

HEAVY ION TRACKS IN SOLIDS: A QUANTUM JUMP TO NANOTECHNOLOGY

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ABSTRACT. Our laboratory has been engaged in the study of heavy ion tracks in solids (mineral crystals, polymers and glasses) since 1980 using heavy ion beams from UNILAC (GSI, Darmstadt), Synchrocyclotron (JINR, Dubna) and Pelletron (NSC, New Delhi). Ion beams from Li to U with fluences ranging from a single ion to 10^{14} ions/cm² were used for material modification. The morphology of heavy ion latent tracks was revealed by atomic force microscopy. Etching and annealing behaviour of ion tracks has been studied in solids. Ion track filters were used for purification of contaminated water, air and blood samples.

Nanotechnology is an emerging field having a vast potential for fabrication of sensors and devices. Materials with micro/nanoscale dimensions have potential technological applications in microelectronics and micro-mechanics. Microstructures comprising micro-dimensional devices, dots, fibrils, wires, cones, tubules and whiskers have invited attention for use in multidisciplinary areas. There are different techniques for development of microstructures but template growth through etched track pores is considered to be very simple. It is a spin-off from the technological application of energetic heavy ion tracks in materials known as solid state nuclear track detectors (SSNTDs). Ion tracks technology is a recent phenomenon, which has given a quantum jump to Nanotechnology. An overview of the work done in our laboratory will be presented in this review lecture.

Nanotechnology and Nanomaterials: Introduction

The roots of Nanotechnology and Nanomaterials can be traced to a lecture delivered by Richard Feynmann (Nobel Laureate) in 1959 in a meeting of American Physical Society, when he speculated that future scientists and engineers would build structures from atoms and molecules. It was only during 1980's with the development of new tools, i.e.; Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM), that the characterization and manipulation of nanostructures became practical. The worldwide thrust in Nanotechnology represents a new phenomenon in innovation as it impacts fields of electronics and information technology; biology, chemistry and medicine, energy, environment and transportation, and especially that of materials.

The Greek word "nano" refers to a dimension, one thousand times smaller than a micron. Nanoscience deals with materials and technologies in the size range of 1-100 nm (10^{-9} m). The ability to control and manipulate nanostructures makes it possible to exploit new physical, biological and chemical properties of the system that are intermediate between single atoms, molecules and bulk materials. In nature, nanoscience has been in existence since billions of years in the form of living beings, with cells acting as multifunctional nanomachines.

Characterization of Nanomaterials

Nanomaterials being very small in size, require highly developed procedures and devices operating with a variety of particle beams and using different kinds of physical effects including field emission and electrical, magnetic, thermal and optical principles. Some of the important techniques used for the characterization of nanomaterials are as follows:

- Transmission Electron Microscopy (TEM)
- Scanning Tunneling Microscopy (STM)
- Atomic Force Microscopy (AFM)
- X-ray Diffraction (XRD)
- X-ray Photoemission Spectroscopy (XPS)
- Mossbauer Spectroscopy
- High Resolution Fourier Transform IR (FTIR) Spectroscopy

Fabrication of Nanomaterials

Both chemical (bottom-up) and physical (top-down) methods are used to synthesize nanomaterials. Molecular chemistry has dominated in the development of nanomaterials by understanding how matter is assembled on atomic and molecular level and the consequent effects on the bulk properties. The most commonly used chemical methods are mentioned below.

Wet Chemical Methods

1. Chemical Reduction
2. Sonochemical Synthesis
3. Sol-Gel Synthesis
4. Exchange Reactions
5. Reverse Micelle
6. Self- Assembly

Physical Methods

Many conventional physical processing techniques can also be used for fabrication of Nanomaterials. The invention of STM and AFM accelerated the process of fabrication with atomic scale accuracy. Some of the physical processes are mentioned below:

1. Aerosol Spray Techniques
2. Gas Condensation
3. Laser Vaporization and Condensation Method
4. Sputtering
5. Manipulative Techniques

Applications of Nanotechnology

1. Medicare and health
2. Information/ Computer Technologies
3. Bio-Technology and Agro - forestry
4. Environment and Energy
5. Metallurgical and Chemical Technologies

Medicare and Health

- Engineered nanodevices for monitoring, repair, construction and control of human biological system at molecular level.
- Early detection and protection from diseases; targeted drug delivery, better hearing and vision aids.
- Replacement of damaged parts (cancerous cells, blood vessels, skins, bones etc.)

Information / Computer technologies

- Miniaurized computing devices with
 - Efficacy improvement by a factor of million.
 - Data storage at multitera- bit level
- Communication systems
 - Integrated nanosystems capable of collecting, processing and very high transmission of large volumes of data at broadband optical frequencies.

Bio-tech and Agro-forestry

- Molecularly engineered chemicals for nourishing plants and protection against insects
- Genetic improvement of plants and animals
- Testing technology to identify genomes sustaining salt and drought stresses
- Processing of biomass in sewerage treatment plants
- Food processing and preservation

Environment and Energy

- Environment
 - Air and water pollution control through light weight, high strength nanoporous filters
 - Nanofilters for isotope separation; nanofluids for nuclear reactors; nanopowders for nuclear decontamination
- Energy storage and conversion
 - Photovoltaic cells
 - Solar absorbers
 - High density rechargeable batteries
 - Hydrogen and hydrocarbon storage devices

Metallurgical and Chemical Technologies

- High strength, tough, light weight, corrosion & heat resistant structural materials (Metals, alloys, ceramic and polymeric) for aerospace vehicles and automobiles
- Design and synthesis of new molecules with multi-functionalities

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