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PREFACE

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Guest Editor

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Over the last decade, rapid progress in the field of nanoscience has been increasingly driving the attention of the scientific community as well as society at large on the corresponding technological applications, which are the object of so-called nanotechnology. A strong interest in assessing the current state of the art of this fast growing field, as well as stimulating research networking, prompted the organization of the International School and Workshop 'Nanoscience & Nanotechnology (n&n2007)', under the patronage of the Italian Institute for Nuclear Physics (INFN), the University of Rome Tor Vergata, the Tor Vergata Polyclinic, and the Catholic University of Rome, with generous sponsorship from 3M, 2M Strumenti, MTS, Ape Research, Crisel Instruments, Veeco and Amira. The aims of this event were as follows:

- to foster the concrete planning of future devices based on innovative (nano)materials, involving both industrial entities and public research institutes;
- to allow sponsoring firms to present their instrumentation and success stories, based on current use by significant customers;
- to lend an opportunity for preparing and presenting joint projects, involving both industry and public research, see e.g. the EU 7th Framework Programs;
- to explore the possibility of integrating nanodevices from their concept into system projects.

The conference http://www.lnf.infn.it/conference/nn2007/ gathered at Villa Mondragone in Monte Porzio Catone, Italy, with leading experts in research and innovative technologies in biology, medicine, aerospace, optoelectronics, materials and instrumentation, coming both from academic research and industrial areas, as well as national security and military defense experts in attendence.

Several successful meetings in this field have taken place in the past, such as the Nanotubes & Nanostructures (N&N) School and Workshop Series [1, 2, 3, 4], including:

- 1. N&N2000, S Margherita di Pula (Cagliari), Italy, 24 September–4 October 2000, http://www.lnf.infn.it/conference/nn2000/default.html
- 2. N&N2001, Frascati (Roma), Italy, 17–27 October 2001, http://www.lnf.infn.it/conference/nn2001/Welcome.html
- 3. N&N2002, Frascati (Roma), Italy, 23–28 September 2002, http://www.lnf.infn.it/conference/nn2002/
- 4. N&N2003, Frascati (Roma), Italy, 15–19 September 2003, http://www.lnf.infn.it/conference/nn2003/
- 5. N&N2004, Frascati (Roma), Italy, 14–20 October 2004, http://www.lnf.infn.it/conference/nn2004/
- 6. n&n2005, Monteporzio Catone (Roma), Italy, 14–16 November 2005, http://www.lnf.infn.it/conference/nn2005/
- 7. n&n2006, Monteporzio Catone (Roma), Italy, 6–9 November 2006, http://www.lnf.infn.it/conference/nn2006/

In order to enable the exchange of knowledge and collaboration among the different scientists in the field of nanotechnology, whilst also offering an opportunity for those who are just beginning to get involved with it, allowing them to meet contacts and get prime, up-to-date information from the experts, a special poster and equipment session displayed various firm's institutional activities in selected areas of application where nanoscience can have a deep impact. The participants were also able to get involved with sample testing. Tutorial lectures were delivered at the school, addressing general and basic questions about nanotechnology, such as what they are, how does one go about them, what purposes can they serve. In tutorial sessions the nature of nanotechnology, the instruments of current use in its characterizations and the possible applicative uses were described at an introductory level.

The first day was devoted to three sessions:

- Aerospace, defense, biomedicine.
- Electronics and mechanical properties.
- Materials and characterizations.

The first session was opened by a lecture by J Kenny, who talked about the use of carbon nanotubes for polymer matrix nanocomposites. He reported how plasma functionalized single-walled carbon nanotubes (F-SWNTs) reacted with a primary aliphatic amine can be used for preparing an integrated nanotube composite material. The results show the emergence of specific interactions of cross-linking between a thermosetting matrix and amino-functionalized SWNTs during the cure reaction with an improvement of the mechanical properties with respect to those prepared with unfunctionalized SWNTs. The possibility of using amino-functionalized SWNT to make a 'mix and match' approach towards classes of hybrid materials was reported suggesting the possibility of tuning the electrical properties by combining the electric field in the assembling processing. Moreover, it was demonstrated as electrophoretically deposited SWNT thin films provide a simple route to obtain layered functional nanostructures by growing homogeneous films of carbon nanotubes and infiltrating polymer or monomer, followed by *in situ* polymerization. Some examples where electrophoretically deposited SWCNT films were infiltrated with monomer and then the monomer was polymerized were reported.

The invited lecture by S D'Auria explored the advantages of using either enzymes or binding proteins to develop non-consuming substrate fluorescence nano-biosensors. He reported a novel approach to address the consumption of substrate by enzyme-based biosensors, namely the utilization of apo-enzymes as non-active forms of proteins which are still able to bind the ligand but cannot transform it into product. He also reported recent studies in which fluorescence labelling proteins by a fluorescent probe allows a wireless monitoring of toxic compounds. Then, he presented a cutting-edge methodology for the detection of target analytes at very low concentration, namely single molecule detection.

C Falessi described how the 'Finmeccanica Focus Group Nano' is coordinating a multiscale nanoscience engineering integration initiative that is an emerging and unified strategy to link the customer operative requirements with innovative high-tech product. He introduced the audience to the 'NanoTechnology Multiscale Project (NMP)', as a complete realization of the vertical and horizontal integration recognized as a condition for nanotehnology application to industry and society, including the definition and development of integrated methodologies and environments to study, design, develop and test nanotechnology based metamaterials, devices, sensors and systems.

F Canganella presented research activities concerning the biofilm properties of some reference bacteria on materials commonly used for the aerospace industry. His group evaluated the effect on these materials on a mixture of biosurfactants produced by the Pseudomonas strain AD1 recently isolated by the research group.

The following materials were investigated: Kevlar, Nomex, Betacloth,

aluminized Kapton, conventional Kapton, Combitherm, Mylar, copper foil, Teflon, aluminum, carbon fiber composite, aluminum thermo-dissipating textile and aluminum tape. Results showed a diverse affinity of materials for the bacterial biofilm development and in some cases sessile colonization was rejected. Pre-conditioning with biosurfactants led, in some cases, to a diminish of biofilm development compared to untreated materials, taking into account both concentrations and experimental conditions. Obtained data may be useful to screen and select appropriate material to be used for life support hardware to avoid or decrease the risk of surface biocontamination.

M Chiaretti reported on the biological effects of multi-wall carbon nanotubes (MWCNTs, CNT for short) on laboratory animals *in vivo*, on the immunological effects and the effects on three different cell types. Large numbers of researchers are directly involved in the handling of nanomaterials such as CNT, nanoparticles. It is important to assess the potential health risks related to their daily exposure to nanoparticles. The administration of sterilized nanosamples has been performed on laboratory animals in acute and chronic administration and the pathological effects on the parenchymal tissues have been studied. The research group studied the serum immunological modifications after CNTs intraperitoneal administration. No antigenic reaction was observed, because the screening of ANA, anti-ENA, anti-cardiolipin, C-ANCA and P-ANCA was negative. No quantitative modifications of immunoglobulins were observed and so no modifications of umoral immunity were documented. The research group also studied the effects of CNTs on the proliferation of three different cell types. MCF-7 showed a significant inhibition of proliferation at all the conditions studied, whereas hSMCs demonstrated a reduction of cell growth only at the highest CNTs concentrations at 72 h and no growth modification was observed in the Caco-2 cell line. It was observed that a low quantity of CNTs does not provoke any inflammatory reaction, although it is important to build a CNT plait and net to study the implantation effects. Moreover, it has to be emphasized that this study does not, at the moment, address the carcinogenicity of CBNs, which requires a detailed follow-up investigation on that specific topic. In view of their subsequent and more extensive use, as to say in applications where carbon nanotubes are injected into the human body for drug delivery as a contrast agent carrying entities for MRI, or as the material of a new prosthesis generation, other extended tests and experimentation are going to be necessary.

L Ghibelli showed how to set up a wide field systematic cyto-toxicological study with multiple variables to envisage the critical points that may affect CNT biocompatibility. To this purpose, she made use of MWCNT and SWCNT, of different sizes, prepared with different modalities (i.e., arc discharge or catalysis) containing different contaminants (i.e., Fe2+; graphite; amorphous C), at different concentrations and times of incubation. The biological targets selected are the following: cytotoxicity (viability, apoptosis, necrosis); sensitization/desensitization to chemotherapic-induced apoptosis; cell proliferation and cell cycle; differentiation; oxidative stress (reactive oxygen species and glutathione levels); mitochondria; calcium parameters. The group focused on blood cells, since nanoparticles can enter the blood stream upon inhalation, accidental bruises, and may be possibly purposely injected in the future for drug delivery, thus being potential targets of CNT. The selected cell systems are human tumor cells (monocytes, U937, and T lymphocytes, Jurkat) and the normal counterparts, i.e., lymphocytes and monocytes from peripheral blood. From the analyses, it can be concluded that: (a), the type of biological effects depend on the target cell type, i.e., on Jurkat cells, CNT induce apoptosis, act as radical scavengers, and do not affect proliferation, whereas in U937 cells they strongly inhibit proliferation, increase radical species production, and do not induce apoptosis or necrosis; (b), the size and type of CNT clearly influence the biological effects, the smaller being the more effective; (c) the contaminants influences the effects, according to their own characteristics. A presentation about

nanotechnologies and occupational safety & health, describing the fundamental aspects of research and networking in Italy and Europe was given by S Iavicoli.

The scope of M S Sarto's talk 'Carbon nanotube technology for next-generation nanointerconects', which opened the second session of the day was to present the most recent results of research on next-generation nanointerconnects and to discuss the internationally most advanced state-of-art technology in this field. The aspects related to the EM modelling of CNT-nanointerconnects in the frequency range up to several tens of GHz were also presented. Unconventional interconnects and innovative materials are being studied as replacements for copper interconnects. Because of their exceptional and unique physical properties carbon nanotubes (CNTs) have aroused a lot of research interest that make them promising candidates as nano-interconnects for future high-speed electronics. Sarto illustrated how a specific focus on European research on nanointerconnects was addressed in the first call of ICT priority of the FP7, within the FET proactive initiative and outlined the successful presentation of the recently approved collaborative project CATHERINE.

N Pugno introduced a new concept, of smart flexible—a property that could be crucial for smart drug delivery—nanovectors, based on smart adhesion. Targeting, in addition to the classical strategies, is enhanced by designing the nanovector in order to activate an adhesion force larger than the drag force only in the capillaries. A hierarchical architecture is used to model a real vasculature. During adhesion, the smart nanovector considerably changes its shape in a controllable way and, in case, can implode due to buckling. Such a mechanism will cleverly deliver the drug in a controllable way, ideally aborting the tumor colonization.

M Pavese presented the growth and the physico/mechanical characterization of millimeters thick layers of self-standing vertically aligned multi-wall carbon nanotubes (MWCNTs). The MWCNT 'forest' was obtained by thermal decomposition of camphor over a silicon substrate, in the presence of ferrocene as a catalyst.

Alcohol vapors sensory properties of nanostructured conjugated polymers were presented by A Bearzotti. He showed how conjugated polymer (PPA = polyphenylacetylene) and co-polymer (P(PA/HEMA)=(poly[phenylacetylene-(co-2-hydroxyethyl methacrylate)])) were prepared by the modified emulsion polymerisation technique; the nanostructured morphology enhances the properties of these materials mainly because of their increase in surface/volume ratio rendering them adapted for applications like sensitive membranes.

The presentation by M Fajfrowski provided a practical reference for using instrumented-indentation testing (IIT), placing emphasis on the equipment, data-analysis, and calibrations required for accurate and meaningful measurements on a variety of materials. IIT has been developed over the last decade for the purpose of probing the mechanical properties of very small volumes of material. IIT is ideal for mechanically characterizing thin films, coatings, and surface layers including those modified by ion implantation, because the layer does not have to be removed from its substrate. Because indents can be positioned to within about 1 micron, IIT also provides the ability to map the spatial distribution of surface mechanical properties with good resolution; for example, one could map out the mechanical properties within and around a weld site. Even when the material sample is sufficiently large to be tested by other means, IIT often remains the method of choice because it requires little sample preparation.

A new method for nanoindentation was proposed in the presentation of L Calabri. It allows hardness measurement with standard sharp AFM probes; the use of these probes enables a simultaneous high-resolution imaging (which is not achievable with standard indenters—*cube corner* and *berkovich*). How the shape of the indenter and the tip radius of curvature affect the hardness measurement was then analyzed to find a relationship between the measured hardness of a material, the corner angle of the pyramidal indenter and its tip radius of curvature.

To experimentally understand this effect a photoresist material has been indented with focused ion beam nanofabricated probes with different corner angles. Then the results obtained experimentally were compared with those obtained by numerical simulations and by theoretical models.

The spectral characterization of AlN, macrosized and nanostructured was the focus of B Berzina's talk, who opened the third session by reporting on the analysis and comparison of the spectral (luminescent) characteristics of the different types of AlN. The results obtained examining the luminescence processes of AlN (ceramics, nanorods, nanotips, nanopowders) were discussed.

Ab initio simulations on the atomic and electronic structure of single-walled BN nanotubes and nanoarches were illustrated by Yu F Zhukovskii.

M B Muradov talked about nanoparticles of cadmium selenide and cadmium sulfide, which yield one of the perspective materials for application to solar cell elements, high-speed computing systems, catalyses and biomarkers in medicine. In the presentation, the process of transformation of nanoparticles cadmium of sulfide to nanoparticles of cadmium selenide by an ionic exchange from solutions of electrolytes was considered. The size of particles was controlled by the quantity of growth cycles. After manufacturing, the structures were investigated by atomic force microscope (AFM). Structures CdS:polymer transformed into CdSe:polymer with the help of ion-exchange. For the realization of the process of ionic exchange, solutions were prepared containing bivalent ions of selenium as follows: $NaBH_4$ and Se in a weight parity 2:1 added in water

$$4NaBH_4+2Se+7H_2O\rightarrow 2NaHSe + Na_2B_4O_7+14H_2$$

In the prepared solution nanostructures CdS:polymer were immersed. Time of endurance was 2 h. After an ionic exchange the obtained structures were investigated by means of EDAX on a chemical composition. Results of analyses have shown that atoms of sulfur are completely replaced by selenium. The band gap of nanoparticles in comparison with initial samples is displaced in the long-wave area. It is connected with the fact that the width of the band gap of bulk crystals CdSe (1.74 eV) is smaller than the band gap of CdS (2.42 eV).

Optical microscopy with spatial resolution beyond the diffraction limit obtained by using near field techniques was the subject of S Prato's talk. Scanning near field optical microscopy (SNOM) has developed into a powerful tool to investigate local optical properties that depend on heterogeneity of materials at nanoscale and to study nanoenvironment of biosystems. Crucial topics in SNOM are: force sensitivity and optical throughput of the probe and scanning position accuracy. Prato showed a method to characterize force sensitivity of piezoelectric transducers and we've implemented a test system for off line characterization of probes. Recent improvements in aperture SNOM were also illustrated in this talk by some biological applications.

H Stadler showed the development of a new instrumentation, combining optical and scanning probe microscopy (SPM) multimodal characterization, specifically designed for SPM based life science research and full integration with optical microscopy. The prerequisites and design of such equipment besides newer application examples in this area were discussed. Stadler also overviewed work on improving quantitative mechanical characterization on the nanoscale. This included hardware like SPM control electronics and probe development as theoretical aspects and software for data evaluation.

Comparative field emission studies of as-produced CNTs *vis á vis* commercially obtained SWCNT were presented by A Tiberia. Carbon nanotubes synthesized at INFN-Laboratori Nazionali di Frascati in the nanotechnology group of S Bellucci by DC thermal plasma process were analyzed by electron microscope and studied for their field emission properties. These carbon nanotubes were deposited on a tungsten wire, which acted as the cathode. Care

was taken to ensure complete covering of the wire. The emission studies were performed in a stainless steel chamber under a dynamic vacuum in the range of 10–8 Torr. The field emitted current was detected using a phosphorous coated ITO (indium tin oxide) glass plate. The phosphorous coat also helped in imaging the tips of the nanotubes. This was crucial in accurately estimating the emitting area and thus the field enhancement factor. The I-V curves for the field emission were recorded for various distances between the electrodes. Similar studies were performed for commercially obtained single walled carbon nanotubes and the results compared with the as-produced nanotubes.

The second day was dedicated to three more sessions:

- Characterization and excitations in nanostructures.
- Superconductivity at the nanoscale.
- Transport in low-dimensional electron systems and spin effects.

The first session of this second day was opened by G Stefani with a lecture on Auger spectroscopies. Then E Perfetto showed the results of a study on electron correlations in carbon nanotubes and graphite from Auger spectroscopy. He determined the screened on-site Coulomb repulsion in graphite and single wall carbon nanotubes by measuring their Auger spectra and performing a new theoretical analysis based on an extended Cini–Sawatzky approach where only one fit parameter is employed. The experimental lineshape is very well reproduced by the theory and this allows the value of the screened on-site repulsion between 2p states to be determined, which is found to be 2.1 eV in graphite and 4.6 eV in nanotubes. The latter is robust by varying the nanotube radius from 1 to 2 nm.

S Ugenti gave a presentation setting up a model aimed for the calculation of three-hole features like the ones due to core-valence-valence Auger decays following Coster–Kronig transitions. While several experiments made in the 1970s and in the 1990s on the Auger LMM spectra of transition metals showed the existence of these structures, a theory able to explain and predict them is still missing today. The described model is grounded on the one-step approach, but the use of a valence band fully below the Fermi level allowed the authors to treat their calculations in a three-step approach, so keeping in this exploratory work complications to a minimum. The Hamiltonian of the system is placed in an Anderson-like picture and the spectra are computed evaluating a three-body Green's function. Within this model one arrives to a simple and closed formula covering the whole range between weak and strong correlation. It is found that in general the satellites cover separated spectral regions with three-hole multiplets, shifted and broadened two-hole features and distorted band-like continua.

The second session of the day started with an invited presentation by I Batov who studied the magnetotransport and differential current-voltage characteristics in small hybrid junctions formed by InGaAs/InP heterostructures coupled to superconducting and normal metal terminals. Highly transparent superconducting contacts to a two-dimensional electron gas located in a InGaAs/InP heterostructure have been realized by using a Au/NbN system. A decrease in the differential resistance with pronounced double dip structure has been observed within the superconducting energy gap. It is argued that the double-dip structure in the differential resistance is related to the transport in SN-2DEG contacts in the ballistic regime. It has been found that the reduced subgap resistance is preserved in high quantizing magnetic fields. The magnetoresistance of the S/2DEG/N junctions has been investigated at various dc bias currents and temperatures. It was found that at dc bias currents below a critical value, the resistance of the S/2DEG/N structures develops a strong oscillatory dependence on the magnetic field, with an amplitude of the oscillations considerably larger than that of the reference N/2DEG/N structures. The experimental findings can be interpreted within the framework of recent theoretical models describing Andreev reflection across a S/2DEG interface in the presence of a magnetic field.

M Cini spoke about superconductivity from repulsive interactions in low-dimensional systems. The local symmetry conditions that allow for the existence of W = 0 bound pairs from repulsive interactions were highlighted. A case was made about a key role of symmetry related ideas in explaining the occurrence of superconductivity in a class of low dimensional systems as a correlation effect. Among these, it was argued about Cuprates, which fail to superconduct at low doping, when the lattice gets distorted, and also about some kinds of doped carbon nanotubes, where a crossover from Luttinger liquid to $W = 0$ superconductivity is likely.

An investigation of the Cooper-pair propagation and the Josephson effect in graphene under conditions in which the distance L between superconducting electrodes is much larger than the width W of the contacts was presented by J Gonzalez. In the case of undoped graphene, he showed that supercurrents may exist with a spatial decay proportional to W^2/L^3, reminiscent of the behavior of the critical current in disordered normal metals. One can observe that there is in general a crossover temperature $T^* \sim v_F/k_B L$ that marks the onset of the strong decay of the supercurrent, and that corresponds to the scale above which the Cooper pairs are disrupted by thermal effects during their propagation. It was also shown that the spatial decay of the critical current changes upon doping into a $1/L^2$ behavior, opening the possibility to observe a supercurrent over length scales above 1 μm at suitable doping levels.

The DC Josephson effect has been observed in submicron quasi-ballistic $In_{0.75}Ga_{0.25}As$ nanostructures inserted between superconducting Nb leads. F Carillo reported his findings of IcRn values among the highest measured on hybrid super/semi/super devices (400 μV). A theory based on quasiclassical equations for diffusive systems can both qualitatively and quantitatively account for the observed ICRN values and IC(T) curves. In ring shaped $In_{0.75}Ga_{0.25}As$ nanostructure Josephson current modulates with a contrast up to 65%.

Superconducting MgB_2 nanostructures have been studied with EBL-based techniques by Eugenio Monticone. He reported on the fabrication and characterization of MgB_2 nanostructures on different substrates, such as silicon nitride and sapphire. Magnesium diboride films are fabricated by all *in situ* methods consisting in the co-evaporation of B and Mg followed by *in situ* annealing at higher temperature. Samples thus obtained are characterized at low temperature and show a T_c of about 38 K. The nanostructures are then defined by electron beam lithography combined with physical etching by RIE and ion milling. By this method MgB_2 nanostructures and meanders are obtained with nice electrical and transport properties both on SiN and on sapphire. The morphological properties of films and nanostructures on both type of substrates were investigated by atomic force microscope and scanning electron Microscope. The analysis of the AFM images by the height–height correlation function shows that the films have a self-affine smooth textured surface with a RMS roughness of 20 nm. Furthermore, the nanobridges are continuous, with a well-defined geometry and a rounded profile, and the nanostructuration process does not significantly affect the film morphology. Electrical and transport characterization of nanobridges and meanders is performed at low temperature, and a critical current density of 8 MA/cm^2 is measured, for meander with width down to 300 nm. For the sake of comparison the measurements are performed as well on 10 μm wide strip patterned on the same sample. The results show that the nanostructuring process does not affect the superconducting properties of the structure. The flexibility of the EBL approach makes it interesting, in view of the fabrication of MgB^2 superconducting devices, such as photon detectors.

In the final session J Lorenzana discussed a dynamical version of the Gutzwiller approximation inspired on nuclear physics techniques. The approximation is shown to perform very well by comparing dynamical correlation functions with exact results. Applications on optical properties, magnetic neutron scattering, ferromagnetism and Auger spectroscopy were shown in this

presentation.

The quasiclassical Green's function method has been very effective in the study of non-equilibrium and transport properties of superconductors and disordered electron systems. The main reason for this is that it provides, in a well-defined regime of physical parameters, a systematic way to derive semiclassical macroscopic kinetic equations from microscopically defined models. In his talk R Raimondi presented the extension of the method to the study of the spin Hall effect in a two-dimensional electron or hole gas in the presence of an internal magnetic field due to a generic spin-orbit coupling. The method allows one to study spin and charge transport from ballistic to diffusive regimes and spin-charge coupled continuity equations are automatically incorporated. In the clean limit Raimondi showed the connection between the spin-Hall conductivity and the Berry phase in momentum space. For infinite diffusive systems he showed how the cancellation of spin Hall conductivity arises as a consequence of the linear-in-momentum Rashba spin-orbit coupling.

Gate-tunable band-gap in bilayer graphene devices were presented by J B Oostinga. Graphene systems, consisting of one or a few crystalline monolayers of carbon, stand out because of their unusual electronic properties and for their potential for application in nanoelectronics. Carrier mobility values as high as 10 000 cm^2/Vs at room temperature—ten times higher than in silicon—are routinely obtained in these materials, without the need for sophisticated preparation techniques. Both the high mobility and the envisioned possibility of low-cost mass-production provide a strong drive to explore the use of graphene for future high-speed integrated electronic circuits. However, in order to develop such 'graphene-based electronics' several problems need to be overcome. Perhaps the most important obstacle is the absence of an energy gap separating the valence and conduction band of graphene. Since graphene is a zero-gap semiconductor, electrical conduction cannot be switched off by using control voltages, which is essential for the operation of conventional transistors. In his presentation Oostinga showed that in a graphene bilayer a band-gap can be opened and controlled by applying an electric field perpendicular to the bilayer. The gap manifests itself in the appearance of an insulating temperature dependence of the conductivity, which becomes more pronounced for larger applied electric fields. This result demonstrates the capability to controllably switch off transport through a graphene bilayer in nano-electronic devices equipped with gate electrodes, and it represents the first step towards the realization of electrostatically controlled graphene-based devices.

D Ercolani presented low temperature transport measurements of a few-electron quantum dot (QD), that manifests a Kondo resonance in the two-electron, integer-spin state, with no external magnetic field applied. The dot is defined in the two-dimensional electron gas of a MBE-grown InGaAs/GaAs/AlGaAs heterostructure. Confinement is obtained by surface metal gates fabricated by e-beam lithography. A nearby quantum point contact is used to unambiguously determine the number, N, of electrons in the QD. The Kondo resonance for $N = 2$ is studied as a function of temperature, magnetic field and dot-lead coupling strength. Ercolani found that the reduction of the dot-lead coupling leads to the evolution of the strong zero-bias Kondo resonance into a weaker double-peak structure. Additionally, the two-dimensional electron gas has been characterized with Hall and Shubnikov-de Haas measurements as a function of a top gate voltage, and the results are compared with Poisson-Schrödinger simulations, resulting in accurate understanding of the subband energies. Observing the Kondo effect in a two-electron system is extremely rare at zero magnetic field, since the ground state is usually a spin singlet and the spin triplet states lie well above in energy. In the considered QDs, however, the presence of the Kondo effect can be explained by a quasi-degeneracy (compared to the Kondo temperature) of the singlet and triplet energy levels. This quasi-degeneracy occurs due to an anomalously large two-electron exchange energy, which approaches the

energy spacing between the lowest single-particle orbital levels. The small but finite singlet-triplet splitting (of the order of 70 μeV) emerges as a split Kondo resonance for weaker tunnel coupling between the QD and its leads.

G Stefanucci investigated the long-time dynamics of open Kohn-Sham systems relevant to quantum transport. The open system is connected to macroscopic metallic reservoir and perturbed by time-dependent electric fields. A general formula for the exact time-dependent density and current was obtained, which includes initial-state correlations, as well as time-dependent correlations. The speaker showed that the steady-state assumption is consistent provided that the density of states is smooth. The resulting steady-state current generalizes the Landauer formula to interacting electrons. On the contrary, the steady-state assumption leads to a contradiction if the asymptotic Kohn-Sham Hamiltonian has bound eigenstates. The density oscillates with history-dependent amplitudes and, as a consequence, the effective potential of TDDFT oscillates too. Such time dependence might open new conductive channels, an effect which is not accounted for in any steady-state approach and might deserve further investigations

The poster session included the following contributions.

Albumin-manganese ferrite nanoparticles for target drug delivery by M Bellusci reported on a process able to produce a high encapsulation degree of magnetic nanoparticles in a polymeric matrix. An aqueous suspension of albumin containing manganese ferrite nanoparticles was cross-linked with glutaraldehyde inside aqueous nanodroplets dispersed in cyclohexane and stabilized by sorbitan monoleate surfactant (water in oil reverse microemulsion). Albumin-nanoferrite compound showed superparamagnetic behavior. The obtained composite powder was successfully functionalized with a model drug and the biological activity was evaluated.

Microstructure of Ag_2BI_4 (B = Ag, Cd) superionics studied by SEM, impedance spectroscopy and fractal dimension analysis by I Bolesta, dealt with a series of experiment and theoretical estimations, including porousity measurements, SEM imaging, density calculations and fractal dimension analysis.

Channeling of protons through carbon nanotubes in dielectric media by D Borka focused on how dynamic polarization of carbon valence electrons influences both the angular and spatial distributions of protons channeled in a (11, 9) single-wall carbon nanotube placed in vacuum and in different dielectric media.

Scaling laws in science were analyzed in the poster by A Carpinteri and N Pugno, where size-scale effects on the mechanical properties of complex materials have been considered. According to the authors' interpretation [5] one can rigorously predict the strength of a material by varying the size-scale. One example is the prediction of the strength of macroscopic nanotube bundles from that of a single nanotube [6]. The result suggests that long nanotube bundles could have a key role in realizing a new generation of kilometer-long bridges, as needed for the three kilometers wide Straits of Messina.

The preliminary study on IR active modes in sterilized carbon nanotubes: a sterilization procedure for *in vivo* nanotoxicity tests by G De Bellis *et al*, focused on the health risks related to their daily exposure to potentially hazardous nanomaterials. The aim of the authors was to investigate the effect of three different types of sterilization procedures on morphological and chemical properties of both multi wall (MWCNTs) and single wall carbon nanotubes (SWCNTs). Three different sterilization processes were used in order to obtain bacteria/spores free CNTs. The preparation of sterile nanosamples is necessary in view of their subsequent use in *in vivo* toxicity tests on lab rats. The processes that were carried out for CNTs sterilization were: humid heat autoclave, UV light source and ethylene oxide treatment. The best of these treatments, i.e. the one that least affected the morphology and chemical properties of CNTs, has been

selected for future *in vivo* tests on rats.

FIR reflectivity of microcrystalline Ag_2CdI_4 between 10 and 420 K by I Karbovnyk reported the experimental results of far-infrared spectroscopy investigations on microcrystalline Ag_2CdI_4 samples prepared by the solid state synthesis, carried out in the wide temperature range of 10–420 K, which includes the temperature of the superionic phase transitions, the material is known to undergo. The purpose of our measurements lies in finding changes in frequencies and other parameters of phonon modes near the phase transitions temperatures. Infrared measurements were carried out at SINBAD infrared beamline of Daphne Light Laboratory (LNF, Frascati, Italy).

TT nanojunctions with spin-orbit interaction as spintronic single-qubit gates by S Bellucci addressed the issue of quantum interference effects in nanometric devices, which provide suitable means for controlling spin at mesoscopic scales. The authors applied such a control mechanism to the spin-dependent transport in a ballistic TT cross junction patterned in two dimensional electron gases (2DEGs). The study was essentially based on the spin-orbit (SO) interaction arising from the asymmetry in quantum well potential that confines the 2DEG (Rashba SO term). The authors focused on single-channel transport and solve analytically the spin polarization of the current. The TT cross junction acts as a one-qubit spintronic quantum gate, whose properties can be varied by tuning the strength of the spin-orbit interaction, as well as by changing the relative position of the junctions.

P Onorato presented two posters: spin currents in ballistic low dimensional nanodevices; spin filtering and spin Hall accumulation in an asymmetric ballistic nanojunction with Rashba spin-orbit interaction. In the first one the authors discussed several topics about the spin Hall effect in low dimensional nanometric electron systems. The basic bricks of these systems are the quantum wires (QWs) patterned in two dimensional electron gases (2DEGs). First we discuss the presence of an integer spin Hall effect in ballistic quantum wires with a spin orbit coupling not of the Rashba type. Next it was shown how nanometric ballistic cross junctions can be used to check the presence of a transverse spin Hall current; we benchmark the effects of two different kinds of spin orbit interactions. The first one (α-SOC) is due to the interface electric field that confines electrons to a two-dimensional layer, whereas the second one (β-SOC) corresponds to the interaction generated by a lateral confining potential. Indeed, the spin Hall effect is due to the presence of an effective small transverse magnetic field corresponding to the Spin Orbit coupling generated by the confining potential. The strength of the field and the junction shape characterize the quenching Hall regime, usually studied by applying semi-classical approaches. The authors discussed how a quantum mechanical relativistic effect, such as the spin orbit one, can be observed in a low energy system and explained by using classical mechanics techniques. In the second poster presented by Onorato, the authors proposed a new scheme of spin filtering employing ballistic nanojunctions patterned in a two dimensional electron gases (2DEG). The proposal is essentially based on the spin-orbit (SO) interaction which results from asymmetric confinement in semiconductor nanostructures. The authors demonstrated that the injection of an unpolarized current through an opportune ballistic cross junction with this spin-orbit coupling induces a spin accumulation in a finite region which is an observable signature of the spin Hall effect in these devices. Moreover it was shown that this device acts as a spin filter, and the spin polarization of the exiting current can be modulated by tuning the strength of the spin-orbit interaction as well as by changing a constructive parameter of the junctions.

Nanomechanical properties of conch shell by M Petraroli, showed how to use nanoindentation methods to explore, at the nanoscale, the mechanical properties of the Conus Mediterraneus conch, in order to compare nanohardness and elastic modulus with respect to the microstructural architecture and sample orientation. For the experimental tests a Nano Indenter XP (MTS Nano Instruments, Oak Ridge TN) has been used. The mechanical tests have been carried out on the inner

surface of the shell and on three layers of its cross section (inner, middle and outer). On each of these surfaces the indentation has been performed at different maximum depth: from 250 nm to 4 μm, with a step of 250 nm. Data obtained suggest the following considerations: the inner surface of the conch shell, from the mechanical point of view, results homogeneous, while the shell structure is not homogeneous along its cross section; nanohardness and elastic modulus grow from the inner side to the outer side. No sensible difference has been observed with regards to the nanoindentation depth. The analysis supports the idea that artificial bio-inspired super-composites could be realized in the near future.

CsPbCl3 nanocrystals dispersed in the Rb0,8Cs0,2Cl matrix: vibrational studies by P Savchyn reported the results of the infrared spectroscopy measurements and analysis intended to clarify the influence of CsPbCl3 nano-complexes, dispersed in the Rb0,8Cs0,2Cl matrix on the vibrational spectra of the host.

Selected papers, based on conference original presentations and follow-up discussions, appear in the present dedicated issue of *Journal of Physics: Condensed Matter*. Tutorial lectures delivered at the school will be published by Springer Verlag Heidelberg, Germany, in their *Lecture Notes in Nanoscale Science and Technology Series*. The next edition of the meeting, n&n2008, planned in 20–23 October 2008, at INFN-Laboratori Nazionali di Frascati, Italy, http://www.lnf.infn.it/conference/nn2008/, will cover a large range of topics of current interest in nanoscience and nanotechnology, including aerospace, defense, national security, biology, medicine, electronics.

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