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Nanotechnology in Space Technology development & Systems

Rupali Chudasama[1], Prof. Amol Joglekar[2]
P.P.S.V.M.I. College, Nanakmatta, U.S. Nagar-262311, Uttarakhand.

Abstract:

Nanotechnology is considered world-wide as one of the key technologies of the 21st Century. Nano technological products and methods hold a huge economic potential for the markets of the future. Also in space technology a high potential for Nano technological applications is suggested. The increasing commercialisation of operated and unmanned space travel as well as ever more ambitious missions for the technical investigation of the solar system and far space needs the development of more effectual, more economical and more resistant space technologies and systems in the future. Nanotechnology could subsidize considerably to explanations and technological breakthroughs in this area (Nano-spin-on). Also the space industry pursues the area of nanotechnology with growing consciousness. Space flight could be exploited for research and development in the field of nanotechnology as well. In this we converse about application of nanotechnology in aerospace research.

Keywords —

1. INTRODUCTION

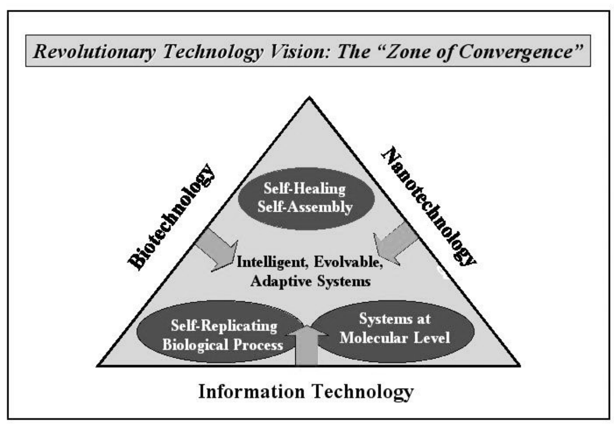
Nanotechnology includes the manipulation of matter at the atomic level, where conservative physics breaks down, to impart new materials or devices with performance characteristics that far surpass those projected for more orthodox methods. For instance, quantum confinement in nanoscale semiconductor particles, quantum dots, gives rise to novel optical behaviour making it likely to tune the colour of their fluorescence basically by altering their diameter. Nanoscale texturing of surfaces can permit for control of adhesion properties prominent to biomimetic (Gecko-foot) self-healing adhesives and self-cleaning surfaces. The uncommon mixture of superior mechanical properties, electrical and thermal conductivity and electronic properties of carbon based nanostructured materials can empower the development of lightweight, multifunctional structures that will transform the design of future aerospace systems. Nanotechnology can have a extensive influence on space missions, with benefits mainly in four areas.

1.1 Reduced Vehicle Mass:

Replacement of conventional aerospace materials (composites and metals) with progressive composites derivative from durable Nano porous matrixes and low density high strength and/or stiffness fibres can decrease aircraft and spacecraft constituent weight by one-third. Supplementary weight savings can be recognized by substituting heavy copper wiring, which accounts for 4000 lb of weight on a Boeing 747 and about one-third of the weight of large satellites, with low density carbon nano tube wiring cables.

1.2 Improved Functionality and Durability:

Nano-electronic devices based upon graphene, carbon nanotubes, semiconductor nanowires, quantum dots/semiconductor Nano-crystals and rods are integrally more radiation and fault tolerant, have lower power requirements, higher speeds than conventional CMOS electronics. Integration of Nano-electronics and nanotechnology derivative emission sources and detectors will lead to the growth of progressive spectrometers and imagers that are one to two orders of magnitude lighter than conservative instrumentation, with double the sensitivity and resolution and half the power necessities.



Visionary technology developments by convergence of nanotechnology, biotechnology and information technology

1.3 Enhanced Power Generation and Storage and Propulsion:

Nanotechnology gives the likelihood of creating high surface area materials with integrally higher surface activities and reactivity that could suggestively improve the presentation of batteries and fuel cells and expand the handling features of propellants.

1.4 Improved Astronaut Health Management:

Nano-porous materials with personalized pore size and shape and surface chemistries will tip to the development of more effectual systems for the removal of carbon dioxide and other scums from breathing air and organic and metallic impurities from drinking water. Dispersed, autonomous state and chemical species detectors could find use in air and water quality monitoring systems, and in astronaut health monitoring. Nano-fluidics based devices will permit the development of real-time, marginally invasive medical diagnostic systems to monitor astronaut health and aid in diagnosing and treating sickness.

Critical Nanotechnology Products for Space research (NASA):

Nano-engineered Materials:

• High strength/mass, smart materials for aerospace vehicles and large space structures

• Materials with programmable optical/thermal/mechanical/other properties

• Materials for high-efficiency energy conversion and for low temperature coolers

• Materials with embedded sensing/compensating systems for reliability and safety

Nano Electronics

• Devices for ultra-high capability, low-power computing & communication systems

• Low-power, integrable nano devices for miniature space systems

• Bio-inspired adaptable, self-healing systems for extended missions

• Quantum Devices and systems for ultrasensitive detection, analysis and communication

Biomolecular nanotechnology:

• Bio-geo-chem lab-on-a-chip for in situ science and life detection

• Nanoscale sensing, assessment and therapeutics delivery for medical autonomy

• Molecule-to-organism bio procedure modeling, digital human and cybermedicine.

• Tools for straight study of space-induced medical effects and countermeasures

2. REQUIREMENTS AND APPLICATION FIELDS FOR FUTURE SPACE SYTEMS

A significant benchmark for the effort of potential nanotechnology applications in space is, to what level these can make an influence to the service of future necessities in space technologies and systems and to the recognition of future missions in space travel.

2.1 Space technology demands

In the subsequent, some substantial requirements for future space travel technologies and systems are abridged, which were well-defined by the European Space Agency (see ESTEC 1999, ESA 2001) and to which nanotechnology might subsidize important solutions.

2.1.1 Cost reduction

2.1.1.1 Space Transportation

The chief starting point for the cost reduction in space travel is savings in space transportation by reduction of mass and volume of spacecraft's and payload. At present, the costs amount to approx. 10.000 to 20.000 €/kg for transport into the earth's orbit (Janovsky 2001). Up to the year 2000, more than 20 nanosatellites were launched universal mainly for universitary or military research resolutions. Temporarily, also first beginnings of a marketable use of Nano satellites appear, operating for instance from carrier platforms in space (Caceres 2001).

Nanotechnology might subsidize solutions in this context in numerous areas, e.g.:

• Data processing and system control (extremely integrated avionics, wireless data communication, sensors etc.)

• Energy generation and storage (e.g. solar cell and fuel cell technology)

• Structure and thermal control elements (lightweight materials, miniaturized cooling loops and heat exchangers)

• Propulsion (electric propulsion technologies, MEMS-propulsion technologies).

2.1.1.2 On-Board Autonomy:

By growing the on-board autonomy of spacecraft's, (e.g. autonomous attitude and orbit control, payload data processing, health monitoring of astronauts etc.) the operating costs for repetitive operations and fault corrections might also be depressed. This might be attained by Nano technologically enhanced information and communication technologies and sensor technology.

4.1.1.3 COTS-Technologies:

Additional cost savings can be understood by using of COTS (Commercial off the Shelf) technologies. Cost-intensive technology growths, e.g. within the ranges of micro- or nanotechnology, are typically not reasonable for the space sector due to budget limits.

2.1.2 Increased capabilities:

Enhanced competences of future space systems are a additional substantial objective both for scientific and commercial applications. In perspective with possible applications of micro-/nanotechnologies, innovation task forces were recognized by the ESA dealing with the subsequent areas:

• Improved communication performance

• Instruments and sensors breakthroughs

• Innovative components and materials

• Intelligent space systems operation

2.1.3 Lowering of mission risks

The costs of payload development for space missions and of the space transportation are typically very high, so that an abridged mission risk is given a great priority. A significant objective is consequently an increased reliability and durability of space constituents and systems. This could be attained for instance by improved fault recognition and correction approaches as well as an augmented fault tolerance.

2.1.4 Innovative system concepts

A supplementary objective within the array of the space technologies is the recognition of new system conceptions for dissimilar targeted applications.

2.2 SPACE APPLICATION FIELDS

The employment of nanotechnology for space applications will be contingent strongly on the development of commercial space activities and the understanding of demanding scientific missions (e.g. manned Mars mission) in the future. Impulses might rise in specific from the commercial variety, for which an extensive rise of the world market volume up to approx. 150 billion $ were predicted for the year 2005.

2.2.1 Earth observation:

The earth observation serves both application orientated/commercial and scientific resolutions. The application orientated earth observation shields uses within the varieties of meteorology and oceanography, environmental monitoring as well as safety-relevant clearing-up. Furthermore, a stronger commercialization of earth observation services is projected at, e.g. within the sorts of mapping for agriculture and forestry ("precision farming"), raw material exploration, land resource administration and disaster monitoring.

2.2.2 Telecommunication:

In the field of telecommunications the importance is put on broadband multimedia submissions and on mobile communication services. Satellite based services enhancement here the terrestrial communications network within some areas (in specific for thinly steady or difficultly accessible areas):

• GEO-systems for less collaborative “asymmetric” data communication (television, video-on-demand etc.)

• Networks of satellites in near-earth orbits for interactive high speed applications (e.g. Internet in the Sky“) by using optical intersatellite links

• Mobile satellite communication services (e.g. S-UMTS)

2.2.3 Navigation and positioning:

Contained by navigation and positioning, the formation of the civilian European satellite navigation system Galileo, is the importance neutral of the ESA and the DLR, in order to become liberated of nationwide controlled systems. Here, a strong commitment from the private industrial sector is intended at. Applications are estimated chiefly in the establishment of intelligent traffic-guidance-systems for safer, ecologically friendly and more effectual traffic management. Particularly for sensitive application areas like automatic landing aids for airplanes, the dependable availability of a positioning system under European dominance will be a vital safety factor for traffic.

2.2.4 Science and exploration:

In the field of science exploration, the importance of ESA activities lies in the investigation of the solar system (in particular Mars and Mercury), astrophysics (particularly the search for planets external the solar system) and fundamental physics (e.g. detection of gravity waves). The exploration of space aims at a better thoughtful of origin, structure and development of the cosmos and at the same time of origin, situations and future of our own presence. Observatories in earth orbits authorization the observation of the universe and its objects within all ranges of the electromagnetic spectrum deprived of interventions through the earth’s atmosphere (Multi-frequency astronomy with importance in the infrared and x-ray/ gamma range).

2.2.5 Manned spaceflight and microgravity:

In the field of manned spaceflight the participation in the institution and the exploitation of the international space station is the most significant goal for the ESA. The European contribution to ISS is in specific made with the completion and operation of the Columbus module and apt devices for microgravity research. In totalling, the growth of robotic systems and inquiries to sustenance the operation of the ISS are scheduled by the ESA. As a unrealistic goal, a manned Mars mission under participation of the ESA is being deliberated at present.

2.2.6 Space Transportation:

A superordinate goal of the ESA in the frame of space conveyance is to secure a modest and liberated European access to space. With the core element of European space transportation events, the ARIANE programme, the responsibility for the alteration to the market requirements (e.g. lowering of production costs, upsurge of the mission flexibility, reliability and transportation capacity) must be transported progressively to the industry. A critical goal for a future generation of space transporters is the important lowering of conveyance costs.

3. NANOTECHNOLOGY IN SPACE

The recognized potential applications of nanotechnology in space travel are henceforth designated, which could in future subsidize significantly to the space requirements and goals defined above. In agreement with setting of responsibilities, Nano-applications are allocated to the suitable activities of the nanotechnology capability centres in Germany:

- Functionality by means of chemistry (Nano-chem)
- Functional ultra-thin films (Nano-layers)
- Applications of nanostructures in optoelectronics (NanOp)
- Production and use of lateral nanostructures
- Ultra-precise surface treatment (Ultraprecise Surfaces)
- Nano-analytics

3.1 Nano-chemistry, nanomaterials and Nano-biotechnology:

The spectrum of nanostructured materials extents from inorganic and organic amorphous or crystalline nanoparticles over Nano-colloids and suspensions up to nanostructured carbon compounds such as fullerenes and carbon nanotubes. In principle all substantial material classes, i.e. metals, semiconductors, glass and ceramics, polymers as well as mixtures can be shaped with nanostructured formations.

3.1.1 Materials for space structures

A variety of applications of nanomaterials lies in the construction of spacecraft's and space structures due their improved mechanical aspects (higher firmness and steadiness and contemporarily a lower density) related with conventional materials. Nanomaterials could in particular subsidize to the decrease of the lift-off masses of spacecrafts prominent to substantial cost savings and also guarantee safer and more flexible space missions. In the perspective of space structures, dissimilar material classes must be taken into thought.

- Nanoparticle reinforced polymers
- Carbon Nanotubes
- Metal-Matrix-Composites
- Nano-crystalline metals and alloys
- Nanostructured ceramics/ceramic nanopowders

3.1.2 Thermal protection and control

3.1.2.1Thermal protection

Due to the zexciting conditions in space, thermal protection is an significant topic. By enhanced thermal protection schemes for re-usable spacecrafts the costs in space transportation could be depressed, and furthermore, a higher mission flexibility and safety in manned space travel could be attained.

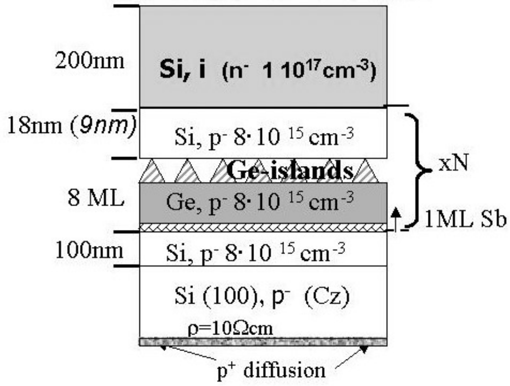
3.1.2.2 Thermal control

Thermal control of space systems is a additional topic of high relevance. This disquiets, among other things, the protection of sensitive electronics against large variations in temperature. This includes for instance an effectual radiation of electronic power dissipation, which in particular signifies a problem within the miniaturization of satellites. Nano- materials offer dissimilar methods for an enhanced thermal monitoring of space travel systems.

3.1.3 Energy generation and storage

Contained by the variety of energy generation and storage nanomaterials, nanolayers and Nano membranes will find applications as enhanced electrodes and electrolytes in condensers (supercaps), batteries (e.g. Li ion batteries) and fuel cells as well as photosensitive materials for high-effectual solar cells (e.g. quantum dot solar cells).

5.2.3.1 Solar cells



Schematic structure of a Si/Ge QD solar cell with layers of Ge quantum dots in the active layer of the Si solar cell substrate

- Thermoelectrics
- Fuel Cells
- Batteries/Accumulators
- Capacitors

3.1.4 Life support

Within the range of life sustenance many potential applications of nanotechnology ascend. As substantial tasks of life support systems in space travel, the following should be stated:

• O2-/ N2 supply
• pressure monitoring
• ventilation
• heat absorption and rejection
• waste water treatment
• monitoring of water quality
• CO2- removal
• hygienics
• air cleaning and filtration
• control of air quality and humidity

3.1.5 Sensors

Sensor technology will gain in specific from Nano technological developments. Out of the multiplicity of dissimilar sensor systems in space technology only a few instances are labelled below, where nanomaterials offer important application potentials.

- Gas sensors
- Sun sensors

3.1.6 Biomedical applications:

Biomedical applications in the area of spaceflight purpose at the decrease of medical risks for astronauts. As precarious risks, the following should be stated among other things.

• bone loss
• heart and blood circulation problems
• performance loss
• distortion of the sense of balance
• distortion of the immune system
• muscle loss
• radiation harms
• insufficient approaches for on-board medical therapy and diagnostics.

3.2 ULTRATHIN FUNCTIONAL LAYERS:

For the production of ultra-thin layers, which plays a vital role as functional coatings in several technical constituents, in specific chemical and physical deposition methods in the gaseous phase are engaged. The alterations amongst the multicipliity of procedures lie mostly in the approaches for the supply of the deposition material, reaching from CVD to high-energy particle beam processes. Also by ion implantation nanostructured surfaces can be attained.

3.2.1 Friction and wear reducing layers

Nanoscale solid films are significant for space technology as friction and wear-reducing layers, e.g. for the development of MEMS machineries.

3.2.2 Thermal protection layers

Thermal protection layers in space technology could be used amongst other things for re-entry technologies or for the thermal insulation of rocket engines.

3.2.3 Optics and electronics

The deposition and functionalization of ultra-thin layers play a vital role in a multiplicity of applications in optics and electronics.

3.2.4 Magneto electronics

Ultra-thin layers are the base for the development of magneto electronic sensors and memory chips with great prospective for space applications. Such components are based on magnetic resistance effects.

3.2.5 Thin film technologies for space structures:

Newer research efforts for instance of NASA aim at the diminishment of space systems only in one dimension, that is very large self-deployable systems comprising of very thin foils. For the development of these so called GOSSAMER spacecrafts the integration of e.g. the subsequent subsystems into the thin film structure is shadowed:

• thin film solar cells (e.g. on kapton substrates)
• antennas (phased arrays) in thin-film technology
• semiconductor circuits deposited on foils
• attitude and orbit control through evaporation of foil material
• fuelless propulsion (sunsails, or laser/microwave propelled sails)

3.3 NANO-OPTOELECTRONICS:

Diffractive optical elements, optoelectronic transducers and photonic constituents, which play a vital role in optical data communication, can be significantly amended by lateral nanostructures. With the development of lateral optoelectronic nanostructures the way to governable diffractive optics is paved. For this, elements with precise interference structures are essential, which act as precise and perhaps controllable transmission or reflection filters. Nanostructured optoelectronic constituents (e.g. quantum well or quantum dot lasers, photonic crystals) offer large market potentials in the future, e.g. for optical data communication or in the range of consumer electronics. In the subsequent, some Nano-optoelectronic constituents are labelled.

- Quantum dot laser
- Photonic crystals
- Infra-red sensors

3.4 LATERAL NANOSTRUCTURES:

Functional lateral nanostructures open up new proportions on the level of subcomponents for products within the sorts of information technology, electrical engineering and optics. These are partially based on totally dissimilar physical principles, but can be understood with a relatively uniform procedure technology, which is consequent from the development of the CMOS technology. Constituents, in which lateral nanostructures make a substantial contribution to functionality, offer potentials for the development of effectual energy-saving data memories and processors.

3.4.1 Alternatives for CMOS electronics

In information technology the enactment of microprocessors has augmented for two decades now with a stable pace. Agreeing to this so called Moores law, the device difficulty and thus performance of microprocessors doubles every three years.

- Molecular electronics
- Spintronics
- Quantum Computing
- Logics with tunneling components

3.4.2 Nanotechnological data storage

Also in the area of data storage, nanotechnology proposals potentials for the production of reduced mass memories with tremendously high storage density as well as for the development of new non-volatile working reminiscences for computer systems, which will participate in the future with conventional memory chips like DRAM. Flash or FRAM some compensation, which is chiefly interesting for aerospace and military requests:

• Low energy consumption
• Inherent radiation resistance
• Aptness for high temperature

3.4.3 Nanostructures in microelectronics/micro system engineering:

Also inside the range of micro system engineering, nanostructures and Nano-technologically enhanced constituents will gain significance in the future. In space travel MEMS proposal the possibility of miniaturization in a diversity of subsystems (e.g. AOCS, propulsion, thermal control).

3.5 ULTRAPRECISE SURFACE PROCESSING:

Ultraprecise surface dispensation includes all manufacturing procedures permitting producing macroscopic bodies and surfaces are shaped with enormously high precision and smoothness. Ultra precise surfaces exhibit enhanced functionalities for a multiciplity of applications.

3.5.1 Manufacturing of ultraprecise surfaces

Mechanical/chemical and optical manufacturing procedures as well as ion beam and plasma processes belong to the most significant processes for ultraprecise surface figuring and form correction.

3.5.2 Characterisation of nano-surfaces

A further significant field in the range of ultraprecise surfaces is the description of the mechanical-physicochemical properties of surfaces comprising local defects. For space applications the behavior of nanosurfaces under space conditions is of specific interest.

3.6 NANOANALYTICS:

The characterisation of materials, structures and surfaces with nanoscale correspondingly atomic resolution is a basic precondition for Nanotechnological developments and is therefore of central significance for the technology field. In the subsequent a restriction is therefore made on nanoanalytic approaches, which can be applied in space for the characterisation of materials and particles with a nanoscale resolution, predominantly in the range of scientific space missions.

3.6.1 Secondary Ion Mass Spectrometer

Secondary ion mass spectrometers offer the likelihood of examining comet matter and interstellar dust bits with a nanoscale resolution (Nano-SIMS).

3.6.2 Scanning probe and tunnel microscopy

Scanning probe microscopy belongs to the most significant approaches in the field of nanoanalytics. Scanning probe approaches are based on a local reciprocation among a surface and a scanning probe tip, which is conveyed very near (in atomic dimensions) to the surface of the example.

3.7 Contribution to space technology objectives

A significant condition for the employ of potential nanotechnology applications in space is to ascertain their involvement to space technology objectives. For the assessment the subsequent objectives were pragmatic:

- Cost reduction
- Improved capabilities
- Lowering of mission risks
- Higher mission flexibility
- New system conceptions

Field of technology	**Nanotechnological application**
Structure materials	· Nanoparticle reinforced polymers · CNT/CNT-composites · Metal matrix composites · Nanocrystalline metal/alloys · Nanostructured ceramic(s)...
Energy generation and storage	· III/V semiconductor solar cells · Thin film solar cells · QD solar cells · Fuel cells · Supercapacitors · Batteries/thin film batteries...
Data processing and storage	· SOI memory · Phase-Change-RAM · MRAM · Biological data memories · Molecular electronics · Spintronics ...
Data communication (optical/ EHF)	· QD Laser · Photonic crystals · HF-components (HEMT, HBT, RTD) · SAW- components ...
Sensor technology/instruments	· Gas sensors · QD IR sensors · Magnetoelectronic sensors · Scanning probe devices · X-ray optics/- mirrors...
Life support systems/ biomedical applications	· Heat exchanger · Nanomembranes · Lab-on-a-chip Systems · Drug-Delivery-Systems ...
Thermal protection/control	· Ceramic fiber composites · Thermal protection layers and isolations · Ferrofluids ...

Nano technologically influenced components and systems with space application

CONCLUSION

The spectrum of nanotechnology applications in space reaches from short to medium-term applications up to long-term and visionary improvements. Important alterations can be determined regarding the economic potential in the terrestrial market, the influence to space technology goals and the economic welfares for the space sector. Afar that, several obstacles regarding Nanotechnological applications in space can be recognized. In this paper we defined the necessities and application fields for future Space systems and application potentials of nanotechnology in space with Nanotechnology solutions for future space demands were also explained.

REFERENCES

1. Nanotechnology Roadmap by Michael A. Meador, Page No: 1-3
2. Bland-Hawthorn, J.; Harwit, A.; Harwit M. (2002): „Laser Telemetry from Space“, Science, 297, p 523
3. Bimberg, D. (2002): „Enabling Photonic Technologies for Space Applications“, ANTARES-Workshop 04.06.02, DLR-Köln-Porz
4. BMBF (2002): „Nanotechnologie in Deutschland-Standortbestimmung“, („*Nanotechnology in Germany, state-of-the-art*“) May 2002
5. Compano, R. (Hrsg.) (2000): „Technology Roadmap for Nanoelectronics“, European Commission, Brussels, Directorate General Information Society
6. ESA (2001): „A world first: Data transmission between European satellites using laser light“ ESA-press release from 22.11.2001
7. ESTEC (1995): „1st Round Table on Micro/Nano Technologies for Space“, 23-25.03.1995, Noordwijk, The Netherlands Proceedings-Band WPP-91
8. ESTEC (1997): „2nd Round Table on Micro/Nano Technologies for Space“, 15-17.10.1997, Noordwijk, The Netherlands Proceedings-Band WPP-132
9. ESTEC (1999): „European Space Technology Requirements Document“ (Dossier 0), October 1999, ESTEC, The Netherlands
10. Graf, J. (2001): „Sensor Needs for Advanced Life Support“, Proceedings Nanospace 2001, 4th International Conference on Integrated Nano/

Microtechnology for Space and Biomedical Applications, 13.-16. März 2001 in Galveston/Texas

11. IWGN (1999): „Nanotechnology Research Directions“, Interagency Working Group on Nano Science, Engineering, and Technology (IWGN) of the NSTC, Workshop report 1999, S. 73