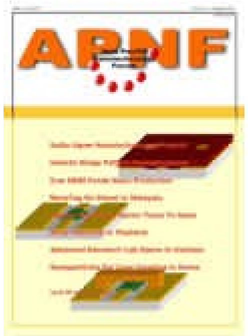
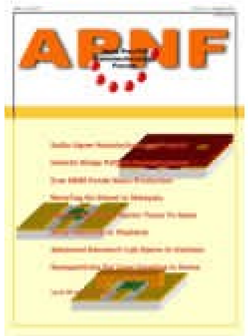
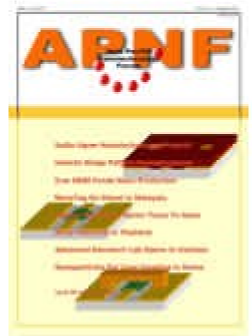
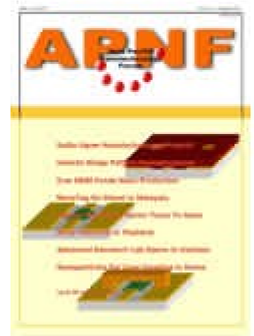





Manufacturing Technology For Medical Nanorobots

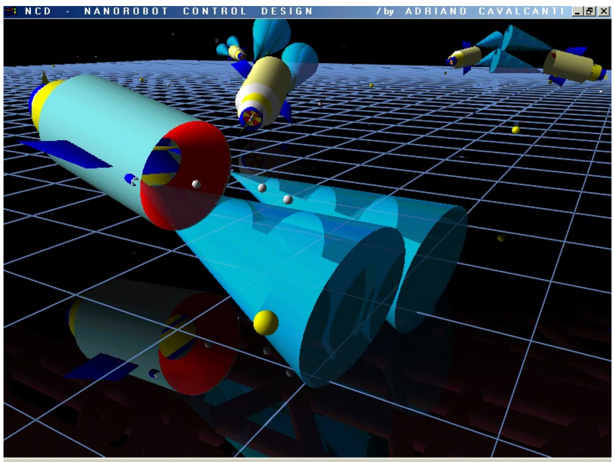
Last month, APNF interviewed Adriano Cavalcanti from the Center for Automation of Nanobiotech (CAN) in Brazil. He recently presented a paper at the International Conference on Computational Intelligence for Modelling, Control and Automation (CIMCA06) in December in Sydney, Australia, as well as the International Conference on Control, Automation, Robotics and Vision in November in Singapore.

Mr Cavalcanti presented new approaches on electronic nanodevices applied to nanorobots. The Asia Pacific Nanotechnology Forum asked Mr. Cavalcanti about advances in nanorobotics and the perspective to have a first working hardware to build nanorobots:

APNF: Mr Cavalcanti, how to define Nanorobotics?

Cavalcanti: Nowadays you have some well defined works under the term nanorobotics. That is important to keep in mind the differences among them. Obviously all different approaches and related works on nanorobotics may be considered very important indeed. We can also remember that quite often a new discovery is the result of a set of advances in many fields, especially when you talk about nanotechnology.

One type of work established in nanorobotics is focused on nanomanipulation with the use of Scanning Probe Microscopes, where the aim is the automation of molecular handling and positional automation. The other kind of work and research in nanorobotics is focused on nanorobots itself, which means really tiny nanorobot built with nanoscale devices. The nanorobot has its own computation, sensing and actuation capabilities. In this aspect you have basically two main questions: how to control nanorobots, and even more important how to construct them.



Schematic view of nanorobot's sensor identification.

APNF: How would one control and construct nanorobots?

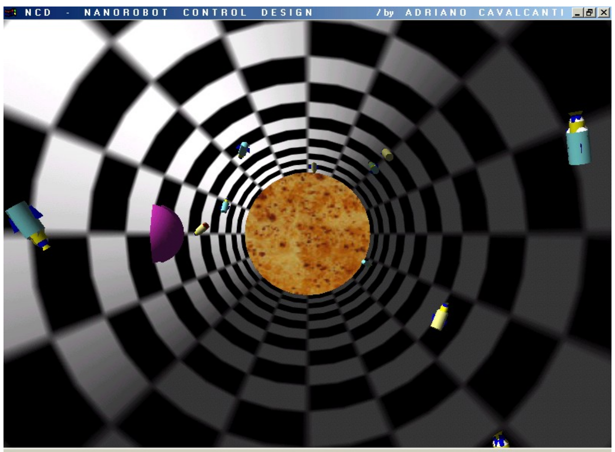
Cavalcanti: There is a growing number of research into the control design of nanorobots for applications in medicine as well as environment monitoring as you have probably seen at APNF's ISNEPP 2006 event in Hong Kong last year (www.isnepp.org). In this aspect, our team has implemented the software NCD Nanoborot Control Design (see the article New Nanorobotic Ideas), which has not only helped in control but also with specifications for nanorobots manufacturing designs. Obviously another very important point for discussion is how to actually construct nanorobots. Currently, there are two kinds of approaches: organic and inorganic nanorobots manufacturing.

APNF: When can we expect to see organic or inorganic nanorobots manufactured?

Cavalcanti: Organic nanorobots are the work on ATP and DNA based molecular machines, also known as bionanorobots. In this case the idea is the development of ribonucleic acid and adenosine triphosphate devices, and even the use of modified microorganisms to achieve some kind of biomolecular computation, sensing and actuation for nanorobots.

Inorganic nanorobots development is based on tailored nanoelectronics. In comparison with bionanorobots, it could achieve a considerably higher complexity of integrated nanoscale components.

For the inorganic nanorobots you have some works on how to enable its manufacturing. One widely discussed approach is about the use of new diamondoid rigid materials, which may help towards manufacturing inorganic nanorobots. Indeed it should be very helpful, and some important works were done to advance diamondoid materials development (see Medical Nanorobotics Feasibility).



The tumor cell is the target represented by the pink sphere. The nanorobots swim near the wall to detect cancer signals - view without the red cells.

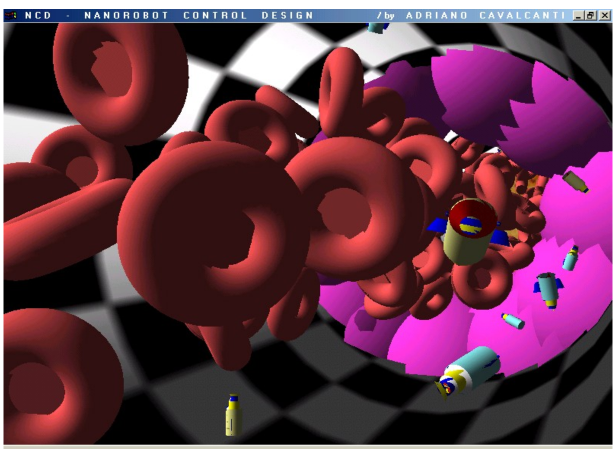
Most recently our team has also defined a new approach for nanorobot manufacturing, the Nanobhis (Nano-Build Hardware Integrated System), a quite effective and feasible methodology to build the first nanorobot much sooner than ever thought possible. Thus, the expectation is to have the first nanorobots in about ten years.

APNF: What is the basic concept behind Nanobhis and what makes it so effective in building nanorobots?

Cavalcanti: The nanorobot proposed prototyping must be equipped with all the necessary devices for monitoring the most important aspects of its operational workspace. The approach we are proposing with Nanobhis is a feasible way for manufacturing nanodevices which may result in a direct impact to achieve nanorobots. Nanobhis combines traditional and new concepts for manufacturing methodologies to accomplish functional hardware for nanorobots.

The application of new materials may enable a large range of possibilities, which may be translated into better sensors and actuators with nanoscale sizes. We used 3D computational simulation with integrated embedded nanodevices as a practical way to build nanorobots. For this purpose, IC design using deep ultraviolet lithography provides high precision and a commercial way for manufacturing nanoelectronics. New CMOS technology may support the pathway as embedded components to assembly nanorobots, where the jointly use of nanophotonic and nanotubes may even accelerate further the actual levels of resolution.

The use of well established techniques such as Electromagnetic Waves, SoC and Lithography, VHDL and 3D Simulation, combined with recent nanotechnology advances, such as mesoscopic nanowires, may contribute to Nanobhis to validate and help the implementation of high complex VLSI. Thus, nanoelectronics can feature functionality with exceptional performance under nanoscale sizes. More details can be accessed at www.nanorobotdesign.com where new results are being disclosed progressively.



Cardiology complications can arise, as stroke and vessel degenerations, due diabetes problems.

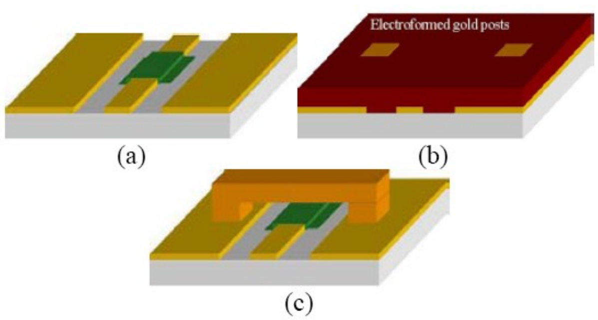
APNF: What kind of hardware is your team developing now?

Cavalcanti: Manufacturing silicon and chemical based sensor arrays using a two-level system architecture hierarchy have been successfully conducted over the last 15 years. Application ranges from automotive and chemical industry with detection of air to water element pattern recognition with embedded software programming. Through the use of nanowire significant costs of energy demand for data transferring and circuit operation can decrease significantly. CMOS sensors using nanowires as material for circuit assembly can achieve maximal efficiency for applications regarding chemical and thermal changes, both in environmental care as biomedical applications.

We are working towards feasible 90nm and 45nm CMOS devices as an actual breakthrough in terms of nanomanufacturing technology into products that can be utilized in a large number of applications. Such circuits if designed as sensors can be differently prototyped to detect electromagnetic fields, to identify different types of metal signatures, and also to recognized thermal signals, actually used in medicine, e.g. for cancer diagnosis. So, the same technology necessary for manufacturing nanorobots may enable a huge variety of high technology applications. Hence, we can also proceed similarly to manufacturing actuators.

APNF: You mentioned nanorobots for environmental monitoring earlier. Can you elaborate in this?

Cavalcanti: Advantages of using nanorobots for environmental tasks are quite clear: more control in measuring micro-organisms, better detection of chemical pollutants, and improved control of water temperature, just to quoting some positive aspects. The system could be used to save many lives against catastrophic storms or natural disaster due a more precise monitoring of surround changes in the environment.



CMOS process sequence overview: (a) Si3N4 DC isolation; (b) Gold posts electrolytic growth, and (c) circuit switch.

In comparison to biomedical nanorobots, the use of nanorobots for environment monitoring could be easier assembled through the implementation of a first series of nanomachines comprised of harmonically integrated nano electromechanical systems (NEMS) and microelectromechanical systems (MEMS) devices. It can be possible, due the fact that for hydrological monitoring the sizes of nanorobots are not strict as for the case of biomedical and cell therapy issues, where the sizes of nanorobot could not surpass 3 microns in diameters in the majority of cases. Medicine may also benefit of such developments of nanorobots in environmental issues, mainly because investigation on manufacturing, control and operation of nanorobots in natural environments should accelerate at the same time the first nanorobots tailored for biomedical applications.

APNF: Where do you see can we expect the first nanorobot being used in a medical application?

Cavalcanti: The development of nanorobots should help in different ways to improve the treatment of several biomedical problems. Some diseases should benefit first from nanorobots due their clear and direct relationship with chemical, electromagnetic, thermal or cellular based therapies. Among those illness, is worth to mention: diabetes, different types of cancer, and cardiovascular occlusion. Basically, in these three specific cases, our team is currently carrying out some studies based on clinical data.

About diabetes, we hope nanorobots can be used to monitor patient's glucose levels, as well as in the process to repair possible pancreas damages. Some possibilities are the use of nanorobots to deliver nanofibers or stem cells for such aim.

We are developing works to detect and repair metabolizing genes associated with cancer therapy. In the detection process nanorobots can be quite effective. It aims to revert or stop the disease progression in many of cases. This first study is being conducted for breast cancer, and is helping us to define strategies for nanorobots control actuator as well as device manufacturing.

For cardiology problems, our team has yet published a first investigation about chemical and thermal signals. This study has clearly demonstrated how atherosclerotic lesion parameters can guide choices on sensors design for nanorobots actuation. In this same biomedical problem our actual work is about defining actuation and system on chip manufacturing design, but also how to use some proteins patterns to build intelligent sensors to control triglyceride.