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Meeting Abstracts

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Proceedings of the First NanoWorld Conference in Boston (NWC-2016). Part I: Introduction and Plenary Keynote Presentations

96 Scientists from 19 Countries

On April 4-6 2016 the NanoWorld Journal (NWJ) hosted in Newton (Boston, USA) its first edition of NanoWorld Conference (NWC) around the theme "Useful Science for a Just World" with an unprecedented gathering of the technological experts and creative thought leaders from reputed universities, industries, government laboratories and agencies. The experts gathered to discuss and share the experience of their advanced research outcomes in the field of Nanotechnology and Nanosciences to address problems arising for humanity from energy to environment and natural disasters, cancer to hardware and space which have been growing and frequently underestimated. The NWJ under the joint sponsorship of United Scientific Group (USA) and Fondazione EL.B.A Nicolini (Italy) hosted the Conference with keynote and featured speakers covering different fields of nanotechnology from reputed academic institutions and cutting edge nanotechnological companies to deliver the transition from laboratories to commercial applications to benefit the society. NWC-2016 program (Figure A Supplement) constitute a platform for discussing the ways to advance in finding the solutions through nanotechnology and nanoscience for the problems facing the world in the key sectors of energy, environment, space, hardware and cancer with the involvement of overall society. As can be seen from these Proceedings the Conference has seen the participation of the world's leading innovators, experts, scholars from many technology and industry sectors, including USA and European Space agencies, to add new elements to the existing scientific and commercial developments. Present at the meeting were Rave LLC Nanomatching and Graphenea LLC from USA.

The NWC intended to focus on new useful science and technology for a just world capable to address the numerous open problems from energy to environment and cancer and from hardware to space and society. Two keynote lectures in Molecular Bioelectronics and Flat Optics by Members of the two world major Academies of Sciences of Russian Federation and USA set the tone for the Conference in two frontiers of human knowledge. Subsequently members of the Editorial Board were involved in three Plenary Symposia in key sectors over problems overcome solutions:

- Cancer from the nanoscale to the patient
- Protein structure at atomic scale by Synchrotron Radiation, CryoEM and XFEL
- Nanomaterials, nanodevices and complexes nanosystems

Later following poster presentations and 44 speakers selected worldwide addressing in parallel sessions advances in Nanotechnology and Nanosciences, a final fourth Symposium summarize the positions being taken by the NWJ during 2015 in reference to energy [1], carbon dioxide [1], nuclear-strategic disarmaments [2], technology transfer and asteroids [3]; all highly controversial but still waiting technological solutions needed for a just peaceful world.

NanoWorld Conference President
NanoWorld Journal Editor In Chief

References:

1. Nicolini C. 2015. A Worldwide Strategy for Energy, Environment and Space Should Emerge in Paris as the Priority of Humanity: A Review. NanoWorld J 1(3): 93-96.
2. Nicolini C. 2015. A New Journal for a New Useful Science and a Just World. NanoWorld J 1(1): 1-3.
3. Nicolini C. 2015. Technology Transfer and Objective Assessment of Science and World Priority. NanoWorld J 1(2): 71-72.

Plenary Keynote Presentations

From Biotechnology and Nanotechnology to Molecular Bioelectronics

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Abstract

Nineteen years later (Nicolini, 1966) molecular bioelectronics is emerging as a new scientific frontier at the crossing of life and physical sciences proving capable to operate at the interface of electronics and biotechnology with significant impact world-wide on the development of both industry and knowledge previously unmatched. The term 'molecular bioelectronics' is utilized in a rather broad context merely to emphasize a new amalgam of electronics and biotechnology which is seen as the best way to achieve many objectives of industrial, health and scientific relevance, including biomolecular engineering, bioelectronic devices, actuators, sensors and materials capable of optimal hardware intelligence and molecular miniaturisation. The idea that production and assembly of molecular electronic components can be obtained with both biotechnology and organic chemistry in an absolutely integrated way has been discussed and numerous open questions still need to be answered but many basic relevant discoveries and 'proofs of principles' have been recently made, as shown in Nicolini 2015. However, our current knowledge of the molecular basis of neurobiology is practically still lacking and the extensive exploitation of parallel processing architecture constitute nothing more than a good precedent, which recently led to the design and construction of new powerful brain-like architectures with existing silicon technology. Similarly, it would appear highly questionable at present that biopolymers such as proteins or nucleic acids could be the primary building block of electronic circuits, at least as the active element, since they are rather unstable and possess large band gaps typical of electronic insulators. Only by means of suitable manipulation in vitro it might be possible to induce optimal semiconducting properties and stability, as indeed shown in this book. Contrary to traditional inorganic (likewise silicon) or organic (polypyrole or polyacetylene) materials which have unidirectional properties, several polypeptides (likewise metalloproteins) possess multiple pathways for the electron transfer which makes them uniquely attractive to mimic natural neurons and to yield by their proper assembly a real neural network (a sort of protein-based cell automata). The alternative approaches to use as molecular switching chemical and structural modifications in the biopolymers - like those relating to changes in geometry, bonding group or position of localized electrons and protons, or the chemical codification like the coding of genetic information within the DNA - appear presently still inadequate because these chemical processes are relatively slow. However, should it be possible to specify an amino acid sequence that will yield a protein with the three-dimensional structure needed for the described function (as redox or receptor) or properties (as electron transfer), be it for use as a passive matrix or as an active element, we would likely be able to obtain biomaterials with unique semiconducting properties and self-bioassembly thereby making the first step toward the development of bioelectronics, namely by engineering from the extremely small to the big (upwards) rather than from the big to the small (downwards) as it is nowadays done by lithographic techniques. An important corollary of these important construction techniques is that the functional elements of such an architecture would be single molecules rather than macroscopic entities. These two aspects - the assembly of architectures from the single molecules and the functional units being individually accessible and controllable at molecular level - are the real revolutionary features of bioelectronics. However, these required efforts are of such a nature that they involve horizontally the most advanced and concrete aspects of industrial research not only that strictly electronic, but also that being at the frontier of biotechnology (namely protein engineering) and of material science. Despite the existing large semiconductor industries are still able to continue to capitalise on the next future successes of lithographic process, a need for quite higher integration density, bypassing the physical limits of VLSI technology is present. World-wide situation makes extremely difficult to start a wide and true internationalisation involving the leading countries in economic, military and financial terms, that is essential to find concrete solutions to the growing problems in all sector of the economy.

Even cancer at molecular scale is strongly interlinked to hardware development, and not only to differentiation, ageing and proliferation, and achieving it will contribute to solve all correlated pending problems also in life sciences. Energy on the other side is strongly interlinked with power generation and automation, while similarly is happening for really intelligent hardware, being strongly interlinked to communication, defence and environment. Also the risk of ecological disaster such as global warming, could be reduced or avoided with the development of new hardware and new energy sources nanotechnology-based from sun, wind and hydrogen (Nicolini, 2015). We have been living on a great fossil fuel inheritance accumulated during more than 500 million years. We will soon exhaust this capital, and we will have to go to work to try to live on current energy income. It will not be a simple easy transition. The data presented here point to the successful engineering of supramolecular layer engineering of potential industrial relevance. The temporal stability of thin layers within required cost effectiveness and the reproducibility within a highly competitive industrial context, this methodology clearly represents a promising general-purpose

tool for the design of new industrial products and processes. This comes after a Workshop called in Bruxelles by the European Commission to launch a big Program on Bioelectronics, comprehensive of neural VLSI chips, engineered proteins, molecular manufacturing and biomolecular electronic devices. The necessity of reducing the size of electronic circuit elements while devising environmentally pure technologies for producing them has, in the last three decades, spawned an interdisciplinary area of research termed bioelectronics, originally based on the idea that a single molecule can work as a self-contained elementary information processor so that novel computer architectures can be built, including those that could emulate the brain. An overview of this area was given in papers by Nicolini in 1996 and 2015 where some of significant progress up to date was in the areas of biomolecular electronics, neural VLSI chip, nanoelectronics and biomolecular engineering. To date, the tiniest transistor in production, belonging to the family of "Ivy Bridge", has an average gate size of 22 nm. (see http://en.wikipedia.org/wiki/Ivy_Bridge_microarchitecture). Beyond this it was difficult to think of further technological evolution of purely silicon based microelectronics structures, but rather of a revolution (Pistorio, 1989). The word 'revolution' is used because the new post-semiconductor bioelectronics, with their polymer, protein and lipid structures will be so completely different and powerful that they are offering the possibility of making giant steps in architectures as well as redefining completely the limits of artificial intelligence and machine power. Molecular electronics describes the field in which molecules are utilized as the active (switching, sensing, etc.) or passive (current rectifiers, surface passivants) elements in electronic devices. Over the past decade organic materials, fabrication methods, and methods for characterizing electrode materials, molecular monolayers, and molecule/electrode interfaces have been discussed. In molecular electronics, single molecules serve as switches, "quantum wires" a few atoms thick serve as wiring, and the hardware is synthesized chemically from the bottom up using electronically configurable molecular-based logic gates. Over the past two decades, the picture has not changed much as a 160-kilobit molecular electronic memory was patterned at 1011 bits per square centimeter using bistable rotaxane. Conducting polymers have then emerged as a real, albeit still minor, technology. However, over the next 10–20 years, molecules may be increasingly viewed not just as the starting points for bulk electronic materials, but as the active device components within electronic circuitry. Although this possibility is hardly a foregone conclusion, a number of fundamental issues favor it and the creation of the first quantum machine was declared to be the "Breakthrough of the Year" in 2010 pointing to quantum ground state and single-phonon control of a mechanical resonator. The promised power of these bioelectronic chips is so vast that they demand totally new architecture to realize their full potential. And even if the biochips themselves never realize the wonderful future predicted for them time ago, the very fact is significant that today they have made possible a greater impetus to new architectural concepts borrowed from human brain, specifically neural VLSI networks. Now by applying these new architectural concepts emerging from organic materials and from neural networks, which are in their own a very advanced step, we have obtained way of expanding towards the full potential of silicon, with explosion of research effort into neural networks solving classes of problems that before were impossible to solve with current digital technology. It is still not possible to realize new architectures in organic and biopolymeric materials, but what is happening is that new architectures as neural networks have been introduced with advanced submicron semiconductor technologies. The reason for which the biological memory, although slow, is extremely powerful is that the biological memory is not an addressable memory, but is an intelligent memory in which the access is attained via similarity, and every access to the memory implies a significant calculation. Bioelectronics can operate in various ways: i) developing systems that would emulate such a functional organization in a technology that would be diverse and more subject to control; ii) solving the problem of interfacing of biological systems with conventional electronic ones making use of the nanocomputation; iii) implementing the signal transmission via soliton waves. To sum up, in addition to a kind of first generation molecular and biomolecular electronics applicable to environment, energy and cancer), the last two decades have seen the constant development of advanced technologies within two well-focused distinct areas which are complementary to the construction of biochip and biocomputer, and which are at the same time realistic. The first is the successful engineering of polymers and biopolymers such as proteins from first principles and the second implements neural and submicron electronics, namely builds silicon hardware based on a growing understanding of neural networks and of human sensory systems - by properly integrating correlated research on neurobiophysics and artificial intelligence. This remains true independently of the revolutionary promise of a molecular kingdom represented by Molecular Bioelectronics which is progressively approaching reality, where the assembly of architectures is from single biomolecules and the functional units are individually accessible and can be controlled at molecular level. Sensors still represent an active area with key examples based on organic, biological and inorganic materials. Improved mechanical stability and optimal performance is achieved with anodic porous alumina, an inorganic matrix realized with cavities 275 nm wide and 160 microns deep to allow stable readout for a long period of time. Thin-film technologies allow the assembly of biological materials as bacteriorhodopsin (bR) in a 2D system for photocells with excellent optical properties and the electric field strongly improves the ability of the membrane fragments to form a monolayer at the water surface and thereby to enhance significantly the photosignal by aligning the fragments at the air/water interface. From the results it is clear that the photoresponse in the case of electric field-assisted monolayer formation is much higher compared to that after a normal LB deposition and a unique efficient device is realized towards light-addressable transducer bacteriorhodopsin based. One of the possible applications of the suggested device is mapping of 2D pH distribution in the measuring chamber. Over the last two decades the close cooperation with numerous leading international companies (STM, ABB, Edison, FIAT, Elsag-Bailey) has been quite active in developing neural sensors with emphasis on the nanostructuring of organic matrices for a wide variety of applications for health and environment. International industries have already developed the commercial capacitors based on organic elements, reaching considerable results and cheaper technology for producing both resistance and capacitance.

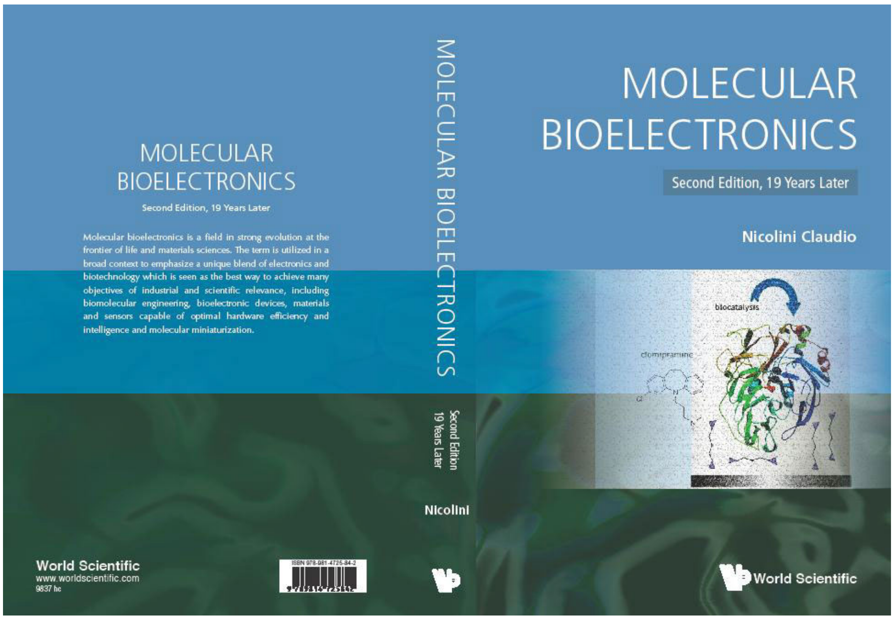

Figure 1: Nicolini C. 2016. Molecular Bioelectronics 19 years of progress, Second edition, World Scientific, New Jersey, USA, 315 pp.

Biography

Professor Nicolini most significant contributions are in *Biosciences* (the discovery and clarification of the quaternary DNA structure in the human genome, until the identification of the structural subunit called fibrosome, associated to the single gene, the discovery of histones enzymatic modifications and of non-histones loosely bound to DNA, and their role in the control of cell function and nucleosome, characterization of the cell cycle with identification of GO e Q cells, 3D atomic structure of histone H1), *Biotechnologies* (discovery of CIDS effect, software for automatic sequential NMR assignment of amino-acids, role of water and structure in protein thermal stability, mechanisms of protein crystallization and LB nanotemplate by microGISAXS, diffraction, Nuclear Magnetic Resonance and AFM technologies, genes controlling cell proliferation in human kidney transplants, Recombinant laccase, 3D atomic structure of human kinase CK2, anodic porous alumina for cholesterol sensing and for biomolecular microarrays, 3D atomics structure of Initiation Factor by NMR, 3D atomics structure of Bacterial Hemoglobin), *Cancer* (identification of leader genes in the control of cell function by bioinformatics and microarray; identification in vivo proteins by NAPPA microarray; long range order of protein Langmuir-Blodgett by synchrotron radiation microGISAX. He has been in recent times among the pioneers of: cell laser microfluorimetry; cell image analysis and complex modeling and pharmaco-enzymatics-kinetic which opened new horizons in cancer) and *Nanobiotechnologies* (nanocrystallography, nanocomposite batteries, nanomaterials for lithium batteries, carbon nanotube biocompatibility, Grazing Incidence Small Angle Scattering at the submicron scale, Label Free Nucleic Acid Programmable Protein Arrays, Mass Spectrometry of NAPPA and cells, Nanosensors for Environment and for Medicine), with the exception in his early life in *Nuclear Physics* with the discovery with the Cambridge Group Padova-MIT-Harvard of the branching ratios of eta zero meson which establishes its quantum numbers. In most recent times he has been among the pioneers internationally of *Bioelectronics and Nanoelectronics* through the development of new monoelectronic device at room temperature; new nanosensors; passive and active electronic elements, photovoltaic cells, nanocatalisys, biomolecular devices, new LB e LS thin film technologies to obtain to heat-proof metalloproteins, organic materials, conductive polymers.

Flat Optics Based on Metasurfaces

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Abstract

Metasurfaces based on sub-wavelength patterning have major potential for revolutionizing diffractive optics by realizing arbitrary control of the wavefront of the diffracted light through local control of the phase, amplitude and polarization. We will discuss novel devices based on this technique: a salient feature is the ability to create with a single digital mask an arbitrary analog phase profile. A variety of flat optical components, including lenses with no aberrations, polarizers, vortex plates, coatings, holograms etc. will be presented.

Biography

Professor Capasso's research cuts across several disciplines in basic physics, applied physics and engineering. A unifying theme of his research is the quantum design and study of new artificial materials and nanostructures with man-made electronic and optical properties, an approach that Professor Capasso pioneered and dubbed bandstructure engineering at Bell Laboratories. At Harvard University Prof. Capasso's group has expanded QC laser research to new coherent light sources utilizing intracavity nonlinear optical effects. These include Raman injection lasers, lasers without inversion and difference frequency generators. Recently his group demonstrated the first Raman injection laser, a device based on resonant stimulated Raman scattering. Professor Capasso's research has recently started to move into new directions by asking questions such as: can one make a phonon laser by analogy with the Quantum Cascade Laser? Recently, the Harvard team collaborated with groups at Caltech and Bell Labs to develop a Quantum Cascade Photonic Crystal Surface Emitting Laser (QCPCSELS) that combines electronic and photonic band structure engineering to achieve vertical emission from the surface. Prof. Capasso has recently teamed up with Prof. John Joannopoulos and his group at MIT to investigate the radiation forces between microptical components such as microsphers and nano-optical fibers. They have found that under certain circumstances an attractive force can develop rather than the conventional radiation pressure force which is repulsive. Another area of Capasso's research is the investigation of quantum electrodynamical phenomena such as the Casimir effect.

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