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NANOMANUFACTURING AND THE INDUSTRIAL APPLICATION OF NANOTECHNOLOGIES

Vasile N.Popa*

*Faculty of Economic Sciences and Business Administration , Transylvania University of Braşov;
Regional Department for Defense Resources Management , Romanian National Defense University
"Carol I", Bucharest , Romania
vasilepopa2001@yahoo.com

Abstract: *"On the molecular scale, you find it's reasonable to have a machine that does a million steps per second; a mechanical system that works at computer speeds." (K. Eric Dexler)*
The paper presents the powerful nanotechnology which will radically transform and extend the capabilities of practically every area of human endeavor by exploring the ultimate limits of fabrication. This technology is a potential very good answer to all of current critical planetary boundaries, and it hands us the power to destroy ourselves and our home more easily than ever before. The field of nanotechnology is one of the fastest growing and most important scientific developments in the last quarter of a century. The work highlights the potentials of nanomaterials in various technologies for the next decade and pinpoints the challenges for research and development.

Keywords: *nanotechnology; nanotech age; molecular manufacturing, nanorevolution, nanofabrication*

1. THE NANOTECH AGE IS COMING SOON

The term 'nanotechnology' was not used until 1974, when Norio Taniguchi, a researcher at the University of Tokyo, Japan used it to refer to the ability to engineer materials precisely at the nanometre level (Taniguchi 1974). The primary driving force for miniaturisation at that time came from the electronics industry, which aimed to develop tools to create smaller (and therefore faster and more complex) electronic devices on silicon chips. Indeed, at IBM in the USA a technique called electron beam lithography was used to create nanostructures and devices as small as 40 - 70nm in the early 1970s. The size range that holds so much interest is typically from 100nm down to the atomic level (approximately 0.2 nm), because it is in this range (particularly at the lower end) that materials can have different or enhanced properties compared with the same materials at a larger size.
According to futurist and inventor, Raymond Kurzweil, the Nanotech Age is expected to begin between 2025 and 2050, bringing an end to the current Information Age which began in 1990.

Humankind is poised at the precipice of the single greatest innovation in the history of science and technology. Coming is a Nano Revolution that will be at least as transformative as the Industrial Revolution (perhaps much more so), but packed into just a few years. Well beyond present-day nanotech applications, mature"molecular manufacturin" or ”molecular nanotechnology” will enable us to manifest our dreams (or nightmares). We are nearing the ability to build molecules out of atoms mechanochemically, and to use these molecular building blocks to construct virtually any substance or device we can conceive of. How might mankind enjoy the fraits of an advanced civilization without endangering the viability of planet Earth for future generations? That is the fundamental challenge that we confront in the 21st century. In a time when the comforts and pleasures that can be derived from the products of modern technology are accessible for a significant portion of the world's population, how can we manufacture and deliver those products in an environmentally benign fashion.

2. THE NANOREVOLUTION IN TECHNOLOGY AND INDUSTRY

Current industrial applications of nanotechnologies are mainly in the characterisation of materials, the production of chemicals and materials, precision manufacturing and ICT. In general, these applications represent incremental rather than truly disruptive advances; however, in the longer term it is likely that many manufacturing processes will be influenced by nanotechnologies, just as they are today by ICT. The revolution in technology and industry will be based on systematic control of matter on the nanoscale and will involve : changes in the foundations from micro to nano; creation of a general purpose technology (similar IT);

The versatile character of nanotechnology further enables application in diverse market sectors and branches of industry (Table 1).

Table 1. Examples of nanoscale based new materials and innovative products.

Information and communication technology	New optoelectronic & molecular electronic devices, new computer concepts (quantum computer); Advanced microelectronic (nanoelectronic) devices; Displays; data storage
Engineering materials	Nanostructured materials: metals, ceramics, intermetallics, nanoparticle-loaded/strengthened polymers (composites), carbon nanotubes as strengthening components
Surface coatings Energy conversion and use	Surface functionality and improvement, including paints and adhesives Photovoltaics, thermovoltaics, fuel cells, hydrogen storage materials, batteries/rechargeables, propellants, additives, lubricants
Sensors/actuators	Materials and devices to generate, transduce, receive and transform mechanical, electrical, optical, chemical, and other signals
Catalytic synthesis	Catalysts, photocatalysts, catalyst substrates, nanoreactors, filters, adsorbents, ion exchangers
Health & cosmetics	Diagnostic and therapeutic systems (biochips,contrast agents, drug delivery), improved implants, biological decontamination agents, cosmetics

Nanotechnology challenges for large-scale facilities responding to industrial-customer benefits are presented in the Table 2.

Table 2 .Challenges for large-scale facilities responding to industrial-customer benefits. Overview of technological tasks

CHALLENGES High quality, high efficiency, low costs	Performance parameters of large-scale facilities as standard measuring technology	BREAKTHROUGH Customer benefit
Automation of measurement and evaluation		High throughput screening
Unique interpretation, validation		Reliability standards
In-situ measuring techniques		Optimisation of fabrication and processing technologies
Combination of measuring techniques		Quantitative structure property relation
Metrology, calibration for laboratory methods		Process integrated non-destructive testing (on-line quality insurance)
Table-top synchrotron On-site nanotech infrastructure, networking		Customer-adapted, one-stop shop

2.1 Nanofabrication techniques

Nanofabrication has three components: nanomachining; nanomeasurement and control; nanomaterials production, Fig. 1.

In nanomachining there are several processes to create nanomaterials, classified as "top-down" or "bottom-up." Table 3.

There are a wide variety of techniques that are capable of creating nanostructures with various degrees of quality, speed and cost. Nanomaterials are not simply another step in the miniaturization of materials. They often require very different production approaches. Although many nanomaterials are currently at the laboratory stage of manufacture, a few of them are being commercialised.

Bottom-up manufacturing involves the building of structures, atom-by-atom or molecule-by-molecule. The wide variety of approaches towards achieving this goal can be split into three categories: chemical synthesis, self-assembly, and positional assembly. The positional assembly (with its many practical drawbacks as a manufacturing tool) is the only technique in which single atoms or molecules can be placed deliberately one-by-one. More typically, large numbers of atoms, molecules or particles are used or created by chemical synthesis, and then arranged through naturally occurring processes into a desired structure.

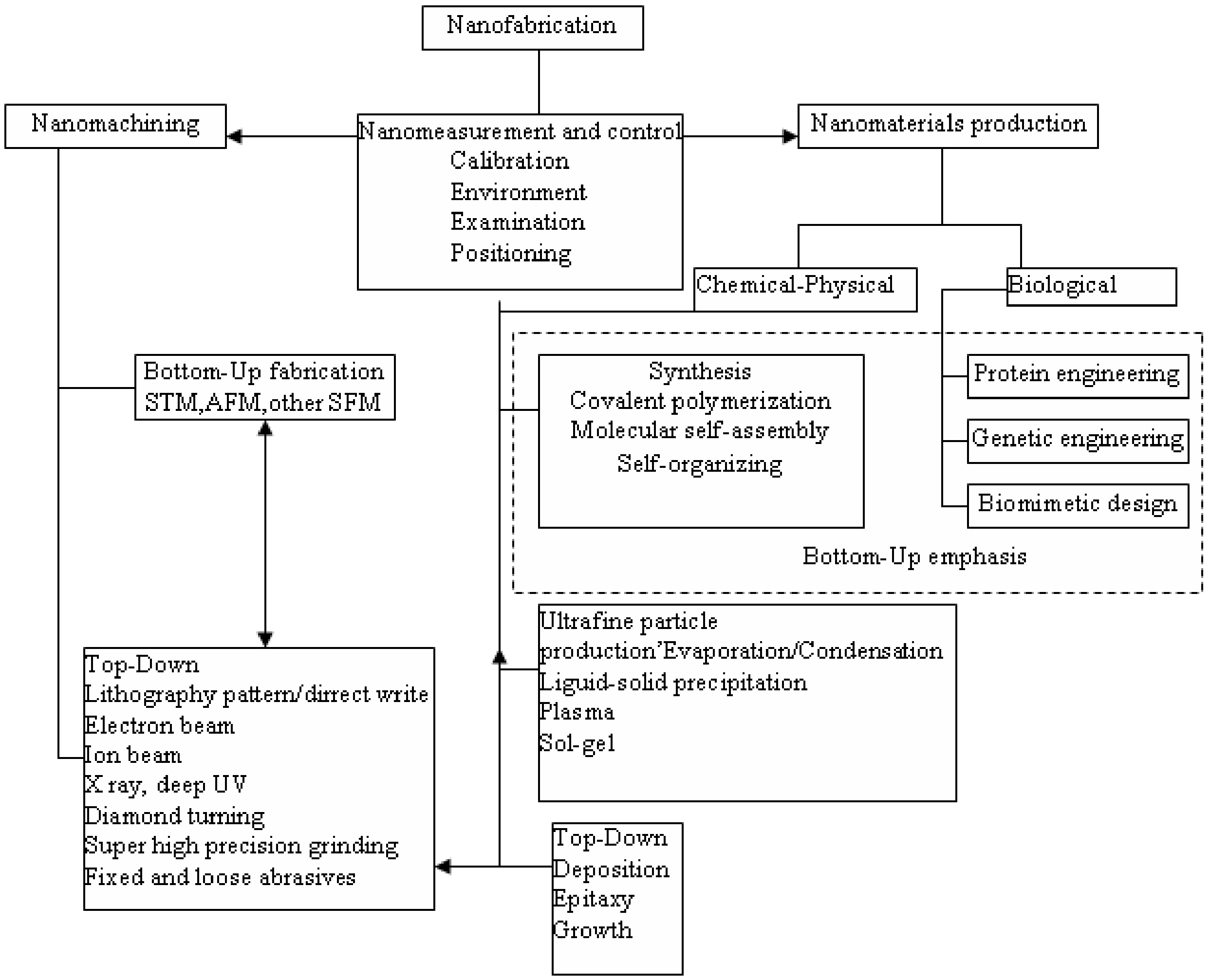

Fig. 1.The components of nanaofabrication

As Fig. 2 indicates, chemical or biological synthesis may work together with probes in the "assembler."

Table 3 The use of bottom-up and top-down techniques in manufacturing

Techniques used in nanomanufacturing			
Bottom-up fields	*1. Chemical synthesis*	*2. Self-assembly*	*3. Positional assembly*
	1.1 Particles Molecules	2.1 Crystals Films,Tubes	3.1 Experimental atomic or molecular devices
	1.2 Cosmetics Fuel additives	2.2 Displays	
Top-down fields	*1. Lithography*	*2. Cutting,Etching, Grinding*	
	1.1 Electronic devices chip masks	2.1 Precision engineered surfaces	
	1.2 Quantum well lasers Computer chips MEMS	2.2 High quality optical mirrors	

One conception of the assembler as a tool for nanostructure fabrication that has been suggested in the literature is a device having a submicroscopic robotic arm(s) under computer control capable of holding and positioning reactive compounds, with respect to molecular workplaces and devices, to control the precise location at which chemical reactions take place (Drexler, 1992).

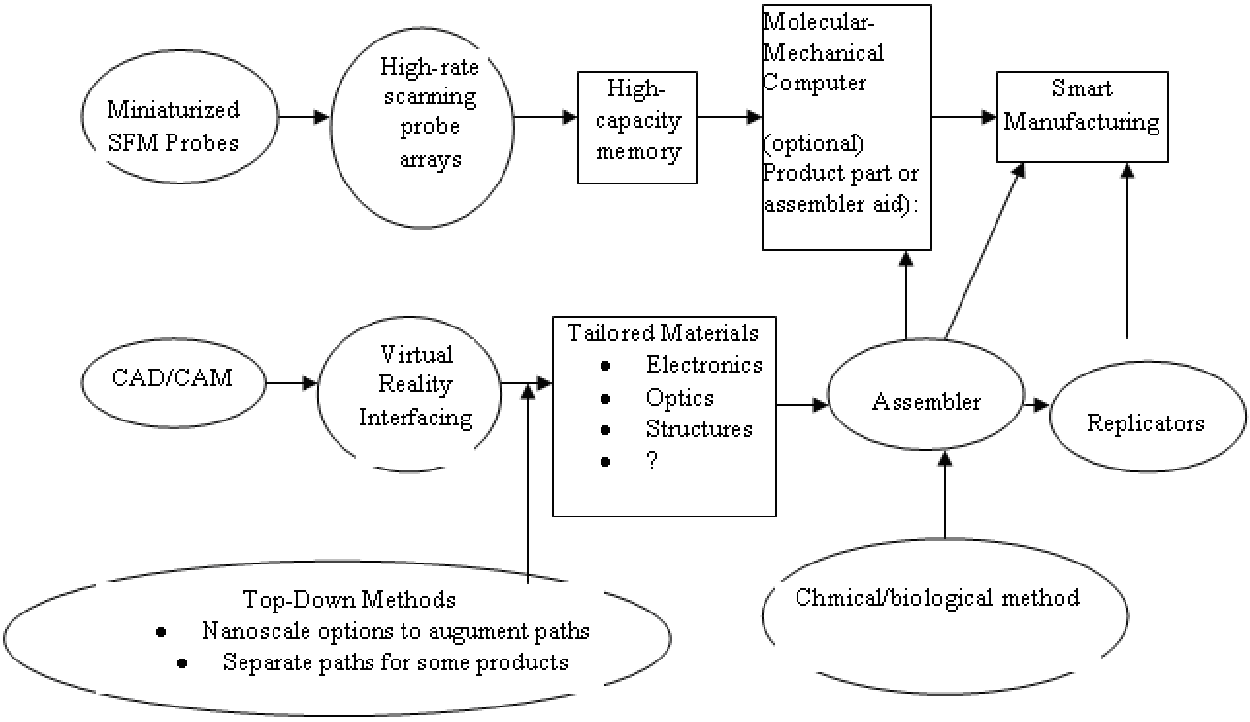

Fig. 2. Use of CAE CAM systems in molecular manufacturing with scanning probes

The world market for nanoparticles is expected to increase during the next few years, to provide perspective, it is worth noting that the global production rate of all chemicals is around 400 M tonnes per annum (European Commission 2001), and so chemicals in nanoparticulate form account for only a tiny fraction of the total (around 0.01%) currently produced. Nanoscalar nanorganic, metallic or semiconductor material often will have multifunctionality, which enables it to be used across many industry sectors. Zinc oxide, for example, will have more commercial use as an optoelectronic material (for displays or advanced solar and photovoltaic cells) where it will be fixed in the final product, than as an ingredient for skincare products, where particles will be free. The use Nano-Particles in Semiconductor Manufacturing is shown in Fig. 3.

2.2 Future researches in nanotechnology

"Assuming advanced molecular nanotechnology becomes a reality, which it appears is a virtual certainty at this point, it

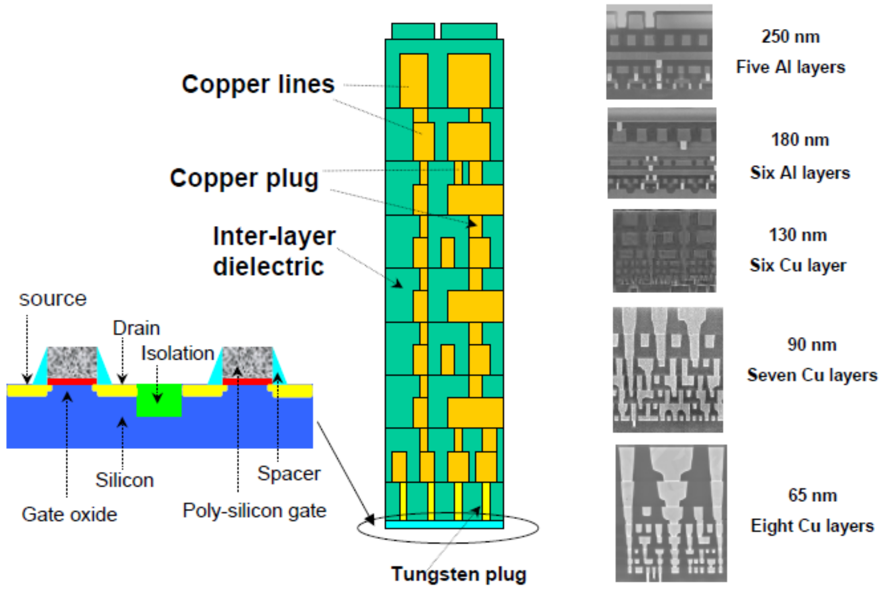

Fig. 3.Trends in the device interconnect [3]

will play a pivotal role in either the survival or extinction of humanity" K. Eric Dexler

In a R&D program nanotechnology researchers are working at the atomic, molecular and supramolecular levels, in the length scale of ~ 1 nm (a small molecule) to - 100 nm range, in order to understand, create and use materials, devices and systems with specific, fundamentally new properties and functions because of their small structure.

The researches a focused in the domains were not possible before: the ability to control and restructure matter at nanoscale; collective effects generate new phenomena and new applications; integration along length scales, systems and applications; sustainable nanotechnology solutions for: clean environment; energy, water, food, mineral resources supplies; green manufacturing, habitat, transportation, climate change and biodiversity.

European industry has recognised its significance to many industrial sectors and that it will bring extraordinary benefits to our industry, economy and welfare in the next decade. In view of its novelty and complexity, the importance for industry to engage in partnership with the scientific community is obvious, requiring highly skilled workforce and the most advanced test facilities to complement in-house R&D activities.

The GENNESYS strategy document [5] is the result of an extensive European-wide study of the needs and opportunities for coordinating future research and development in nanomaterials science and nanotechnology for the advancement of technologies ranging from communication and information, health and medicine, future energy, environment and climate change to transport and cultural heritage. A further focus of this study has been the investigation of the future strategic role of the European research infrastructure, i.e. of the unique analytical potential provided by the European neutron and accelerator- based x-ray facilities in this effort. This study, carried out during 2003 - 2008, brought together leading European scientists and industrial specialists in the fields of materials science, physics, chemistry, biology, and engineering, as well as experts from the neutron and synchrotron radiation facilities. These experts headed thematic task forces with respect to particular research areas - such as information technology, catalysis or functional materials as well as energy and environment issues - and developed roadmaps through numerous informal seminars, workshops and discussion rounds involving colleagues across Europe and the world.

It is expected that nanomaterials will fundamentally change products and how they are produced over the next two to three decades [8].

The main domains where nanotechnology could be applied in the future are the follows:

1. Electronics and communications: bio-nanodevices, neuromorphic engineering in transmitting signals directly from the human organism to a machine, quantum computing, recording using nanolayers and dots, wireless technology, molecular electronics. New devices across the entire range of communication and information technologies will be developed with factors of thousands to millions improvement in both data storage capacity and processing speeds, with reduced costs and improved power efficiency compared to present electronic circuits.

2. Healthcare and life sciences: nanostructured drugs and delivery systems targeted to specific sites in the body, biocompaticable replacements for body parts i.e. biocompatible coatings for implants and nanopolymers for catheters, sensors for lab-on-a-chip, material for bone and tissue regeneration etc. Medical and life science applications may become the most popular and profitable markets for nanotechnology i.e. cancer research diagnostics and treatment. Nanoscale devices can interact with biomolecules and have the potential to detect disease and deliver new ways of treatment.

3. Chemicals and materials: catalysts to improve the energy efficiency of chemical plants, to reduce the exhaust gases of motor vehicles thus lowering the pollution emissions, cutting tools, deep drilling nanomaterials/coatings for petroleum exploration, lubricants, smart textiles.

4. Energy nanotechnologies: solar power, clean fossil fuels, new generation nuclear reactors and fusion reactors, new types of batteries, artificial photosynthesis for clean energy, production and storage of hydrogen, energy saving from using lighter materials.

5. Food and agriculture: nanoscale pesticides, targeted nanofoods with greater capability and sustainability, nanoseeds, nanopackaging materials.

6. Transport: light-weight vehicles.

7. Processing and manufacturing: tools to manipulate matter at the atomic scale, sintering of nanopowders into bulk materials with specific properties that may include smart sensors to detect failures and actuators to repair the problems.

8. Environment: selective membranes and filters that can remove contaminants, clean water, pollutants from industrial effluents, detection of nanoparticles in the environment, reduced sources of pollution, increased opportunities for recycling.

9. Security: detectors of chemical and biological agents, camouflage materials, light and self-repairing textiles, miniaturised surveillance systems.

3. CONCLUSION

In the next decade, nanotechnology R&D is likely to shift its focus to socio-economic needs-driven governance, with significant consequences for science, investment, and regulatory policies

It will be imperative over the next decade to focus on four distinct aspects of nanotechnology development: how nanoscale science and engineering can improve understanding of nature, generate breakthrough discoveries and innovation, and build materials and systems by nanoscale design - "knowledge progress"; how nanotechnology can generate economic and medical Value - "material progress "; how nanotechnology can address sustainable development, safety, and internaţional collaboration -"global progress"; how nanotechnology governance can enhance quality-of-life and social equity - "moral progress".

The nanotechnology priorities in the next decade are the follows: advance partnerships between industry, academia, NGOs, multiple agencies, and international organizations; support precompetitive R&D and system application platforms; promote global coordination; create an international cofunding mechanism for databases, nomenclature, standards, and patents; support horizontal, vertical, and system integration in nanotechnology education and personalized learning; use of nanoinformatics and computational science prediction tools; new strategies for mass dissemination, public participation for creating standing organizations and programs to fund and guide nanotechnology

Meeting the requirements of the following aspects would result in exciting challenges for the nanomaterials industry in Europe: economic aspects; logistic aspects; networking and partnership alliances; technological factors

I have presented new opportunities to develop product features, especially those intangible features of extended products and value-added services.

REFERENCES

1. www.wtec.org/nano2/Twelve trends to 2020

2.Farhang Shadma, *Environmental Challenges and Opportunities in Nano-Manufacturing, Green Nanotechnology,* Project on Emerging Nanotechnologies, Woodrow Wilson International Centerfor Scholars, 2006.

3.http://www.nanotechproject.org/events/archive/researchdirections/.

4. Mihail C. Roco , Mark C. Hersam, Chad A. Mirkin , *Nanotechnology Research Directions for Societal Needs in 2020*, Springer Netherlands, 2011.

5. *GENNESYS* (Grand European initiative on Nanoscience and nanotechnology using NEutron- and SYnchrotron radiation Sources), White Paper - A new european partnership between nanomaterials science & nanotechnology and synchrotron radiation and neutron facilities, Max-Planck-Institut für Metallforschung, Stuttgart, H. Dosch, M.H. Van de Voorde,2009

6.http://www.nanotec.org.uk/report/Nano report 2004 fin.pdf

7.http://nanoengineer.com/content/index.php?option=com_content&task=view&id=39&Itemid=49

8.http://www.nature.com/nnano/journal/v1/n1/full/nnano.2006.45.html

9.http://www.nano.gov/NNI_Manufacturing_at_the_Nanoscale.pdf

10.http://foresight.org/roadmaps/Nanotech_Roadmap_2007_main.pdf

11.http://www.hse.gov.uk/horizons/rapidmanufacturing.pdf

12.http://www.wtec.org/sbes-vision/RDW-color-FINAL-04.22.10.pdf