

Nanoparticles and Nanodevices in Biological Applications

The INFN Lectures - Vol I

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Preface

This is the first volume in a series of books on selected topics in nanoscale science and technology, based on lectures given at the well-known Italian Institute for Nuclear Physics (Istituto Nazionale di Fisica Nucleare, or in short INFN) schools of the same name (Nanoscience & Nanotechnology 2006, Nanoscience & Nanotechnology 2007). The aim of this collection is to provide a reference corpus of suitable, introductory material to relevant subfields, as they mature over time, by gathering the significantly expanded and edited versions of tutorial lectures, given over the years by internationally known experts.

The field of nanoscience has witnessed a rapid growth in the last decade. Recently, the attention of the community of nanoscientists has been focusing more and more on technological applications. Nanotechnology is an enabling technology, with a high potential impact on virtually all fields of human activity (industrial, health-related, biomedical, environmental, economy, politics, etc.). Its potential yields high expectations for solutions to the main needs of society, although it issues of sustainability and compatibility need to be addressed. The fields of research application in nanoscience include aerospace, defence, national security, electronics, biology, and medicine.

A strong interest in assessing the current state of the art of the fast-growing fields of nanoscience and nanotechnology, as well as the need of stimulating research collaboration, prompted me to promote and direct the International School and workshop, “Nanoscience & Nanotechnology (n&n 2006)” on November 6–9, 2006 under the patronage of INFN, the University of Rome Tor Vergata, and the Catholic University of Rome, with generous sponsorship by 3M, 2M Strumenti, Physik Instrumente, and RS Components. The aims of this event were manifold:

- To foster the concrete planning of future devices based on innovative (nano) materials, involving both industrial entities and public research institutes
- To allow the presentation by sponsoring firms of 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 Framework Programs)
- To explore the possibility of integrating nanodevices from their concept into system projects

In this context, tutorial lectures were delivered at the school, addressing general and basic questions about nanotechnology, such as what it is, how does one go about it, and what purposes can it serve. In these 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. Given the great success and broad range of these lectures, it was decided to publish them over time as a collection of well-edited topical volumes.

The present set of notes results, in particular, from the participation and dedication of many prestigious lecturers and colleagues. As usual, the lectures were carefully edited and reworked, taking into account the extensive follow-up discussions.

A tutorial lecture by *Vincenzo Balzani* and collaborators (Univ. Bologna, Italy) introduces the reader to the topic of molecular devices and machines, seen as a journey into the nano world. The *Santina Carnazza* (Univ. of Messina, Italy) contribution deals with surface biofunctionalization (by controlled ion implantation and fibronectin adsorption) aimed to enhance promonocytic cell adhesion and spatial confinement, and micropatterning of polymer surfaces (by controlled ion irradiation on stripes of given dimensions) to obtain alignment and controlled positioning of adherent fibroblasts. The former may be important for biosensing, and the latter in preparing cell-based integrated circuits; hence having an impact both in biomedicine, particularly in regenerative medicine (including tissue engineering), and in BioMEMS applications. *Andrea Salis* and coworkers (Univ. Cagliari, Italy) go about biotechnological applications of lipases immobilized onto porous materials—i.e., biodiesel production and biosensors. For biosensing use, the immobilization of the lipases was performed by the Cagliari group on porous silicon.

Cellular interactions with engineered nanoparticles are dependent on many variables—some inherent to the nanoparticle (size, shape, surface reactivity, degradation, agglomeration/dispersal, and charge), and some due to the inherent properties of the cells or tissues responding to the nanoparticle (cell type; cell surface interactions with the nanoparticle; whether cellular membranes have pores that allow or block passage of nanoparticles, cellular enzyme degradation of the outer protective surface revealing a toxic nanoparticle core; cellular storage of nanoparticles or degradation products (bioaccumulation), within the cell ultimately causing the cell's death). Functionalization and shorter exposure times increased biocompatibility; however, nanoparticle size and reactivity in relation to the type of cells and organs to be targeted seemed to be equally important. Understanding the biological effects of nanoparticles at the gross (microPET) and microscopic levels (light and electron microscopy) is essential in predicting nanoparticle processing, degradation and excretion in cells, and mammalian systems in general. In this respect, in her lecture, *Barbara Panessa-Warren* (BNL, USA) provides the reader with an overview of the types of phenomena that have been reported in the literature with living cells and tissues exposed to nanoparticles, as well as new experimental data on the biological cell and tissue responses in vitro (using human lung and colon epithelial monolayers) and in vivo (in mice) to nanoparticles designed for biomedical use (prepared with and without surface functionalization); with specific attention directed to how dose, exposure time, and surface reactivity affect biocompatibility and cytotoxicity. A contribution that reviews recent results about the toxicity of nanomaterials, con-

centrating in particular on carbon nanotubes, is the subject of the tutorial by *Stefano Bellucci (INFN-LNF, Italy)*.

I wish to thank all lecturers, and especially those who contributed to the first volume in this series, for the time and effort put into this book project. I am confident that this first set of lecture, will, in turn, provide an opportunity for those who are just now beginning to get involved with nanoscience and nanotechnology, allowing them to get contacts and prime, up-to-date information from the experts. I wish to especially thank Mrs. Silvia Colasanti for precious help in carrying out organizational and secretarial work.

Total love and gratitude go to my wife Gloria, and our fantastic daughters Costanza, Eleonora, Annalisa, and Erica for providing me relentlessly with endurance, energy, enthusiasm, and patience.

Frascati,
April 2008

Stefano Bellucci

