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Study and Investigation of Characterization Techniques, Synthesis and Applications of Nanoparticle

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Abstract

Nanotechnology is critical for the twenty-first century. A nanomaterial is any atomic molecule with a diameter of 1 to 100 nanometers. This review focuses on nanoparticle characterization, production, and applications. Techniques such as X-ray diffraction, SEM, EDX, TEM, DC conductivity, PSA, and TG/DTA were utilised for nanoparticle characterization. Nanoparticle characterization is required for understanding its features and applications. During nanoparticle manufacturing, we explored the physical and chemical properties of nanoparticles, such as size, shape, and chemical composition. This review also looks at nanoparticle classification. HRTEM, STEM, EELS, and EFTEM can be used to investigate the three-dimensional structures of the particles. The nanomaterial's primary applications are in biomedicine for medications, gene delivery, and cancer therapies. It is frequently utilised in television and monitor displays. It is used in food technology to protect and package food items. It has also reduced the cost of construction materials.

Keywords: *Applications Synthesis, Nanotechnology, Characterization, HRTEM, STEM, EELS, and EFTEM*

INTRODUCTION

The prefix "Nano" is derived from the archaic Greek word nanus, which means "extremely little or short in size." Although we refer to nanotechnology as a "little science," this does not imply that it only has small shapes and outcomes. 1 This review is interested in the features of nanoparticles such as their characterization, categorization, health-relatedness, and phrenology.2 Analysis of nanotechnology can result in control of conditions on an atomic and molecular scale.

In today's textiles, nanotechnology creates a key focus by employing distinctive features and also stimulating techniques for textile matter advancement. Nanotechnology is emerging as a much-anticipated sector with enormous implications in every industry of technology. It has also driven an increase in research and development initiatives. Nanophysics and nanostructured materials are also piqueing the interest of textile and polymer researchers and industrialists.

The materials have various specific properties that differ from their comparable dimensions; their dimensions have been reduced to the nanoscale. A snag is formed in the characterization of nanoparticles by their characteristics, yet the same features make them more appealing for their use. VSM measurements are used to investigate magnetic characteristics (Vibrating Sample Magnetometer). The X-ray diffractometer (XRD) was used to confirm and identify ZnO nanoparticles. 4 Nanotechnology allocates particles of size range between 1 and 100 nanometer at least for a dimension.5 To recognise and authorise the synthesis and approach of nanoparticle characterization is required.6 Material science provides various types of characterization techniques.7 Nanoparticles can be differentiated on the basis of dimensions such as one, two, and three dimensions.

TYPES OF NANOPARTICLES

Inorganic Nanoparticles

Metal and metal oxide particles are known as inorganic nanoparticles. These particles do not include carbon.

Carbon Based

Fullerenes, graphine, and carbon nanotubes are examples of carbon-based nanoparticles. Carbon-based nanoparticles include nanotubes and carbon nanofibers.

Liposomes

The liposome architecture includes a sphere-shaped blister to contain and transport the molecule of interest, as well as one or more phospholipid bilayer layers. Food and agricultural fabrication necessary in enclosing are broadening the supply technique that can capture unsteady compounds.

Dendrimers

Every study field has its own set of terminology and circumstances, and dendrimers have a plethora of temporary construction nomenclature to explain the chemical processes that occur at their surface. Dendrimers with well-defined molecular structures are dendritic polymers.

Characterization of Nanoparticle UV-Visible Absorption Spectrosco

Absorbance spectroscopy is used to identify the optical properties of a solution. A light from the sample solution is used to quantify absorbed light. Beer Lamberts Law may be used to calculate the concentration of a solution based on its absorbance. The absorbance was evaluated at each variation of the wavelength. 13 Azadirachta indica was synthesised with iron nanoparticles by the identification of suitable surfaces. Plasmon resonances with high band strengths and peaks were detected using UV-visible spectroscopy in the range of 216–265 nm.

X-Ray Diffraction (XRD) Analysis

XRD is a contact-free, rapidly rising approach that is ideal for learning. It is particularly important due to its restorative properties and its possession of X-ray photons in the nanoscale range.15 X-ray diffraction is used for the resolution of morphology and crystallographic structure. The amount of components affects the increase and decrement in strength and is also utilised to initiate metallic behaviour of particles, which provides information about transitional symmetry, size, and structure of the cell where the atoms are positioned from peak strengths.

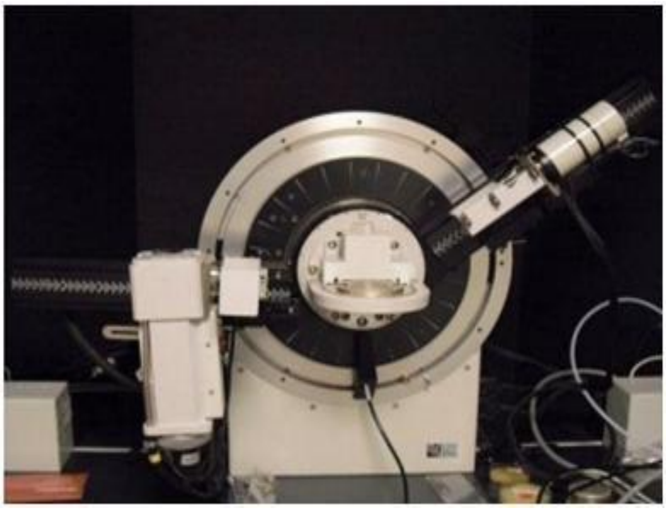

Figure 1. X-Ray Diffraction (XRD)-Equipment17

Scanning Electronic Microscopy (SEM)

The interaction of atoms and electrons causes the sample to produce signals that provide information about the surface topography, composition, and electrical conductivity.

SEM is used to provide very high resolution pictures that disclose information about surface sizes ranging from 1 to 5 nm. SEM micrographs with a large depth field are used to provide a three-dimensional image of the sample surface. SEM may also be used to investigate the chemical makeup of the sample utilised during the EDX process. See Figure 2

EDX

One of the X-ray Florence spectroscopy types that investigates a sample by interaction between electromagnetic radiation and matter, evaluating X-rays generated by the matter in reaction to striking the charged particles. A high-intensity beam of charged particles such as electrons or protons, or an X-ray beam, is focused on the object to be investigated. See Figure3

Figure 2. Scanning Electronic Microscope (SEM)

Figure 3. Scanning Electronic Microscope (SEM)

Thermal Conductivity of Nanomaterials

Because solid materials have higher thermal conductivity than liquid materials, fluids with higher capacities can achieve several thermal management options. The thermal conductivity of particle combinations is expected to increase. 19

Atomic Force Microscope

It provides 3D visualisation as well as qualitative and quantitative data on a variety of physical parameters such as size, morphology, surface texture, and roughness. Statistical data, such as size, surface area, and volume distributions, may also be obtained.

The Transmission Electron Microscope

The goal of developing such a microscope was to reach a higher resolution than light microscopes. 21 A transmission electron microscope is a complicated device that allows a high intensity electron beam to pass through a very thin object to be studied.

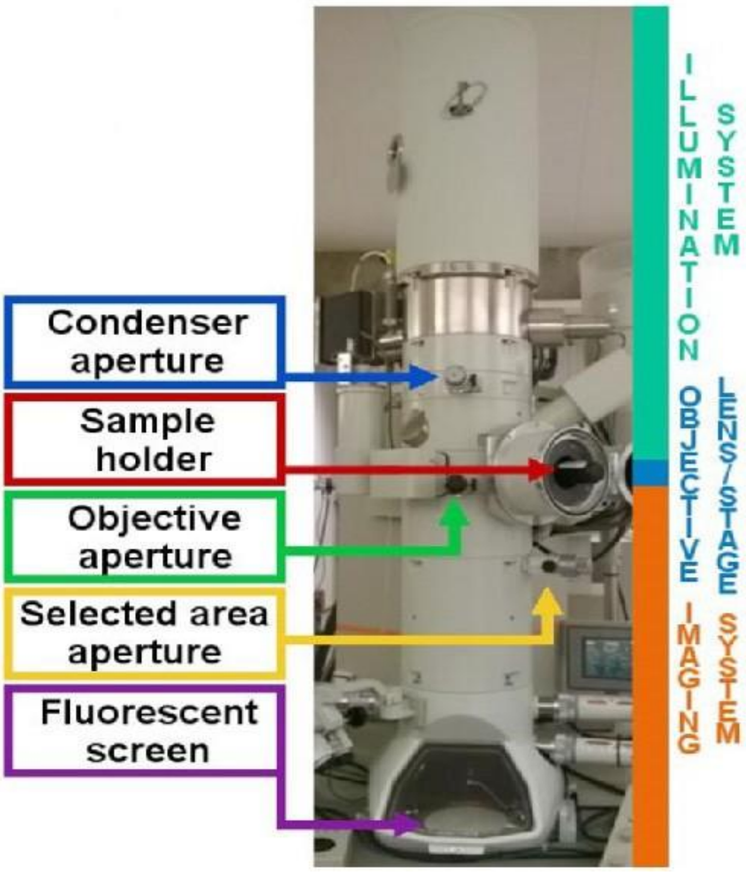

Figure 4.Ttransmission Electron Microscope40

Synthesis of Nanomaterialhigh-Temperature Thermal Decomposition

With the assistance of cuprous complexes, high-temperature thermal decomposition is employed to obtain a generic approach for the production of distribution nanoparticles of transition metal oxides. Mx Cup (M = metal ion; Cup = N-nitroso-N-phenylhydroxylamine,[C6H5N(NO)O]).

Liquid-Liquid Interface Reaction

The nanoparticles are created and covered up by a liquid-liquid interface. The particles are energetic at the liquid-liquid interface and rapidly achieve equilibrium. 23 However, unlike other procedures, this process is one step permitted for the creation of nanoparticles and can line up under numerous environmental conditions. 24

BOTTOM-UP METHOD

There are different types of bottom-up approaches which are as follows:

- **Sol-gel -** due to its simplicity, this process produces the greatest quantity of nanoparticles. A Sol-gel is a big solid molecule submerged in a solution. This approach makes use of metal oxides and chlorides as precursors. It is a wet chemical process in which a chemical solution reacts as the precursor to tiny particles.
- **Chemical Vapor Deposition (CVD):** The substrate Sol-gel - due to its simplicity, this process produces the greatest quantity of nanoparticles. A Sol-gel is a big solid molecule submerged in a solution. This approach makes use of metal oxides and chlorides as precursors. It is a wet chemical process in which a chemical solution reacts as the precursor to tiny particles. Chemical Vapor Deposition (CVD): The substrate temperature is the regulating factor in CVD. On the surface of the repaired and used substrate, a thin film is assembled. The advantage of CVD is that the nanoparticles are more pure, homogeneous, rigid, and sturdy. On the other hand, it is inconvenient since specific instruments are required, and the gaseous byproducts are more toxic25.

TOP-DOWN METHOD

There are some of top-down methods studied:

- Mechanical milling: among the several top-down procedures, this technique is commonly used for the production of nanoparticles. This approach is helpful for post milling and plasticizing nanoparticles since the individual materials are milled in an inert atmosphere.

- Laser ablation: Laser Ablation Synthesis in Solution (LASiS) is a well-known method for producing nanoparticles using various solvents. Laser beam reflection or radiation of metal metals submerged in liquid solutions liquefies a plasma crest from which nanoparticles are produced.

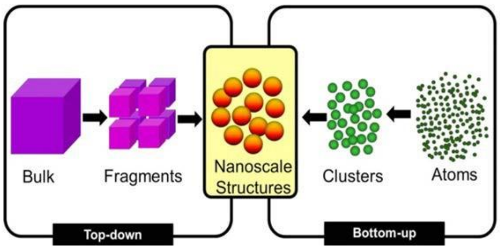

Figure 5.Top-down" and "bottom-up" synthesis of nanofabrication

Literature Review

Juh Tzeng Lue and colleagues36 This review focuses on the nanoparticle's physical characteristics, which are as follows: Structures, field emission, electrical and magnetic characteristics, linear optical properties, and nonlinear optics Nanoscience advances via the use of novel physical characteristics and technologies in sample preparation and device manufacture. There are three forms of sample preparation. 1) Nanoparticles of metal 2) insulator nanoparticles, 3) semiconductor quantum dots, and 4) magnetic ferrite nanoparticles are all studied. Following an examination of nanotubes and nanowires, it is found that carbon nanotubes are the most promising due to their stiffness, strength, elasticity, and field emission. Aside from that, nanodevices are being researched. For physical qualities, the researcher concentrated on the size of classical and quantum nanoparticles at the same time.

Victor Songmene and colleagues 37 The main goal of this research is to start characterising, measuring, and controlling nanoparticles. Because past research indicates that nanoparticles have a harmful influence on the environment and human health, the measurements were studied using three distinct types of microscopes: the SPM (scanning electron microscope), the TEM (transmission electron microscope), and the AFM (atomic force microscopy). Perfect measurement is improved by the emergence of correction factors. Various solutions for reducing emissions during machining and friction were also investigated. This technique emits two distinct sizes of nanoparticles, and data correction is necessary in this variant to improve measurement efficiency. Sathish Boddolla and colleagues 38 This research focuses on nanoparticle characterization since understanding the use and characteristics of nanoparticles requires knowledge of characterization. Various approaches are researched for characterization, such as 1) X-ray diffraction, which offers information on unit dimensions, bond angles, chemical composition, and crystalline structure of naturally produced materials, 2) A scanning electron microscope (SEM) provides a three-dimensional picture that allows us to identify the surface of a material as well as analyse its chemical makeup. 3) Energy Dispersive X-Ray (EDX) analysis of sample elements or chemical characterization 4) The Transmission Electron Microscope (TEM) detects a phase based on assumptions provided by chemical analysis literature and the researched system. 5) DC conductivity measures a material's capacity to conduct an electric current. The particle size analyzer (PSA) resolves the nanometer size range of particles, which is an important aspect of the characterization of nanoparticles. 7) Ultraviolet Dispersive Spectroscopy detects absorption, transition in liquids or opaque materials, and so on. 8) Differential Thermal Analyzer/Thermal Gravimetric Analysis In this work, we explored porosity, solubility, particle size distribution, aggregation, hydrated surface analysis, zeta potential, wettability, adsorption potential, shape, and size of interaction surfaces.

Ajeet Kumar and colleagues39 This research study focuses on nanoparticle characterization approaches. Because of their applicability, it is necessary to characterise nanoparticles for various physical, chemical, and biological characteristics. We can obtain extensive information on physical and chemical characteristics, as well as nanoparticles, thanks to various cutting-edge techniques. They characterise nanoparticles for biomedical applications utilising in vivo delivery. Several essential physiochemical features of nanoparticles are also investigated. The methodologies and procedures for characterising nanoparticles are as follows: 1) Morphology and topography analysis, which provides information on the shape and size of the particle, Dynamic light scattering is used to investigate particle distribution on size ranges and hydrodynamic particle size. 3) Electron microscopy is used to disclose the specific shape and surface of nanoparticles. 4) Other approaches examined include density gradient and size exclusion centrifugation for particle size determination, as well as a particle size theory calculator. Furthermore, nanoparticle surface area and porosity are employed to restrict some parameters in vivo. Surface charge analysis is explored to determine the surface charge of a nanoparticle colloidal solution. The chemical and physical composition of nanoparticles is controlled by stability evolution. Agglomeration, sedimentation, and creaming, change of crystalline state, stability concerns with the sodification process, chemical stability, and stability issues connected to biomolecule loading, sterility evaluation of nanoparticles, endotoxins, and bacteria were all investigated.

Arnaud Mayence et al.40 This proposal includes an examination of the chemical and structural properties of inorganic nanoparticles with specific morphologies and assemblages created using various transmission electron microscopy methods. Electron Diffraction Tomography (3D EDT), a recently developed technology, is used to determine the three-dimensional composition of crystalline media. The use of thermal disintegration of metal composite forerunners in organic solvents with the highest boiling point and the hydrothermal technique for mixing spherical and aeolotropic nanoparticles are described. The investigation of filling orders and defects in nanoparticle production was carried out by increasing the small angle diffraction mode in electron diffraction tomography. Iron manganese oxide composite nanoparticles were studied in three dimensions using High Resolution Transmission Electron Microscopy (HRTEM), Scanning Transmission Electron Microscopy (STEM), selected area electron diffraction (EFTEM), and Electron Energy Loss Spectroscopy (EELS).

Suman Ghorai et al.41 present novel approaches for quantifying aerosol characteristics in their thesis, including scanning transmission X-ray microscopy (STXM), where we may compute a function of humidity, atomic force spectroscopy (AFM), micro-FTIR spectroscopy, and scanning electron microscopy (SEM). Aerosol density, elemental content, and hygroscopic characteristics all play a role in controlling aerosol effects. To determine the influence of aerosol particle composition on the hygroscopic characteristics of NaCl, micro-FTIR spectra were employed. We can recognise the density and elemental composition of micrometer-sized nanoparticles by combining STXM and AFM. Chemical transformation and atmospheric RH influence the composition of atmospheric particles.

Mechanical features of these nanomaterials drive single crystal to single crystal reactivity. We basically recognised the mechanical properties of a series of organic nanocrystals. The prediction of diverse fusions is evolving in order to construct reactive films with customizable physical and chemical characteristics.

Raliya R et al.42 investigated various critical aspects of nanoparticles in their review work. We concentrated on the production and characterization of nanoparticles in particular. A nanomaterial is any atomic material with a scale of 1 to 100 nanometers. Nanotechnology is popular owing to its superior capacity to react quickly and cover a larger surface area. Carbon, metal, dendrimes, and composite nanomaterials are the most commonly produced nanomaterials. Nanomaterials are favoured in a variety of disciplines, including the environment, medicine, commerce, military, and agriculture. We considered various generic approaches to nanomaterial production in two ways. Bottom-up and top-down procedures are used. Bottom-up processes involve particles chemically assembling themselves to form a substance. Similarly, in the top down process, bigger particles, such as nanoparticles, form the things. Because these processes use a large quantity of energy, the pressure and temperature rise. The use of microorganisms is a novel approach to producing nanoparticles. Because microorganisms possess a huge number of enzymes, this method of production is easier. Fungus proteins are employed to stabilise the biosynthesized nanoparticles. Characterization is carried out in order to control the stability of nanoparticles. Various strategies for characterising nanomaterials have been discussed.

Heera P. and colleagues 43 since the last several decades, there has been a surge in scientific interest in the topic of nanoparticles. Several disciplines, including information, environmental, and meet. Particles are better suited to nanotechnology. We investigated how nanotechnology plays a crucial part in day-to-day living directions in this review study. We research a variety of nanoparticles, including inorganic, polymer, solid lipid, liposomes, nanocrystals, and nanotubes. Solvo thermal synthesis, chemical reduction, and laser ablation procedures are used to create nanoparticles both physically and chemically. We concluded that sol-volatile thermal synthesis would be the optimum method for producing nanoparticles. UV-absorption, X-ray diffraction (XRD), and

Fourier transfer infrared (FTI) are some further characterization methods for nanoparticles. Nanoparticles have a variety of uses in the food industry, including increasing nutrition and flavour, as well as lowering manufacturing and consumer prices. AM Ealias et al.9 In this review, we looked at certain characterization methodologies, synthesis procedures, and nanoparticle applications. Nanoparticles are divided into three types: inorganic, organic, and carbon-based nanoparticles. There are three basic procedures used to create nanoparticles: physical, chemical, and mechanical. According to their appearance, nanoparticles can be zero-dimensional, with all of their properties concentrated in a single spot. In terms of categorization, inorganic nanoparticles are further subdivided into metal and metal oxide based nanoparticles. Dendrimers are organic nanoparticles, whereas graphene is a carbon-based nanoparticle. Nanoparticles have a wide range of applications in electronics, cosmetics, medicine, and food. We investigated how nanoparticle characterisation methods alter with size, shape, and concentration. It also takes into account the appearance of nanoparticles in the state in which it is. SL Pal et al.1 This review study evaluated the health implications of working with nanoparticles. We concentrated on the characteristics of nanoparticle synthesis, application, and characterization. We noticed that the term "nano" was discovered in the early decades in order to recognise its uses in numerous industries. The capacity of nanoparticles to build themselves is applied in a wide variety of industries. According to their appearance, nanoparticles are classified into three types: one-dimensional, two-dimensional, and three-dimensional. This review research investigated many types of nanoparticle preparation techniques, such as the emulsion-solvent evaporation method, the double emulsion and evaporation method, the salting-out method, the emulsion diffusion method, and the solvent displacement precipitation method. We may conclude from extensive trials, studies, and debates that the emulsion solvent evaporation method may be the optimum method for creating nanoparticles. Nanoparticles are most likely involved with the health of several uncommon sections of the body, such as the lungs, digestive tract, and skin. Abhishek Garg and colleagues 44 In this paper, many approaches for characterising and preparing nanoparticles are described. Furthermore, they have discussed nanoparticle formation utilising numerous approaches, like: 1) dispersion of completed polymers 2) Polymerization technique 3. Technology for supercritical fluids 4) Method of Ionic Gelatine The size of the nanoparticle is the most important characteristic in nanoparticle characterization. We can identify the fusion and approach of nanoparticles by describing them. Various approaches can be used to determine particle size. Nanoparticles are commonly employed to improve human health. It is concluded that non-soluble and poorly absorbed chemicals can be changed into positive forms through various methods of management. ASN Husainy and colleagues45 This research focuses on the features of nanofluid preparation and stability. A nanofluid is a fluid that contains nanometer-sized particles known as nanoparticles. Nanofluid preparation is divided into two categories. Production and dispersion occur concurrently in this process. This procedure consists of two steps: first, it is made, and then it is dissolved. This approach is widely used. The properties of nanofluids are classified into five types: thermal fluids, heat transmission, particles, colloid, and lubrication. Stability of nanofluids is classified using various methods such as zeta potential analysis, sedimentation method, centrifugation method, spectral analysis method, and the 3 method. Stability enhancement processes include surfactant addition, surface modification techniques, pH control of nanofluids, and ultrasonic agitation. Nanotechnology is significant in a variety of applications, such as biomedicine, transportation, and electronics. Xinwie Wang and colleagues46 The experimental results of the thermal conductivities of nanoparticle fluid mixes containing nanoparticles such as Al_2O_3 and CuO, which dissolve in base liquids, are the subject of this work. The steady state approach and the transient hot wire method are the two methods for measuring the thermal conductivities of liquids. There are several methods for dissolving Al_2O_3 powder in water. 1. Method of Mechanical Blending 2. Polymer-coated particle method 3. Using the filtration technique, coat the particle. The thermal conductivity of a nanoparticle fluid mixture is related to the particle size. It is concluded that nanoparticle mixtures can be used to boost the thermal conductivities of base fluids. The increase in heat transmission in fluids is due to complementary phenomena in nanoparticle fluid mixes, such as microscopic motion, particle structure, and surface characteristics. M. Joshi and colleagues 4 This review focused on nanoscience and nanotechnology, which are important technologies in the twenty-first century. Nanotechnology is required for functional and high performance textile applications in research and development activities such as polymers and advanced materials for improving property and gaining newer multifunctional ties. As there are many challenges and for achievement, researchers would rely on cost, availability, and ease of handling, and various instrumental techniques were described in this paper. When the size is lowered to the nanoscale range, the material characteristics change. For nanotechnologies such as nanofinishing, nanocomposites, nanocoatings, and nanofiber, several characterization approaches were employed to increase the attributes of the nanomaterial. Particle size analyzers, electron microscopy (SEM, TEM, and HRTEM), atomic force microscopy, X-ray diffraction, Raman spectroscopy, and X-ray photon spectroscopy were also used to regulate nanoparticle size and size distribution. This paper looks at the main idea and method behind these instrumental techniques used to study nanotechnology in textiles.

Ravi Sharma and colleagues15 This work focuses on a strong X-Ray Diffraction approach for characterising nanoparticles (XRD). It is a commonly used and very successful technique for studying the crystallographic characterisation of materials, thin film thickness, structural characteristics, and atomic organisation in amorphous materials. There are other scanning methods, but X-Ray Diffraction is thought to be the most successful since it is non-destructive and has a wavelength in the nanometre range. XRD is utilised in a variety of applications, including polymer crystallinity analysis, texture analysis, and residual stress. It functions similarly to a fingerprint. They came to the conclusion that Single Crystal and Polycrystalline diffraction are equivalent. The XRD equipment is made up of four parts: an X-ray detector, an X-ray source, a specimen stage, and reception optics.

P. Saravanan and colleagues47 The synthesis and characterization of nanomaterials are explained in detail in this review. The paper expresses the characteristics of the synthesis and characterization of nanoparticles of metals, nonmetals, metal mixtures, and oxides in the narrow form of film and heavy configuration. Two-phase nanocomposite magnets are also being investigated.

The combination of two methods Metals, nonmetals, and oxides are developed using 1)high-temperature thermal decomposition and 2) liquid-liquid interface reactions. In addition to physical methods, such as high energy ball milling, thick and narrow films are manufactured. The physical and chemical procedures based on size were discussed. The main point of this paper is to look at how different nanomaterials have changed over time in terms of their range, size, shape, and chemical make-up.

Applications of Nanoparticles

Nanoparticles are mostly used in biological applications such as medication and gene delivery, cancer treatment, and diagnostic equipment. These applications have been under scrutiny for many years. Following this, nanoparticles are frequently employed in the display and brightness of monitors and television sets due to their small size and form and higher surface ratio. 28 Nanoparticles have recently been employed in industries such as information and communication technology, power engineering, industrial engineering, environmental engineering, the chemical industry, medicine, pharmaceuticals, and cosmetics. 29

Applications of Nanoparticles in Cancer Treatment

Various nanoparticle systems are being researched for biological applications in cancer therapies. As a result, some of the more costly metals, such as gold and silver complexes Au and Ag, as well as metal oxides such as magnetite Fe_3O_4, have a strong response because they include quantum dots and are referred to as natural nanoparticles."

Application of Nanoparticle in Gene Delivery

Gene transfer It is an essential approach because it may readily allow a gene of interest to exhibit its encoded proteins in a suitable host cell. Under gene delivery techniques, several accelerated vectors, such as retroviruses and adenoviruses, nucleic acid electroporation, and nucleic acid transfection, are used.

Electronics

The use of nanoparticles in displays is now prompted by the demand for large display sizes and high brightness in monitors and television sets. Light-emitting diodes (LED) in current displays employ materials such as nanocrystalline lead telluride, cadmium sulphide, zinc selenide, and sulphur dioxide.

Medicine

Tissue engineering with nanotechnology can replicate or mend damaged tissues. We can limit medicine consumption and adverse effects by taking the recommended dosage. This lowers the cost of the medications as well as their adverse effects. Tissue engineering can be used instead of organ transplantation and implants. 33

Food

The incorporation of nanotechnology improves food manufacture, processing, protection, and packaging. By using nanocomposite packaging technology for food packaging, for example, an anti-microbial item on the covered film surface is known. 34

Construction

Nanotechnology has made construction technologies more economical, accessible, and safe. When nanosilica (SiO_2) is mixed with regular concrete, the nanoparticles can improve the material's mechanical properties while also increasing its strength. The addition of haematite (Fe_2O_3) nanoparticles to the concrete increases its toughness. Steel is a more easily accessible and widely used building material. Steel features may be improved by applying nanotechnology to steel, for example, in bridge building, the use of nanosized steel enables stronger steel cables. 35

CONCLUSION

In the twenty-first century, nanotechnology plays a significant part in human existence. We ended this review study by discussing the characterization, instrumentation, synthesis, physical, chemical, mechanical, biological, and applications of nanoparticles. We investigated many types of nanoparticles, including inorganic, polymer, solid lipid, liposomes, nanocrystals, and nanotubes. There are three types of nanoparticles: carbon-based, inorganic, and organic. In physical terms, nanoparticle size is both classical and quantum. Strategies for nanoparticle emission during milling and friction were studied. We investigated characterization using several approaches in order to recognise the characteristics and uses of nanoparticles. Characterization varies according to size, shape, and concentration. The correct form and surface of the nanoparticle may be achieved using electron microscopy, as well as in vivo delivery nanoparticles for biomedical applications. The chemical and structural properties of nanoparticles are assembled using transmission electron microscopy methods. STXM, AFM, and SEM were employed to determine the aerosol characteristics of nanoparticles. Nanoparticles have uses in the environmental, medical, commercial, military, and agricultural domains. Chemical, physical, and mechanical methods are used in the synthesis of nanomaterials. Nanoparticles are used to increase the thermal conductivity of base fluids.

NOMENCLATURE

XRD - X-ray diffraction
SEM - Scanning Electron Microscopy
EDX - Energy Dispersive X-Ray
TEM – Transmission Electron Microscopy
PSA - Particle Size Analyser
TG/ DTA - Thermal Gravimetric Analysis/ Differential Thermal
Analyser
HRTEM - High resolution transmission electron microscopy STEM - Scanning transmission electron microscopy EFTEM - Energy-filtered transmission electron microscopy EELS - Electron energy loss spectroscopy
VSM - Vibrating Sample Magnetometer
UV – Ultraviolet
FTI - Fourier Transfer Infrared AFM – Atomic force microscope

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