Review of Nanotechnology and Properties of Nano Particle

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ABSTRACT

Nanotechnology deals with the phenomena and structures of materials of size in the range 1 to 100nm. Nanoparticles show many novel properties that are considerably dissimilar from those shown by their bulk counterparts. Chemical compounds with Iron (III) oxide Fe2O3 as their principal components are known as ferrites. Nano ferrites find wide range of applications in magnetic memories, noise filters, isolators, ferro fluids, transformer cores, gas sensors, smart sensors etc. Metal nano structures findapplications in biochemical and medical applications. Lot of applications ofnano materials is explored on daily basis. Therefore, nano science has becomethe focus of modern materials science, because of the potential technologicalimportance, which stems from the unique physical properties of nano materials.

KEYWORDS- Nanotechnology, Nanoparticles, Metal, Magnetic, Nano Ferrites

INTRODUCTION

The term 'nano' is originated from the Greek expression 'nanos' means dwarf. The science of particles, whose any one dimension is of the size scale 1 to 100nm is known as nano science. When particles are brought to a nano scale, the surface to volume ratio increases, since a large fraction of the atoms will be present at the surface. As a consequence, The surface properties of the particle transcend those of the particle in the inside. As a result of this, the quantum size effect occurs.When a particle reaches the nano scale the physical, chemical and biological properties of the material differs much from the properties shown by its bulk matter. Hence in a nano material, its fundamental properties like hardness, melting point, optical and magnetic characteristics can be changed without changing its chemical composition.

Nanotechnology is a multidisciplinary subject which requires contributions from physics, chemistry, material science, biology, engineering, pharmacology etc. Nanotechnology finds wide range of applications in basic branches such as electronics, optics etc as well as in ultra-modern fields namely nano medicine and nano biological system. Nanotechnology has changed human life immensely, and the advances in nanotechnology are progressing at such an incredible pace, that its impact on human life and its wellbeing will be very high in times to come. Nanoparticles are also widely used in cosmetics. Nano TiO_2 is used in sunscreen lotions, as it enhances the Sun Protection Factor (SPF) which in turn eliminates stickiness. These nanoparticles will block the UV radiations for a long period and will thus help to retain the natural skin colour. In recent past, technology in ferrites has assumed new importance.Modern applications of ferrite nanoparticles embrace gas sensing, catalytic application and high density magnetic storage media. Ferro fluids are steady colloidal delays of magnetic nanoparticles in organic or inorganic liquid carriers. Bio-compatible ferro fluids find wide range of biomedical applications like cell separation, purification and magneto hyperthermia of tumour cells.

NANO PARTICLES

Nanotechnology is concerned with the production & control of materials at the nanoscale (nm) scale, either by scale - up from single atomic groupings or by reducing or purifying bulk materials. A nanometre is $1x10^{-9}$ m or one millionth of a millimeter. Particles in the size range of 1 to 100 nm are called nanoparticles. The physicochemical and biological properties showed by nanoparticles are significantly different from which we observe in bulk materials. Bulk materials possess relatively constant physical properties regardless of their size, but nanoparticles sized dependent physic chemical properties. Nanoparticles are intermediates between the bulk materials and the atomic and molecular structures. Nanoparticles materials possess unique size dependent property known as specific surface area which is the ratio of surface area to volume. Smaller the size of particle greater will be the specific surface area. Larger surface area means more contact with the national switch enhance the reactivity and properties of the nanoparticles.

Nanotechnology is an interesting branch of material science. Nanotechnology has emerged as an interdisciplinary field combining biology, physics, and chemistry and material science. The production of nanoparticles can be achieved through two methodologies known as „top-down approach‟ and „bottom-up method‟. In the top-down method, the bulk material is broken down into particles at nanoscale through different processes like grinding, milling etc., In the bottom-up approach, the atoms self assemble to form new nuclei which grow into a particle of nanoscale.

Metal Oxides in Nature

Over 60% of the bio minerals now known to be essential for an organism's proper operation are said to be correlated to either hydroxyl moieties or water molecules, allowing for the quick release of ions in solution [Zheng et al. 2014]. Particularly metal oxides serve as a crucial building block for the creation of useful nanomaterials. The lowest free energy states for the majority of metals on the periodic table in an oxidizing environment, such as the earth's atmosphere, show applications ranging from semiconductors to insulators [Yuan et al. 2013]. Since SiO_2 and Al_2O_3 are irreducible oxides, they are the two most frequently utilized supports for catalysis. Semiconductors with high electrical resistivity, including ZnO and SnO_2, offer different gas sensor templates. Surprisingly, the characteristics of metal oxides used in technology are not that dissimilar from those found in natural systems. [Sun, C., Su et al. 2013]. Within these magnetosome-containing organelles, magnetite nano crystals are synchronized with the geomagnetic field of the Earth. For instance, during migration, freshwater salmon use these magnetic nanoparticles in the nasal canals of their forehead as a biomagnet compass.

PROPERTIES OF NANO PARTICLES

Physical & chemical properties of nanoparticles that may change at the nano scale include.

- Color.
- Melting temperature.
- Crystal structure.
- Chemical reactivity.
- Electrical conductivity.
- Magnetism.
- Mechanical strength.

Oxides are becoming a very promising n-type oxide semiconductor. In the past decade, global research interest in wide band gap semiconductors is attracted towards oxide due to its excellent properties as a semiconductor material. The high electron mobility, high thermal conductivity, good transparency, wide direct band gap 3.37 eV, large exaction binding energy and easiness of growing it in the nanostructure form make metal oxide suitable for optoelectronics, transparent electronics, lasing, sensing and a wide range of applications.[Vidal-Abarca et al. 2008]

Mechanical properties

The main mechanical qualities relate to observables at high temperatures (superplasticity) and low yield (stress & hardness). High heat capacity, high heat conductivity, low thermal expansion high melting point (1300^{o}C) and Soft material with an approximate hardness of 4.5 mohs scales.[Farhadi et al. 2013]

Chemical properties

For absorption & catalysis, metal oxides are utilized for both their redox & acid/base characteristics. They are used as additive to concrete, sunscreens, skin care lotions, antifungal properties, food additive, vulcanization of rubber, natural rubber related polymer converting more durable materials adding sulphur (accelerator) forming cross-links.

MAGNETISM

Magnetic materials are time honoured materials and have guided to some of the most important advancements in technology to date. Magnetism and magnetic materials play ansignificant role in our life. In last two decades innovations in the field of nano magnetism and magnetic nanomaterials are subjects of intense research and attracted the attention of researchers in all over the world. Magnetism is a very interesting and fascinating phenomenon from fundamental physics point of view as well as for technological applications. Any material which can be magnetized in external magnetic field is named a magnetic material.

ORIGIN OF MAGNETISM

All materials are made up of atoms which consist electrons, protons and neutrons. Among them the protons & neutrons are confined in nucleus while the electrons revolve around the nucleus in different orbits. An electron revolving around the nucleus forms a tiny current loop which is equivalent to a magnetic dipole. In addition, electron also spins about its axis and results in spin moment. In a macroscopic view these moments can be treated as magnetic dipoles. The orbital & spin motions of electrons in atom are responsible for different magnetic properties of materials. Generally due to random orientation of orbital and spin moments of atoms they cancel out each other. However, orbital and spin moments try to align themselves in the direction of magnetic field (H) and the material becomes magnetically polarized [Stephen B. Et al. 2001; Cullity B.D 1972].

CLASSIFICATION OF MAGNETISM

Different materials react quite differently in an external magnetic field. The response of the materials depends on various factors such as atomic distribution, molecular structure and magnetic field associated with the atoms. The spin moments of paired electrons cancel each other resulting in no net magnetic moment in the material; however, there is always some net magnetic moment in materials having unpaired electrons. Different materials show different interactions with magnetic field. On the basis of the nature of interactions, materials are mainly classified into five types [Chikazumi S 1964] as given below:

a) Diamagnetism
b) Paramagnetism
c) Ferromagnetism
d) Ferrimagnetism
e) Antiferromagnetism

a. Diamagnetism

Diamagnetism is a very weak and inherent character of all materials in presence of external magnetic field. Diamagnetic character is masked when material also exhibits paramagnetism or ferromagnetism [Halliday D., 2002]. Diamagnetic materials are composed of atoms which have no unpaired electrons hence no net magnetic moment is observed. When these materials are exposed to external magnetic field, a current is induced in opposite direction to circulating atomic current and generates a very small and opposite magnetization [Jackson 1998]. This induced magnetization vanishes as external field is removed. This character of diamagnetism in any material is observed only in the absence of paramagnetism or ferromagnetism.

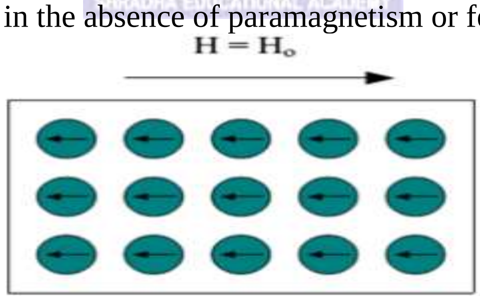

Figure1.1: Diamagnetic material: when magnetic field H_o is applied

b. Paramagnetism

Paramagnetic is the class of materials in which each atom or molecule acquire its own individual permanent magnetic moment. The magnetic moments in these materials are randomly oriented in absence of external magnetic field and therefore overall magnetization of the material remains zero. However, these randomly oriented moments try to align themselves in the direction of applied field and net magnetization is observed in the direction of the field as presented in Fig.1.2 (a) and (b). The magnetization returns to zero as magnetic field is vanished. These materials are known as paramagnetic materials and this phenomenon is called paramagnetism. Materials having unpaired electrons show permanent dipole moments and exhibit paramagnetism.

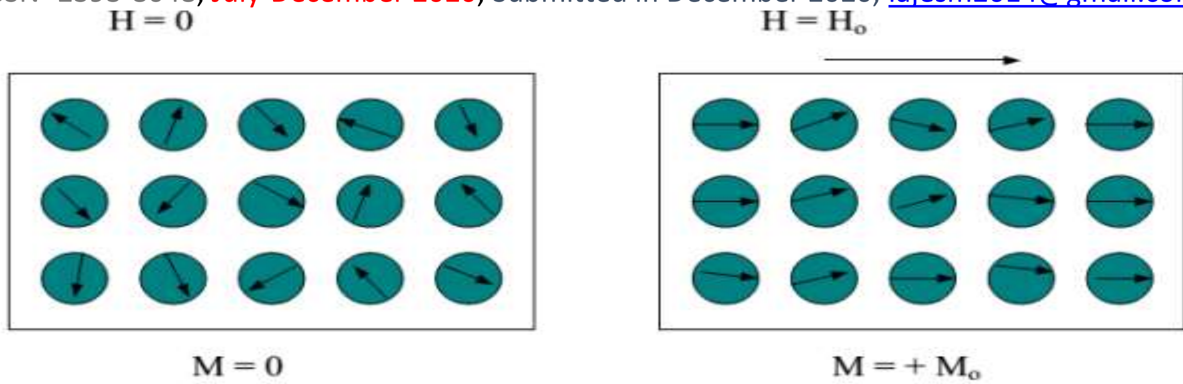

Figure1.2: Paramagnetic material when (a) H=0, all magnetic moments are random oriented (b) When a magnetic field Ho is applied, the atomic moments are oriented in the direction of the field

c. Ferromagnetism

Spontaneous magnetization flaunted by a material even in the absence of external field is known as Ferromagnetism. It is the strongest form of magnetism observed in materials like transition metals (Fe, Co, Ni) and rare-earth and their alloys. The origin of ferromagnetism in these materials is due to incompletely filled 3d and 4f shells. Ferromagnetic materials possess positive susceptibility with large values. As illustrated in Figure 1.3, these materials' spin moments are organized in a lattice & display very potent dipolar interactions, which encourage a parallel configuration of spin moments & ensuing significant spontaneous magnetization even in the absence of an external magnetic field.

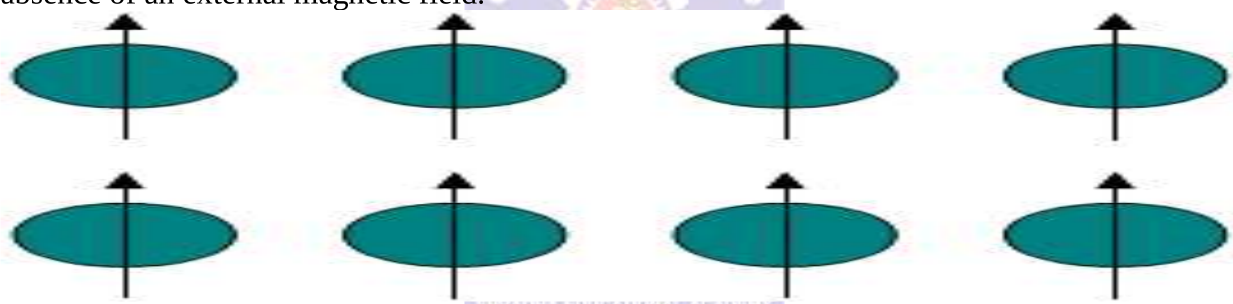

Figure1.3: Ferromagnetic material in the absence of external magnetic field

d. Antiferromagnetism

In some materials antiparallel spin alignment exists which results in cancellation of overall spontaneous magnetization and this phenomenon is called antiferromagnetism. Antiferromagnetic materials are very similar to ferromagnetic materials but due to opposite alignment of neighbouring magnetic spins, their magnetic moments are cancelled out in the non-existence of magnetic field as shown in Figure 1.4. Therefore, no net magnetization is observed and material's behaviour is similar to paramagnetic materials.

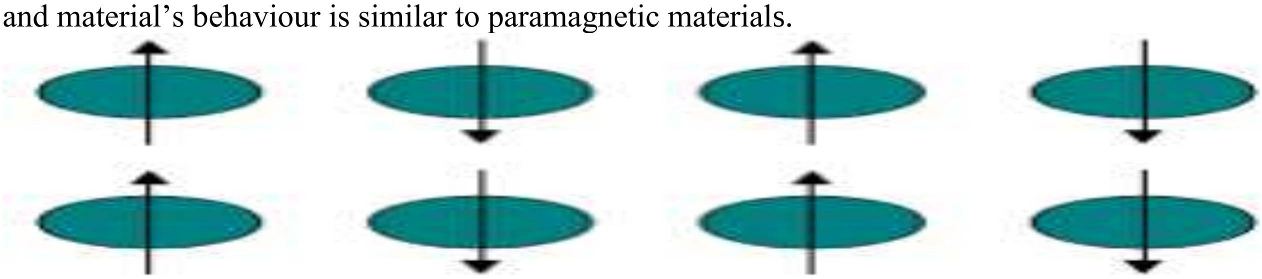

Figure: Antiferromagnetic material in the absence of external magnetic field

e. Ferrimagnetism

Ferrimagnetic materials are those materials which are microscopically like antiferromagnetic i.e., they have both spin-up and spin-down moments, but the magnetization of these two sub lattices is not equal and the difference of two sub lattices results in a net magnetization [Morish 1965]. Ferrimagnetism is generally exhibited by compounds which possess complex crystal structures.

Figure 1.5 shows spin arrangement in a ferrimagnetic material at room temperature in the non existence of applied field. Ferrimagnetic materials show spontaneous magnetization like that of ferromagnetic materials. Magnetization in ferrimagnetic materials vanishes beyond a critical temperature Tc, like ferromagnetic materials, known as the Curie temperature above which ferrimagnetic materials behave like paramagnetic materials.

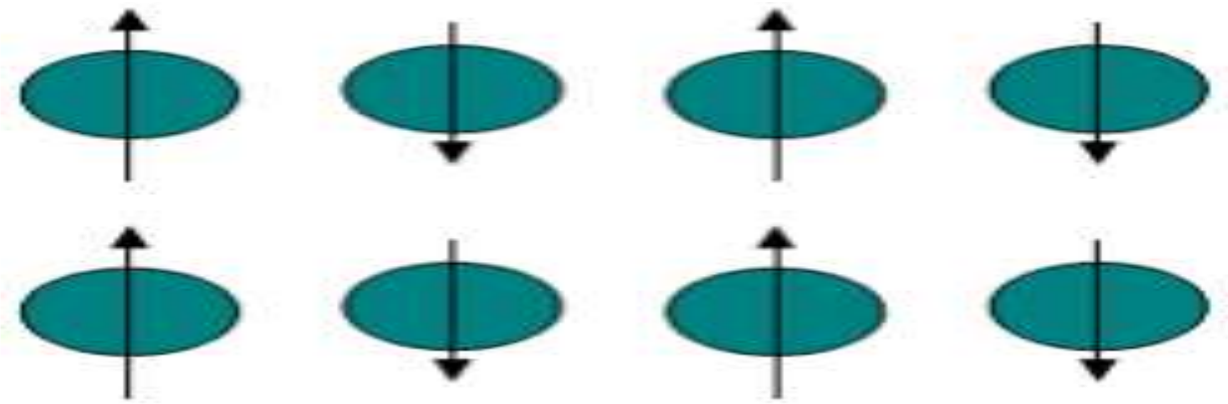

Figure: Ferrimagnetic material in the absence of external magnetic field

LITERATURE REVIEW

According to SitiKhodijahChaerun et al. (2022), the development of pharmaceuticals, agriculture, & natural remediation have all contributed to the growth of nanoscience& nanotechnology. Since the early 2000s, nanoparticles have been a major research and development focus in the field of materials science. Because copper is more reasonably priced than silver & gold, research into copper nanoparticles (in metallic copper & copper oxide) is intriguing from a financial perspective. It has been found that copper nanoparticles can be used as a stand-in for silver & gold nanoparticles in a number of applications, including those involving antibacterial and antiviral properties. Recent efforts in the study of copper nanoparticles have centered on developing more ecologically & sustainably friendly methods of manufacturing. Several factors, including the unfamiliarity of conventional technologies & environmental concerns they raise, have shifted research toward biological synthesis and its potential to manufacture copper nanoparticles. This paper explores the alternatives to traditional chemical synthesis (biological synthesis) by examining the factors (temperature, precursor concentration, pH, reaction time, & likely reduction mechanism) that influence the formation of copper nanoparticles. This study also describes the potential of copper nanoparticles as antimicrobial (antifungal and antibacterial) & antiviral agents, which is especially important as climate change causes new infectious diseases caused by viruses & bacteria. For the most efficient use of CuSO4•5H2O, CuCl2.2H2O, Cu(CH3COO)2.H2O, & Cu(NO3)2.3H2O as precursors, 80, 70, 60, respectively. If you're using CuSO4•5H2O, 2 mM is the sweet spot for your precursor concentration, and 4–10 is where you want to be for pH. The time required for the formation of copper nanoparticles varies from 1 minute to 120 minutes depending on the type of reductant& precursor used.

This study by JiayuZhang et al. (2022) was created to improve the photocatalytic activity of g-C3N4 nanosheets by incorporating La2(MoO4)3 nanoparticles with a size range of 200-600 nm & inserting a thiophene group. The optical properties of g-C3N4 were considerably improved by the incorporation of a thiophene ring into the matrix, as this allowed for an extra absorption at around 500 nm. As an added bonus, the thiophene group promotes electron delocalization, which in turn increases the distance between photogenerated electron-hole pairs. Thiophene-inserted g-C3N4 (TPCN) had La2(MoO4)3 loaded onto its surface, making it easy for electrons to go back and forth between the two materials. The improved photoactivity under visible light is a direct result of the lower conduction band (CB) of La2(MoO4)3 compared to that of TPCN, which allows photoexcited electrons in TPCN to move to the La2(MoO4)3 CB or further inhibit the recombination of electron-hole pairs. Tetracycline (TC) degradation rates of 0.048 min1 are presented by the ideal La2(MoO4)3/TPCN composite, which is 3.4 & 1.8 times higher than those of g-C3N4 & TPCN, respectively. Moreover, the cycle studies confirmed that the La2(MoO4)3/TPCN hybrid is very stable in its photocatalytic destruction of TC. This finding further highlights the merits of increasing g-photoactivity C3N4's by combining doping & surface modification.

JaisonJeevanandam et al. (2021*)* This provides an overview of the various common risk assessment techniques that are available to assess the toxicity of nanomaterials, as well as their drawbacks & difficulties. It also makes some recommendations for the development of original assays for assessing the toxicity of nanomaterials.It discusses nanomaterial toxicity in general and especially towards microbes, the risk assessment of nanomaterial toxicity towards microbes, and the associated shortcomings, future perspectives, and salient inferences. However, utilization of animal models for risk assessment of toxicity, involves various ethical clearance and regulatory issues, which has led to the emergence of in silico-based computational methods to evaluate nanomaterial toxicity. Even though risk assessment methods help to evaluate and identify the toxicity of nanomaterials, there are certain drawbacks, which hurdle the clinical translation of nanomaterials in the pharmaceutical field. In vitro studies are beneficial only to predict the cellular interactions, toxicity of nanomaterials, and their toxic mechanisms, for an initial screening of toxic nanomaterials.

Rehana P. Umme et al. (2021) In a PMMA matrix, thin films of BiFeO3–NaNbO3 composites were produced. For structural analysis, XRD & HRTEM were utilised. HRTEM images were utilized to conclude the grain size &shape morphology of samples. Any material's self-cleaning feature expedites its industrial applications. As a result, in addition to optical limiting performance, the photocatalytic& antibacterial activity of BiFeO3–NaNbO3 composite samples was investigated. When stimulated by 5 ns laser pulses at 532 nm, BiFeO3–NaNbO3 films produced in the PMMA matrix exhibit substantial optical nonlinearity. The weak absorption saturation & strong excited state absorption were used to explain the origin & magnitude of the measured optical nonlinearity. Ferrites' optical nonlinearities are generally unknown, and reports are few in comparison to organics, semiconductors, & metals. The photocatalytic performance of samples was determined using the Methyl Orange dye degradation method. The dye degradation rate in the presence of the catalyst is monitored over a specified time interval to determine the samples' photocatalytic performance. The material's antibacterial action might be demonstrated by destroying microbial organisms that come into touch with it. Additionally, the effect of particle size on photocatalytic activity was examined.

Elias JigarSisay et al. (2021) Membrane separation processes for wastewater treatment in dairy industry gives so many benefits such as less ecological footprint, reliable contaminant removal, low cost, possibility of renewable energy use, simple technology and can easily integrate with other processes. However, the fouling issue limits its widespread application. Numerous researchers have focused more on the development of self-cleaning membrane technology, which modifies membranes using heterogeneous photo-catalytic nanomaterials& their composites.In this paper, characteristics of dairy wastewater and possible membrane separation processes applications in dairy wastewater treatment are summarised and discussed. Fouling mechanisms of protein, the interaction of molecules, factors affecting fouling are highlighted. Physical, chemical, and self-cleaning fouling control and mitigation strategies are reviewed. Membrane modifications by renewable or non-renewable energy-driven heterogeneous photo-catalysis and possible ways that enhance the photocatalytic efficiency are also addressed. Finally, challenges & prospective solutions are reviewed.

Powar, Rohit R., et al (2020) We used a surfactant-assisted co-precipitation approach to synthesise MgFe2O4 ZMF nanoparticles with the common method ZnxMg1xFe2O4 (x = 0.00–

0.75) and evaluated their H2S gas sensing capabilities. Fourier-transform infrared & X-ray diffraction analyses suggest that a cubic spinel ferrite structure is generated. The influence of zinc substitution on the physicochemical parameters of MgFe2O4 was investigated and addressed in detail in this article. The polycrystalline ZMF nanoparticles are magnetic & shown superior gas sensing properties, including sensitivity to and selectivity for hydrogen sulphide (H2S) gas. While operating at temperatures ranging from room temperature to 400 °C, the ZMF gas sensors demonstrated excellent detection of a variety of test gases/vapors, including H2S, H2, Cl2, Co2, liquid petroleum gas, ammonia, & ethanol. At 400 °C working temperature, the Zn0.5Mg0.5Fe2O4 composition exhibited the strongest reaction to a 10 ppm H2S gas.

Ann Rose Abraham et al. (2019) Multiferroics, which enable sole manipulation of the magnetization vector using electric fields, have generated considerable interest in memory & logic device applications. To this end, we describe the encapsulation of non-ferroelectric magnesium ferrite (MgFe2O4) in a ferroelectric shell of BaTiO3 to create a system with tailored dielectric, magnetic, magneto-electric, & ferroelectric features. The interface outcome on strain transmission was discovered to have a significant effect on magneto-electric coupling and the system's electric and magnetic characteristics. The model polyhedral picture of MgFe2O4@BaTiO3 aided in gaining an understanding of the core-shell structure. The multiferroicity caused by the good coupling between the ferroelectric and magnetostrictive phases at the core-shell contact opens up a plethora of possibilities for device downscaling and data storage applications. Using TEM & atomic force microscope pictures, the effect of magnetostrictive stress on magneto-electric coupling effects and domain dynamics was further investigated. Interestingly, the creation of a superparamagneticmultiferroic system represents a breakthrough in magnetic data storage technology, enabling ultrahigh density magnetic data storage. The P-E hysteresis loop revealed evidence for spontaneous polarisation and the ferroelectric property exhibited by the multiferroic samples. The conclusion is that interface engineering provides a influential instrument for manipulating the magnetic, dielectric, & magneto-electric properties of multiferroicheterostructures for high density electrical energy & magnetic data storage.

CONCLUSION

Nanotechnology's potential application in virtually any industry is one of its most intriguing characteristics. The identification of nanoparticles (NPs) of various sizes, shapes, & composition has pushed the boundaries of technology in ways that were unimaginable to scientists a century ago. Huge varieties of nanoparticles have appeared in our daily lives, in every industry from medicine & electronics to paint and cosmetics. Nanomaterials have also found applications in a variety of fields, including drug delivery, biological labeling, environmental remediation, computer modeling, storage devices, and electronic devices. In high temperature response environments, metal oxide nanoparticles are used with energy-intensive techniques as laser ablation, ion implantation, & chemical deposition. The use of metal oxide nanoparticles is crucial in many fields of chemistry, physics, & materials research.

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