

An Overview of Nanoscience and its Applications

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Abstract :

Nanoscience is the nanoscale science, or items with sizes between nanometres. The study of structures at the nanoscale, both natural and man-made, is known as nanotechnology. Depending upon the material structure and its properties nanoparticles have different types. These different nanoparticles have different properties such as magnetic, optical, electric, chemical etc. Synthesis of nanoparticles are mainly classified into two types such as top-down method and bottom-up method and further divided into physical, chemical and biological methods. Nanoparticles have a variety of applications in many diverse fields such as environment, medicine, agriculture, food, electronics, defence etc. In this review, we described nanomaterial, its history, properties, synthesis methods, factors affecting synthesis of nanoparticles, characterization techniques and its applications.

Keywords: Nanoscience, Nanotechnology, Synthesis Methods, Characterization Techniques.

I. INTRODUCTION

In nanoscience materials are studied at the nanoscale. One billionth of one meter, or 10^{-9} , is referred to as a nanometre [1]. Means meter's one billionth is equal to one nanometre. For nanoscience to be relevant, at least single dimension of the material or structure should be between 1 and 100 nm. When structures are sufficiently small, they can acquire interesting as well as practical properties. When compared to their bulk quantities, their properties in the nano regime are quite distinct [2]. Nanostructure can be formed from metals [3], semiconductors [4], carbon-based materials [5] or liquids [6] by using special methods and techniques. Synthesized nanostructured materials are observed using special equipment. Nanoscience is now used by scientists and engineers of several disciplines such as material science, physical science, chemical science, molecular biology, semiconductor physics, microfabrication, molecular engineering, pharmaceuticals, memories and information storage, computer etc.

In the fourth century A.D. Roman glass makers fabricated nanosized metal glasses. In London, the British museum has a Lycurgus cup which was fabricated from soda lime glass containing silver and gold nanoparticles [7]. In 1959, new era of nanotechnology was started by the great physicist Richard P. Feynman with a famous talk, "There's Plenty of Room at the Bottom" [8]. In this talk he explained manipulating and controlling things on a small scale. Nanotechnology is manipulation of matter on atomic scale with one dimension in the range

between 1 to 100 nanometres [9]. Nanotechnology is the study of materials at the nanoscale, both natural and artificial. Fundamentally, nanotechnology is the engineering of microscopic devices with the potential to construct objects from the ground up utilising methods and instruments currently under development to create fully functional, extremely sophisticated goods. Nanotechnology produces novel nanomaterials with numerous uses such as nanomedicine [10], nanoelectronics, biomaterials, energy production [11], cosmetics [12] etc.

II. PROPERTIES OF NANOMATERIALS

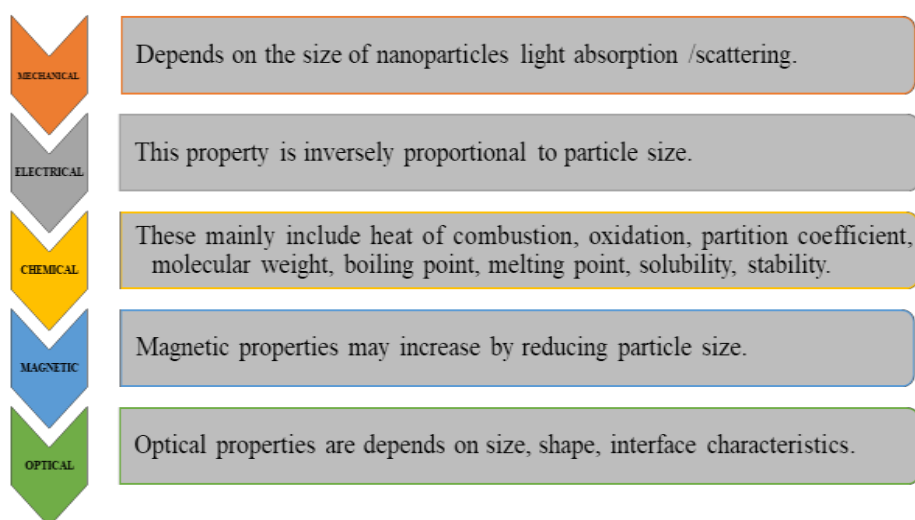


Figure 1: Properties of Nanomaterials

III.SYNTHESIS OF NANOMATERIALS

Synthesis methods are broadly classified into two categories such as top-down method and bottom-up method.

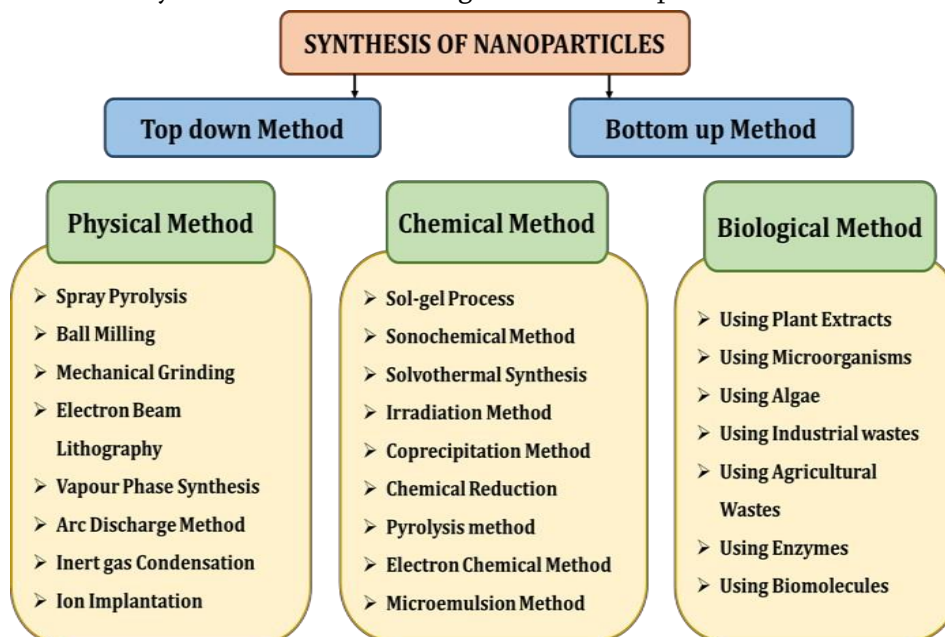


Figure 2: Method for Synthesis of Nanoparticles

Synthesis methods are further divided into three classes such as physical methods, chemical methods and biological methods as shown in above figure. Nanoparticles are synthesized using above listed physical

methods. These methods work at higher temperatures, usually greater than 350°C. Chemical methods are listed in the above figure, temperatures required for these methods are usually below 350°C. Large quantities of materials can be synthesised by using these methods. Biological synthesis methods are environmental and less toxic methods so they are called green synthesis.

A. Top-Down Approaches

Top-down approach of the synthesizing method is used for larger structures where processing is externally controlled [13]. In this method pattern is generated on a larger scale and then reduced to nanoscale by using top- down synthesis methods. This method requires large installations and huge capital for setup so this method is quite expensive. Growth process of this method is slow and so not suitable for large scale production.

B. Bottom-Down Approaches

This approach includes miniaturization of materials components with a self-assembly process. Basic components are combined into more substantial, stable structures during the self-assembly process by means of physical forces acting at the nanoscale. In bottom-up methods atoms or molecules are built to nanostructures by direct manipulation of atoms or molecules. Basic principle of the bottom-up approach is molecular recognition. [14].

IV. FACTORS AFFECTING ON SYNTHESIS OF NANOPARTICLES

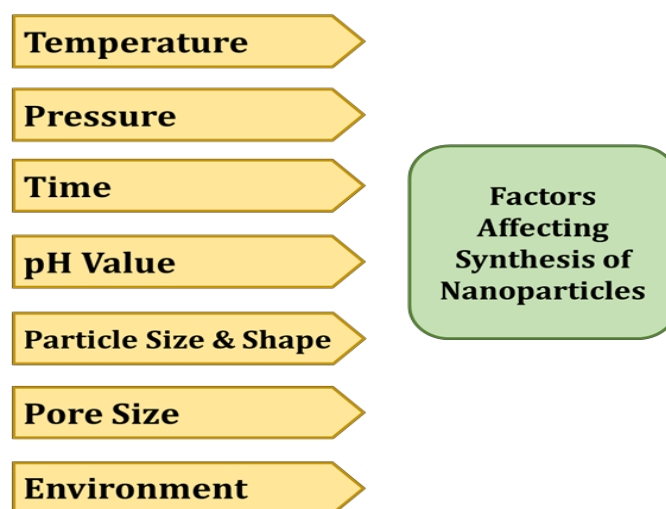


Figure 3: Factors Affecting on Synthesis of Nanoparticles

Above figure shows factors which are affecting the synthesis of nanoparticles, these are temperature, pressure, time, pH value, particle size and shape, pore size and environment [15]. Temperature is a main parameter which affects synthesis of nanoparticles. Synthesis temperature is different for physical, chemical and biological synthesis methods. For the physical synthesis method required synthesis temperature is usually greater than 300°C, for chemical methods it is below 300 °C and for biological methods it is less than 100 °C. Size and shape of nanoparticles affected due to pressure. Reaction time affects the quality of synthesized nanoparticles. Properties of nanoparticles are mainly dependent on particle size such as the melting point of nanoparticles decreases with decrease in size of particles. Chemical properties of nanoparticles depend on the shape of the particles. Cost of nanoparticles decides potential applications of materials. Synthesis methods should be cost

effective Physical methods and chemical methods are not cost effective but biological synthesis methods are less cost and so used for large scale production.

V. CHARACTERIZATION TECHNIQUES

- A. X-Ray Diffraction: One popular method for figuring out a composition or structure of crystal is X-ray diffraction. The atom structure of bigger crystals, like inorganic compounds and macromolecules, can be ascertained using this method. It can determine phase purity, composition, and crystallinity if the size of the crystal is too small [16].
- B. UV Visible Spectroscopy: On the basis of wavelengths, UV-Visible spectroscopy can be classified into the visible, ultraviolet, and near-infrared sections of the spectrum. Weak absorption bands are identified since their frequency is near to the over frequency of many natural vibrations. As a result, it can be applied to non-destructive assessments like figuring out food's sugar, fat, and protein composition as well as identifying medications [17].
- C. Electron Microscope: Electron microscope is a such type of microscope where the light source is an electron beam that has been accelerated. With an electron's wavelength up to 100,000 times shorter than the visible light. Electron microscopes are able to expose the smaller objects structure [18].
- D. TG-DTA: A simultaneous thermal analyser which can characterise a material's numerous thermal properties. Temperatures of breakdown, reduction, or oxidation are measured by the TG component. It detects weight changes related to oxidation, decomposition, and any other chemical or physical processes that cause the sample to gain or lose weight all at once. The DTA component indicates the endothermicity or exothermicity of decomposition processes. The DTA also records temperatures for phases including melting, crystallisation, and glass transitions where there is no mass loss [19].

VI. APPLICATIONS

A. Environment

Nanoparticles are used for water purification, air filtration, and soil remediation. These nanomaterials have shown promise in improving the efficiency of environmental remediation processes and reducing the impact of pollution on ecosystems [20].

B. Medicine

The medicine sector includes targeted drug delivery, imaging techniques, and disease diagnosis nanoparticles. These nanoparticles have the potential to revolutionise the field of medicine by improving treatment outcomes and reducing side effects for patients [21].

C. Agriculture

Nanoparticles in the agriculture industry include enhancing crop productivity, improving nutrient uptake in plants, and reducing the need for chemical pesticides. These nanomaterials have the ability to address food security challenges and promote sustainable agricultural practices [22].

D. Food

Nanomaterials have the potential to ensure food safety, reduce food waste, and meet the growing demands of a global population. Food industry includes improving food packaging to extend shelf life, enhancing food quality through encapsulation of nutrients, and detecting food contaminants [23].

E. Electronics

Applications of nanoparticles in the electronics industry and automotive industry include improving the performance and durability of electronic devices, as well as enhancing the efficiency of automotive components. These nanomaterials have the potential to revolutionise these industries by enabling smaller, faster, and more energy- efficient products [24].

F. Defence

The defence industry includes enhancing the strength and durability of materials used in military equipment, as well as improving the effectiveness of sensors and detection systems. These nanomaterials have the potential to greatly enhance national security by providing advanced technology for defence purposes [25].

VII.CONCLUSION

Nanotechnology is a promising era and has opened doors for technology. Nanomaterials having optical, magnetic, electric, chemical properties which enhance the applications of nanomaterials. Top-down and bottom-up approach synthesis methods are continuously enhanced to increase applications of nanoparticles. Researchers are developing new applications for nanoparticles to enhance the applications of nanotechnology in many sectors. Furthermore, there has been a noticeable increase in the use of nanotechnologies to alter the functionality and performance of systems. Thus, additional research is required to find better ways to apply knowledge of nanotechnologies in engineering, computers, electronics, and other fields.

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