN GRAPHENE: FROM STRAIN-INDUCED CLUSTERING TO QUASI-1D ELECTRONIC STATES ALONG DOMAIN BOUNDARIES

Topological defects (TDs), mainly in the form of fivefold and sevenfold rings, occur commonly in graphene samples prepared by techniques aiming at mass-scale production of the material, such as reduction of graphene oxide and chemical vapor deposition. In polycrystalline samples, one-dimensional (1D) periodic patterns of such defects form the structure of grain boundaries (GBs) between adjoining misoriented grains. Further, in a recent experiment, a 1D domain boundary, which core is formed also by a periodic array of TDs, was purposefully created by shifting the deposition of a graphene layer over a nickel substrate from a face-centered-cubic to a hexagonal-close-packing stacking registry, with respect to the layers of the underlying substrate. In this talk, we will present results from ab initio calculations, based on the density functional theory (DFT), for

the morphology of clusters of TDs induced by strain on functionalized graphene. Our results suggest a rich variety of deformation mechanisms in plastically deformed graphene and functionalized graphene, with a myriad of TD morphological patterns being generated, depending on the nature and magnitude of the initial deformation imposed on the graphene layer. We will also show results that suggest: (i) the formation of strongly laterally confined quasi-1D electronic states in the FCC-HCP domain boundary; and (ii) that electronic states associated with large-angle tilt grain boundaries hybridize strongly with the graphene bulk states are not laterally confined. The formation of an anisotropic Dirac-cone of electronic states, along the GB direction will also be discussed.

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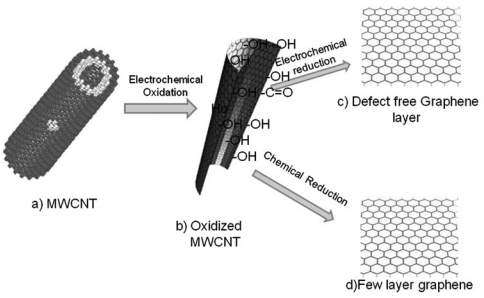
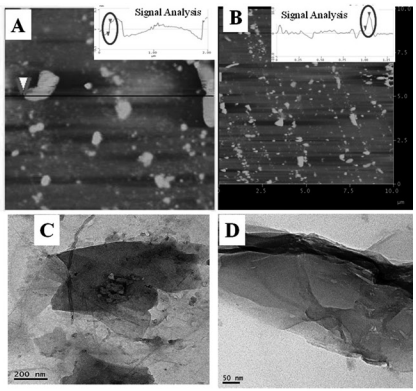
ELECTROCHEMICAL TRANSFORMATION OF MULTIWALLED CARBON NANOTUBES GRAPHENE LAYERS

Here we report a remarkable transformation of Multi Walled Carbon Nanotubes (MWCNTs) to few layers of graphene by a two step electrochemical approach. This consists of the oxidation of MWCNT at controlled potential followed by its subsequent reduction to form graphene nanoribbons (GNRs) having smooth edges and less defects as evidenced from multiple characterization techniques including Raman spectroscopy, Atomic Force and Transmission Electron Microscopy(as shown in the scheme, AFM and HRTEM images below) . This type of an unzipping of CNT in presence of interfacial electric field provides unique advantages with respect to the orientation of CNTs in longitudinal direction so that the production of GNRs with controlled widths and less defects could be possible. Electrochemical approach is an effective tool to modify electronic states by modulating electric field (chemical potential) to change the Fermi level of the electrode materials. Interfacial electric field is expected to orient the CNTs in our method and hence longitudinal unzipping is more likely rather than a random breakdown in chemical methods.





One of the important advantages of this electrochemical approach for the synthesis of high quality graphene with controlled layer thickness is the possibility of precise control of ribbon dimensions based on the diameter of MWCNT. As many of the limitations of chemical unzipping

create over oxidation and edge defects, these could be eliminated by using this controlled potential step experiments which will also not result in any contamination of the product. Although the electrochemical route for graphene synthesis described here can have several advantages of tuning the orientation, control of edges and planes along the length up on first oxidation step, some of the electronic characteristics might get affected due to the adsorption of cations, anions and solvent molecules on the defect site or due to intercalation. However this study opens new pathways for the preparation of high quality graphene in good yield and there are also profound implications for certain applications like fuel cells, Li batteries electrodes where CNTs are continuously under kept electric field.

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CHARACTERIZING GRAPHENE BY RESONANCE RAMAN SCATTERING

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Raman spectroscopy is a very useful tool to study graphene, since it furnishes information about the atomic structure, presence of disorder, defects, charges and strain. However, important information about electrons can be also obtained in a resonance Raman investigation, where the energy of the laser excitation can be tuned. We will present experimental results of the dispersion of electrons and phonons in graphene devices, where an applied electric field and changes in the Fermi level can be controlled by an external gate voltage, showing that Raman spectroscopy is useful to quantify the interaction of graphene with its surrounding environment. We will also show that Raman spectroscopy can be useful to characterize twisted graphene layers in samples grown by CVD on copper foils. Finally, we will present results of the electronic dispersion in uniaxial strained bilayer graphene.

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of graphene devices. He has 35 scientific papers with about 550 citations. He is also CTO of the Center for Microsystems and Nanosystems (CMINAS), a micro and nanofabrication facility that is being created at the Belo Horizonte Technological Park.

FABRICATION AND ELECTRIC TRANSPORT INVESTIGATION OF GRAFENE DEVICES

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Graphene, a truly two dimensional crystalline system, is now one the main topics of research in condensed matter physics and electric transport played a major role in the "discovery" of graphene. As an example, it was through electric transport measurements that the fact the electrons in Graphene behave as massless Dirac Fermions was established. The fact that Graphene presents ambipolar transport that can be widely controlled through field effect also makes it a promising system for future nanoelectronics. Some even speculate about Graphene being a future replacement for Silicon in many electronic devices. A handful of basic physical phenomena have already been observed is are being studied in this novel two dimensional system, such as quantum Hall and Fractional quantum Hall effects, Klein tunneling and the measurement of fundamental physical constants, such as the fine structure constant. In this talk I will make an overview of the research done at UFMG aimed towards fabricating a diversity of Graphene devices for electric transport studies. I will address fabrication methods that have been developed using direct laser writing photolithography, electron beam lithography, focused ion beam (FIB) and porous Alumina templates. I will also present some recent results in the investigation of electric transport, specially the influence of the substrate doping in defining the electrical behavior of devices and electric transport measurements on devices with artificially created periodic potential modulations.

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FASCINATION FOR NANOCARBONS

Since the discovery of fullerenes in 1985, much has been done in carbon chemistry, in particular on nanostructures involving not only carbon but also of other inorganic layered materials. Thus, inorganic fullerenes are well documented. After the discovery of carbon nanotubes in 1991, inorganic nanotubes were prepared and characterized. Graphene has created sensation in the last three to four years. We shall highlight some of the properties of graphene, specially the sensitivity of its electronic structure to doping and molecular charge transfer. We shall examine charge-transfer and related aspects of nanotubes with emphasis on the electronic properties and on selective synthesis of nanotubes with specific properties. We also report on the analogues of graphene made of inorganic materials such as boron nitride and molybdenum sulfide.

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SPIN-RELATED PROPERTIES OF GRAPHENE WITH ADATOMS

The ultimate goal of Nanotechnology is the fabrication of nanoscopic devices with the ability to perform complex tasks. One of the routes to achieve this goal is the use of multifunctional materials. Graphene is one of the most promising multifunctional materials. It has outstanding electronic, optical and mechanical properties. However, for many spintronic applications, it could be desirable to have a graphene layer with magnetic properties. In this talk, I will discuss the consequences of doping graphene with magnetic adatoms. The vanishing density of states of graphene close to the Dirac point is responsible for two effects: adatoms can easily form local magnetic moments; also the interaction between these magnetic moments and the spin of carriers can be surprisingly strong and controlled my gating [1]. Both effects enhance the magnetic properties of graphene in the presence of adatoms. Moreover, when the layer is doped with a large number of adatoms, it is possible to modify the electronic properties of the system by controlling its magnetization [2]. I will show that a random distribution of magnetic adatoms can open a robust gap in the electronic spectrum of graphene. The electronic gap results from the interplay between the nature of the graphene sublattice structure and the exchange interaction between

adatoms and its size can be controlled by both temperature and external magnetic field. Finally I will also discuss the possibility of generating spin currents in a graphene layer doped with non-magnetic adatoms.

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Antonio José Roque da Silva (March 23rd 1964) is a Brazilian physicist. He currently works as Director of the Brazilian Synchrotron National Laboratory (LNLS). Since 2007 he is a full Professor at the Department of Physics of the University of São Paulo (USP-Brazil), where he started to work in 1998. He did his bachelor (1986) and MSc (1989) at the Physics Institute of the University of Campinas (UNICAMP-Brazil), his PhD (1994) at the Physics Department of the University of California at Berkeley, and a post-doc at the Chemistry Department of the University of California at Los Angeles (1995-1997). He has more than 100 published articles in refereed journals and those articles were cited more than 2000 times. His research field is Computational Simulation in Material Science with emphasis in electronic, transport, magnetic and structural properties of Nanomaterials.

"Structural, electronic and transport properties of carbon nanosystems via ab initio calculations"

I will discuss results of ab initio calculations based on the Density Functional Theory to describe a variety of properties of graphene and carbon nanotubes. This will be done through few examples including defects in nanotubes, transport through disordered systems, dual-gated bilayer graphene nanotransistors, and doping by atoms and molecules. This work was supported by FAPESP and INCT/CNPq.

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A.K. Sood is a Professor in Department of Physics at Indian Institute of Science, Bangalore and is currently holding the prestigious Bhatnagar Fellowship of CSIR. His research interests include Physics of Nano systems like nanotubes and graphene, and physics of soft condensed matter. The latter includes shear-induced instabilities like spatio-temporal rheochaos and interface rheology. He has published more than 288 papers in refereed international journals and holds a few patents. His work has been recognized by way of many honors, awards and fellowships of the Academies in India and The World Academy of Sciences (TWAS). He is one of the Executive Editors of an International journal, 'Solid State Communications'. He is President of Indian Academy of Science since January 2010.

PHYSICS ISSUES IN FET AND RESISTIVE SWITCHING DEVICES OF GRAPHENE

The talk will cover our recent work on frequency multiplication and unipolar resistive switching in graphene devices. An on/off resistance ration of 10 E 5 is easily achieved in graphene two terminal devices. Using top-gated field effect transistors (FET) made of single and bilayer graphene wherein transport measurements are combined with in-situ Raman scattering, effect of electron and hole doping on the graphene 2D phonons is quantitatively studied. We will also present recent studies on graphene FET devices showing simultaneous p and n type carrier injection by varying the longitudinal bias across the channel and the top-gate voltage. Spatially resolved Raman scattering across the graphene channel in FET quantifies the variation of the doping.

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Antonio Gomes Souza Filho was born on June 12, 1975, in Jucás, Brazil and received his doctorate degree in physics from the Federal University of Ceará (UFC), Fortaleza, Brazil, in 2001. In 2000, he joined the group of Prof. Mildred Dresselhaus at MIT as a Ph.D. visiting student, where he worked on single carbon nanotube resonance Raman spectroscopy. His Thesis work was awarded (Honorable Mention) in Brazil as an outstanding PhD thesis by the Brazilian Physical Society in 2002. He has authored/co-authored about 150 papers in referred international journals including review articles and book chapters. He is currently an adjunct professor of physics at the Federal University of Ceará and CNPq Fellow 1C. He was one of the recipients of 2009 Sômiya Prize awarded by International Union of Materials Research Societies (IUMRS) and elected affiliated member of the Brazilian Academy of Science in 2011. The main research interest is the electronic and optical properties of nanomaterials with emphasis in carbon nanostructures.

FILLING AND INTERCALATION EFFECTS ON THE MECHANICAL STABILITY OF DOUBLE WALLED CARBON NANOTUBES: RESONANCE RAMAN SCATTERING STUDIES

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Ressonance Raman scattering emerges as very powerful technique for studying carbon nanotubes at extreme conditions (such as high pressure), because both electronic and structural changes induced by this variable in the nanotubes are well-seen in the vibrational spectra, which are easy to measure.

Since carbon nanotubes are considered as model systems for nanoscience, high-pressure investigations of these materials are also important for learning about the high pressure effects at the nanoscale, in general. Most of the high-pressure Raman scattering studies of carbon nanotube systems have been performed on single-walled carbon nanotubes (SWNTs). Double-walled carbon nanotubes (DWNTs) system is interesting their own because it is an intermediate structure between SWNTs and multi-walled carbon nanotubes. Since DWNTshave only two tubes and the diameters of the outer tubes are often similar to those of SWNTs, the quantum confinement effects are almost as prominent as those manifested in SWNTs. In this talk we discuss both pristine and intercalated double wall carbon nanotubes (DWNTs) at high pressures. Firstly, we discuss the collapse of DWNTs which happens in two-step; the colapse of the outer tube followed by the collapse of the inner tube; both happening at pressure values quite different from that reported for single wall carbon nanotubes with similar diameters. According to calculations, the pressure collapse of DWNTs scales as d_{tav}^{-3}, where d_{tav} is the average tube diameter of the DWNT. We show that filling a tube with another tube leads to a pressure stabilization against collapse, in strong opposition to what is observed when filling a tube with fullerenes or iodine, for example. Secondly, we show that the mechanical resistance of the DWNT system is found to be affected in the case of bromine intercalated DWNTs thus leading to lower collapse pressure than pristine counterparts. It was observed at about 15 GPa in X-ray absorption measurements slightly modifications in electronic structure of bromine as well a sudden upshift of two Raman active modes which are recovered after releasing pressure. Such modification are interpreted as being related to the colapse of DWNT which change completly bromine environement leading to a formation of different nanostructures.

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Umesh Waghmare received a B Tech (with institute silver medal) in Engineering Physics from the IIT, Bombay (1990) and a PhD in Applied

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THEORY OF DEFECTS IN GRAPHENE AND RELATED MATERIALS

We present (a) first-principles density functional theory based calculations aimed at determination of properties of topological defects in graphene and related 2-D materials, and (b) a continuum theory that captures the nonlinear elastic properties as well as the effects of Stone-Wales defects. We use this continuum model in finite element analysis of graphene subjected to various types of mechanical loading and boundary conditions, and suggest experiments which should reveal interesting signatures of our first-principles and finite element theoretical predictions.

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Brazilian Chemical Society (2008-2010). Actually is the head of the Chemistry Graduate Program at the UFPR (2011-2013), associated editor of the periodic Química Nova, and member of the Steering Committee of both the Brazilian Network for Research in Carbon Nanotubes and the Brazilian Institute of Science and Technology of Carbon Nanomaterials. Your main research interests are the synthesis, characterization, study of properties and applications of nanometric materials, mainly carbon nanotubes, graphene, metal nanoparticles and different kind of nanocomposites.

CARBON NANOTUBES- AND GRAPHENE-BASED NANOCOMPOSITES

One important application of carbon nanostructures (nanotubes, graphene) is in the field of nanocomposites, aiming synergistic effects and novel properties. Different fascinating kind of carbon-based nanocomposites with polymers, metals, inorganic materials, gels, among other classes of materials have described in the last years, resulting in novel and fascinating materials with tuneable electrical, magnetic and optical properties arising from the nanoscale coupling. Our research has acquired a large experience on the development of novel route to synthesize carbon nanotubes (and more recently graphene) and their different nanocomposites with conducting polymers (polyaniline, polythiophene), natural rubber, metal nanoparticles (gold, platinum), Prussian blue, among others. A summary of the main works developed by our research group in these fields will be presented. Results related to the application of the nanocomposite materials in transparent electrodes, photovoltaic devices, biosensors, gas sensors and fuel cells will be also demonstrated and discussed.

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