American Journal of Nano Research and Applications
2022; 10(2): 14-20
http://www.sciencepublishinggroup.com/j/nano
doi: 10.11648/j.nano.20221002.12
ISSN: 2575-3754 (Print); ISSN: 2575-3738 (Online)

Advances in Nanomaterials and Analytical Techniques

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To cite this article:
Adil Emin. Advances in Nanomaterials and Analytical Techniques. *American Journal of Nano Research and Applications*. Vol. 10, No. 2, 2022, pp. 14-20. doi: 10.11648/j.nano.20221002.12

Received: July 28, 2022; **Accepted**: September 28, 2022; **Published**: October 24, 2022

Abstract: The rapid development of nanotechnology is affecting and changing many application fields and has greatly promoted the development of science and technology and the progress of human civilization. Nanoscience & technology is considered a vital field of science and technology in this century, which will significantly impact the survival and development of human beings. Nanoscience and technology is a science and technology based on many modern advanced science and technology, it is dynamic science (dynamic mechanics), modern science (chaotic physics, intelligent quantum, quantum mechanics, mesoscopic physics, molecular biology) and modern technology (computer Technology, microelectronics and scanning tunneling microscopy, nuclear analysis technology) combined product, nanoscience technology will lead to a series of new science and technology, such as: nanophysics, nanobiology, nanochemistry, nanoelectronics, nanofabrication technology and nanometrics, etc. A large number of research results have demonstrated the huge application value of nanotechnology in today's energy, environment, biomedicine, and other fields. Therefore, the types, structural characteristics, properties, preparation methods, X-ray diffraction technology, scanning tunneling microscopy, atomic force microscopy, and scanning probe microscopy of nanomaterials are mainly introduced-applications and progress in performance analysis. The concept of nanotechnology, the process of generation and development and the prospect of its application are introduced. It is believed that nanotechnology will be a new productive force, cause a new industrial revolution, and promote greater progress of human society.

Keywords: Nanomaterials and Classification, Structure and Properties, Composition and Structural Characterization

1. Introduction

Nanomaterials are single crystals or polycrystals with a 1-100 nm grain size. Due to the small grain size, the number of atoms on the grain boundary is more than that in the grain; that is, a high concentration of grain boundaries is generated, thus making nanomaterials have Many properties are different from general coarse-grained materials, such as increased strength and hardness, low density, low elastic modulus, high electrical resistance, low thermal conductivity, etc. Furthermore, the continuous energy bands typically exhibited in large crystalline materials are split into energy levels close to molecular orbitals due to the non-infinite long-range order of the atomic arrangement in nanograins [1-9]. The special structure of high concentration interface and atomic energy level makes it have different properties from conventional materials and single molecules, such as surface effect, volume effect, quantum size effect, macroscopic quantum tunneling effect, etc., resulting in the mechanical properties, magnetic properties, dielectric properties of nanomaterials. The changes in electrical, superconducting, optical, and even mechanical properties make them of great value in electronics, optics, chemical ceramics, biology, medicine, etc. It is precise because nanomaterials have these excellent properties, which will have a wide range of applications [10-18].

Since the 21st century, the rapid development of nanotechnology is affecting and changed many application fields and has extensively promoted the development of science and technology and the progress of human civilization. Nanoscience & technology is considered a very important field of science and technology in this century, which will significantly impact the survival and development of human beings. At the same time, entering the 21st century, energy and environmental issues have become increasingly prominent and have become two daunting challenges to globalization that humankind is currently facing. Humans need to develop energy technologies and expand access to energy while avoiding environmental pollution. We propose to apply nanotechnology widely in related fields such as energy and environment and to meet the challenges brought by global energy and environmental problems through diversified nano-fabricated delicate structural design methods and delicate nano-fabrication processes. Nanotechnology will play an important role in improving energy using efficiency, innovating electrochemical energy storage technology, improving environmental quality, and improving people's environmental adaptability; it provides powerful means and expands various applications [19-21].

Nanomaterial analysis technology includes two aspects: composition and structure characterization and performance research. The characterization of nanomaterial structure refers to the characterization of the phase structure and morphology of the nanosystem, including the primary structure of the particle, the aggregated state structure (the structural characteristics of the nanoparticle itself, the particle shape, the particle size, and its distribution, the distribution of particle spacing, etc.) The structure and function of the interface with the substrate. The research on the properties of nanomaterials includes the bonding strength, wear-resistance, and edge peeling resistance of nanocoatings and the contact fatigue, fracture resistance, and impact resistance of nanomaterials. This paper systematically expounds on nanomaterials' structure, properties, preparation, characterization, and application to gain a more profound and comprehensive understanding of nanomaterials [17-22].

2. Classification of Nanomaterials

Nanomaterials can be divided into four categories according to their structure: three-dimensional (3D) nanomaterials with a grain size in the range of several nanometers in at least one direction. Two-dimensional (2D) nanomaterials with a layered structure and 2D nanomaterials with a fibrous structure. One-dimensional (1D) nanomaterials with atomic clusters and atomic beam structures are called zero-dimensional (0D) nanomaterials.

3. Preparation of Nanomaterials

There are many ways to prepare nanomaterials. In theory, any method that can produce fine grain size polycrystals can be used to make nanomaterials. If there is a phase transition, the nucleation rate will be increased, and the growth rate will be decreased during the phase formation process. The general methods for synthesizing nanomaterials are inert gas condensation, mechanical fusion, physical vapor deposition, chemical vapor deposition, CVD, plasma deposition, vacuum forming, hydrolysis, hydrothermal, chemical co-precipitation, microemulsion, reverse phase Deke method, laser-induced CVD method, spark corrosion, electron deposition, quenching of molten metal at high pressure, etc. This article describes only two basic methods.

4. Properties and Performance of Nanomaterials

4.1. Small Size Effect

When the nanoparticle size is comparable to the wavelength of light waves, the de Broglie wavelength of conduction electrons, and the coherence length or penetration depth of superconducting states, the periodic boundary conditions of the crystal will be destroyed. Acoustic, light, force, heat, electricity, magnetism, internal pressure, chemical activity, etc., have great changes compared with ordinary particles, which is the small size effect (also called volume effect) of nanoparticles.

4.2. Surface and Interface Effects

Due to the small size, large surface area, and high surface energy of nanoparticles, the atoms on the surface account for a considerable proportion. These surface atoms are in a serious vacancy state, so they are extremely active and unstable. When they meet other atoms, they combine quickly and stabilize them. This activity is the surface effect. The surface and interface effects of nanomaterials cause changes in the transport and configuration of atoms and changes in spin conformation and electron energy spectrum.

4.3. Quantum Size Effect

When the particle size drops to a minimum value, the electron energy level near the Fermi level will change from a quasi-continuous state to a discrete energy level, and the absorption spectrum threshold will shift to the short-wave direction. Magnetic, thermal, and superconductivity differ significantly from macroscopic properties known as quantum size effects. For most metal nanoparticles, the absorption spectrum is just in the visible light band, thus becoming a light-absorbing black body; for semiconductor nanomaterials, it can be observed that the spectral line is blue-shifted as the particle size decreases, and it has a nonlinear optical effect.

4.4. Dielectric Confinement Effect

When the surface of semiconductor ultrafine particles is modified with a material with a small dielectric constant, the specific surface area increases with the decrease of particle size, which significantly affects its properties. The electric force lines of the charge carriers in the coated ultrafine particles are more likely to pass through the coating film, resulting in the weakening of the shielding effect and the enhancement of the Coulomb interaction between charged particles, the binding energy of excitons, and the strength of the oscillators.

4.5. Macroscopic Quantum Tunneling Effect

The tunneling effect refers to the ability of microscopic particles to penetrate the potential barrier. Later, it was found that some macroscopic quantities, such as magnetization, the magnetic flux in quantum coherent devices, etc., also have a tunneling effect, called the macroscopic quantum tunneling effect. Macroscopic quantum tunneling and quantum size effects define the limits of further miniaturization of microelectronic devices and the shortest time for information storage using magnetic tape and disk. The high concentration of grain boundaries of nanometer grains and the proximity of grain boundary atoms determine that nanomaterials have excellent properties different from general materials, single crystal, polycrystalline, and amorphous.

4.6. Mechanical Properties

Due to the large surface area of nanocrystalline materials, the concentration of volume ratio impurities at the interface is greatly reduced, thereby improving the material's mechanical properties. The Young's modulus of nanomaterials is reduced by more than 30% due to the increase of interatomic gaps at grain boundaries and the presence of pores. In addition, the strength and hardness of nanomaterials are 4-5 times higher than those of coarse-grained materials due to the reduction of grains to the nanometer order. Therefore, nanomaterials have high strength and hardness and have good plasticity and toughness.

4.7. Electrical Properties

The resistance of nanomaterials is higher than that of similar coarse-grained materials due to the increase in the atomic volume fraction on the grain boundaries. In addition, the GMR phenomenon of nanomaterials (reduction of material resistance in a magnetic field) is very obvious. The resistance of coarse-grained materials in the magnetic field is only reduced by 1% to 2%, while the resistance of nanomaterials can be reduced by 50% to 80% important properties.

4.8. Magnetic Properties

The magnetic saturation M_e and the ferromagnetic transition temperature of nanomaterials will decrease because changing the atomic spacing can affect the ferromagnetism of the material. Another important magnetic property of nanomaterials is the magnet-to-caloric effect. If small magnetic particles are contained in a non-magnetic or weakly magnetic matrix, the magnetic rotation direction of the particles will match the magnetic field in a magnetic field. Thus increasing the magnetic order reduces the magnetic entropy of the spin system. If the process is adiabatic, the spin entropy will decrease with increasing lattice entropy, and this is a reversible process with increasing sample temperature. Thermal properties: The specific heat of nanomaterials is greater than that of similar coarse-crystalline and amorphous materials. The increase of C_p is related to the interface structure. The more open the interface structure, the greater the increase of C_p. This is due to the weaker interface atomic coupling. Optical properties: There has not been much progress in studying the optical properties of nanomaterials, but it has been demonstrated that changing the processing of the sample can change its light transmission. Other properties: Since the atoms of nanomaterials are highly dispersed on their grain boundaries, the dispersibility of nanomaterials is stronger than that of similar single crystal or polycrystalline materials, which has an important impact on a series of properties such as material creep, superplasticity, etc. In addition, the solid solubility of finite solid solutions will be enhanced when the material is in the nanometer state. The increase in nanopowder dispersibility will also lead to a decrease in sintering temperature. The chemical activity of nanomaterials is also higher than other samples of the same kind. The corrosion behavior of some nanomaterials has been reported recently. Because nanomaterials have fine grains and uniform structure, nanomaterials are subjected to uniform corrosion, while coarse-grained materials are mostly grain boundary corrosion, which was reported by Thorpe et al. [12] and Rofagha et al [13].

5. Main Analytical Techniques of Nanomaterials

5.1. X-ray Diffraction (XRD) Technology

Composition and organizational structure are the basic factors that determine the properties of materials. The composition of the material can be known by chemical analysis, the microscopic morphology of the material can be revealed by morphological analysis, and the information on the phase structure and element existence state of the material can be given by XRD. XRD can be used not only for qualitative and quantitative analysis but also for analysis of special information, such as grain size determination, stress determination, film thickness and mesoporous structure determination. To measure the grain size, the width of the diffraction line can be measured first, and then the grain size of the nanomaterial can be calculated through the XRD spectrum and the Scherrer formula. The method of analyzing the material structure by using the diffraction effect of crystalline substances on specific X-rays is called X-ray diffraction analysis, and it is one of the most commonly used methods to identify the composition of crystalline materials. Because the total number of crystal structure types is certain, each has its specific parameter characteristics, including unit cell parameters, interplanar spacing, lattice constant, etc., so a specific X-ray (usually using Cu target Kα wavelength) is used. Irradiating the sample can cause the substances in the sample to generate identifying X-rays because of their crystal structure. Atoms have a scattering effect on X-rays, and atoms in different layers of the same crystal face group in a crystal are equivalent to countless X-ray scattering sources with the same spacing. The diffraction effect of the crystal plane must satisfy the Bragg equation: $2d\sin\theta = n\lambda$, where, d is the interplanar spacing, θ is the diffraction angle, λ is the wavelength of the X-ray, and n is the diffraction order. The implication of Bragg's equation is that diffraction occurs when the optical path difference ($2d\sin\theta$) is equal to an integer multiple of the wavelength. Qualitative and quantitative analysis of compounds can be carried out by measuring the peak positions of diffraction angles and the peak intensities of spectral lines. X-ray diffractometers have the advantages of simple sample preparation, relatively cheap cost, high analysis efficiency, no damage to samples, and more effective information. They are widely used in science and engineering disciplines such as materials, physics, chemistry, and pharmacy. Usually, X-ray diffractometry is mainly used to characterize the sample composition, and the XRD pattern is used to qualitatively analyze the composition, crystal structure and grain size of the sample through the analysis software Jade.

5.2. Scanning Tunneling Microscopy (STM) Technique

STM uses tunneling current to study the surface morphology and surface electronic structure of materials. STM can work in the atmosphere, vacuum, solution, low temperature and high temperature. Electrochemical deposition and electrochemical corrosion processes were investigated in solution. Using the spatial resolving power of STM, the electrical, mechanical and chemical properties of single molecules, single nanoparticles, single nanowires and nanotubes can be measured. This gave birth to the new field of single-molecule science and promoted the development of new-generation nanoelectronic and molecular electronic devices. STM is increasingly used to induce changes in localized physical or chemical properties of material surfaces to develop a new generation of nanoelectronic devices or ultra-high-density information storage devices. The biggest advantage of STM memory technology is its ultra-high memory density (in principle, the size of memory cells can be as small as a single atom). Although STM memory devices have shortcomings such as slow data access speed, it is still a major development direction in information storage. For example, thermochemical hole-burning storage technology refers to generating highly localized tunneling current Joule heat through the STM tip, inducing charge transfer to the composite surface for localized thermochemical gasification and decomposition, thereby forming a nanoscale information hole array.

5.3. Atomic Force Microscopy (AFM) Technology

AFM technology uses force-sensitive probes to detect the interaction force between the tip and the sample to achieve surface imaging. During the scanning process, the feedback loop is used to keep the force between the needle tip and the sample constant, and the needle tip moves up and down with the undulation of the surface. AFM can detect material properties such as morphology, size and mechanical properties of various samples in the atmosphere, high vacuum, liquid and other environments.

Using transmission electron microscopy (TEM) techniques can only measure the lateral dimensions of nanoparticles and their structures, but not the longitudinal dimensions. AFM measures the size of nanoparticles in 3 dimensions with a longitudinal resolution of 0.01 μm. Because the magnification effect of the AFM tip in the lateral direction often causes the measured size to be too large, the nanoparticles can generally be studied in combination with TEM or STM techniques. Using AFM technology can study the surface structure of various materials and the mechanical properties of materials such as hardness, elasticity, plasticity, and surface micro-region friction properties. In recent years, the use of AFM technology to study nanomaterials has become more and more common. For example, conductive AFM can be used to study the electrical properties of nanomaterials and to manipulate atoms, molecules, nanoparticles and nanotubes.

5.4. Scanning Probe Microscopy (SPM) Technology

Since the invention of SPM, the technology has been widely used in mechanics, materials science, electronics, atomic and molecular manipulation and surface science. SPM can be used to characterize the ultrastructure of the material surface and the three-dimensional topography of the surface and quantitatively study the surface roughness, pore size, distribution, and particle size. Through the functional design of the SPM tip, a lot of research work with rich chemical characteristics can be carried out. The designed tip has chemical recognition and response functions, which can be used to image the chemical composition of the sample surface or track the chemical reaction occurring on the surface to give the localized chemical reaction properties. By modifying specific molecules (such as biomolecules) on the tip of the needle and the sample's surface, the interaction between molecules can be quantitatively studied.

The functionalized SPM tip can act as a "lens" for chemical reactions, confining chemical reactions in nanoscale spaces. In this way, the reaction characteristics of the limited molecular system can be studied, and the nanoscale chemical modification and processing can be performed on the surface of the material. For example, the world's first single-electron transistor operating at room temperature was fabricated using SPM to localize titanium oxide film. First, a 15 nm thick titanium film was deposited on a silicon/silicon dioxide insulating substrate, and then SPM and conductive AFM tip were used to align the titanium film. The membrane undergoes local chemical oxidation, and under the action of moisture in the air, a nano-sized electrolytic cell is formed between the needle tip and the needle tip. This is the basic structure of a single electron transistor.

5.5. X-ray Photoelectron Spectroscopy (XPS) Technology

XPS is one of the most widely used surface analysis techniques, which can qualitatively analyze the composition (all elements except H and He) and chemical valence states of the sample and can also semi-quantitatively analyze the ratio of atomic numbers in the sample. When XPS detects the surface depth of materials, the detection depth of inorganic substances is about 2 nm, and the detection depth of organic substances and polymers is about 10 nm. The sensitivity of surface detection is not more than 10-2 monolayer.

5.6. Raman Spectroscopy (Raman) Technology

Raman spectroscopy is an absorption spectroscopy technique developed based on the Raman scattering effect. The Raman shift generated by it is only related to the structure of the scattering molecule and the change of the molecular vibrational energy level, independent of the wavelength of the incident light, and is sensitive to the local environment, so it can be used to characterize the information of the structure, groups and chemical bonds of different molecules, The commonly used light source is usually a laser, because the intensity of Raman scattering is very low, and the laser light source can effectively improve the intensity of Raman scattering. The confocal Raman spectrometer uses an optical microscope to focus the laser beam into a tiny spot, increasing the spatial resolution to the micrometer scale, which can reflect the sample information more accurately. Raman spectroscopy has the advantages of large degree of freedom in light source selection, non-destructive detection, high detection resolution, no sample preparation, and fast speed. It is widely used in the analysis of surfaces, thin films, biological macromolecules and organic chemistry. The composition, relative content, phase structure, space group and functional group of the sample can be analyzed by Raman spectroscopy.

5.7. Fourier Transform Infrared Spectroscopy (FTIR) Technology

Fourier transform infrared spectroscopy, like Raman spectroscopy, is a commonly used modern spectroscopy technique. When the sample is irradiated with near-infrared light, due to the different composition and structure of the sample to be detected, the

By absorbing infrared rays of a specific wavelength, performing analog-to-digital conversion on the detected transmitted light and reflected light signals, and then by Fourier transform, the corresponding characteristic infrared absorption spectrum can be obtained. Different chemical bonds or functional groups have different absorption frequencies, so Fourier transform infrared spectroscopy is often used for qualitative analysis of substances. Near-infrared spectroscopy is still studying molecular vibrations, and its information is mainly about X-H bonds in organics, including C-H, O-H, C-N, etc., as well as stretching vibrations of alkanes, alkenes, aldehydes, ketones, esters and other groups. Infrared spectroscopy has a very high universality to samples, and it is often used together with Raman spectroscopy to detect molecular structures, chemical bonds, and functional groups of substances. Fourier transform red spectroscopy has the characteristics of high detection sensitivity, high measurement accuracy, fast measurement speed, simple operation, low astigmatism and wide wavelength band, and is widely used in catalysis, chemistry, materials and other fields.

5.8. Ultraviolet Photoelectron Spectroscopy (UPS) Technology

Ultraviolet Photoelectron Spectroscopy (UPS) is also known as Photoelectron Emission Spectroscopy (PES). Ultraviolet photoelectron spectroscopy UPS (ultraviolet photo-electron spectroscopy) photoelectron spectroscopy using ultraviolet light as the excitation light source. The photon energy of the excitation source is low, and the photon is generated from the de-excitation of excited atoms or ions. The most commonly used low-energy photon sources are helium I and helium II. Ultraviolet photoelectron spectroscopy is mainly used to investigate the valence electron structure of gas phase atoms, molecules and adsorbed molecules. The outer electrons of the sample atoms are excited by photons with ultraviolet energy of 16-40 eV to analyze the orbital structure, energy band structure, empty state distribution and surface state of the outer shell of the sample. UPS can detect the depth of the material surface up to 1nm, and the detection sensitivity is less than 10^{-3} monolayer. The electronic structure of lead phthalocyanine and single-walled carbon nanotube bundles at the interface of self-assembled organic/inorganic semiconductors can be analyzed by UPS.

5.9. Auger Electron Spectroscopy (AES) Technology

In the field of materials science, Auger Electron Spectroscopy (AES) is mainly used for the determination of material components, the detection of purity and the study of surface chemical adsorption and surface chemical reactions. AES has been successfully used to study interfacial diffusion reaction of nanofilms, nanofilm preparation, nanofilm catalysts, and metal-supported nanofilm photocatalysts to determine surface cleanliness and thickness nanofilms, and the determination of nanometer multilayer films.

5.10. Laser Detection Technology

As a non-contact, non-destructive testing technology, laser detection technology has the advantages of simple operation, high accuracy and easy alignment. The thermal diffusivity of material (including nanomaterials) is related to its thermal conductivity, specific heat, and density. It is a comprehensive parameter involving mechanics and heat.

5.11. Laser Scattering Technology

Laser scattering is also known as “dynamic light scattering”, “quasi-elastic light scattering,” or “photon correlation spectroscopy”. It is a general term for obtaining information such as particle weight, size, distribution and aggregate structure by detecting scattered light intensity, frequency shift and its angular dependence outside the direction of incident light using a laser as a light source. This technique is suitable for determining nanoparticle size and distribution and studying nanoparticle formation kinetics and influencing factors, such as nanoparticle kinetics formed by molecular association, aggregation, assembly, micelles and microemulsions etc., real-time online tracking.

5.12. Other Analytical Techniques

Time-of-flight secondary ion analysis has the advantages of high transmission rate, high resolution, and parallel detection of ions with different mass-to-charge ratios, wide mass range of the measured ions, high surface sensitivity and micro-area analysis. In addition to obtaining information about elements and isotopes, information about molecular structure can also be obtained directly. For example, the time-of-flight secondary ion mass spectrometry technique can be used to analyze the self-assembled monolayer and the cationization effect of self-assembled film and self-assembled monolayer on polymers and proteins can be carried out.

Electron Energy Loss Spectroscopy (EELS) in electron microscopy combined with transmission electron microscopy in line scan mode enables the analysis of nanoscale multilayer structures. EELS is mainly used to analyze single nanotubes, analyze the composition and electronic structure of Y-Ba-Cu-O nanorods synthesized by laser ablation, and analyze coaxial (coaxial) nanocables.

Surface-extended X-ray absorption fine structure spectroscopy (SEXAFS) can be used to analyze the structure and magnetic properties of Cu (110) self-assembled nanoscale Fe islands. Near-edge X-ray absorption fine structure spectroscopy (NEXAFS) can analyze the morphology, photoluminescence and electronic structure of silicon oxide nanoclusters.

Scanning electron microscope (SEM) is an electron-optical instrument that scans the sample with an electron probe, and receives signals such as secondary electrons and backscattered electrons through various probes to obtain the surface morphology of the sample and the qualitative and semi-quantitative information of regional elements.

Transmission electron microscopy (TEM) also uses a high-energy electron beam as a light source. The difference is that it uses the electron beam to pass through the sample and focus the transmission electrons for imaging to obtain a two-dimensional image. Transmission electron microscopy has higher magnification than scanning electron microscopy, smaller beam spot diameter (about 0.2 nm), i.e. higher resolution, and more capabilities, including transmission electron microscopy, High Resolution (H-TEM), Scanning Transmission Mode Imaging (STEM), EDX Spectral Imaging, Selected Area Electron Diffraction Patterns (SAED), etc.

In addition to the analytical techniques introduced above, many analytical methods are widely used in the analysis of nanomaterials, such as photoelectron spectroscopy, vibrational spectroscopy, extended X-ray absorption fine structure spectroscopy (EXAFS), nuclear magnetic resonance (NMR), mass spectrometry, Ultrafast Laser Spectroscopy, Differential Thermal and Thermogravimetric Analysis, Liquid Chromatography, Magnetic and Electrical Analysis Systems, etc.

6. Applications of Nanomaterials

Nanomaterials are new materials, and people are developing their new uses. Although nanomaterials have not been widely used in industry, their special properties will be widely used. Nanoceramics have high plasticity and low sintering temperature but still have hardness similar to ordinary ceramics. These characteristics allow the processing of nanoceramics at room temperature and sub-high temperature. If the nanocrystalline ceramic particles are processed and shaped at a sub-high temperature and then subjected to surface annealing treatment, a high-performance ceramic with the surface maintaining the conventional ceramic hardness and the interior still has the ductility of the nanocrystalline material can be obtained. The magnetic properties of nanomaterials are very special. For example, Fe-Co alloys and iron nitrides with a single domain critical size have a very high coercive force. Therefore, the magnetic recording media materials are not only the sound quality, images and information. The noise ratio is good, and the recording density is ten times higher than the current γ-Fe_2O_3, so it is the primary material to lead the next generation of information storage systems. The optical transparency of nanomaterials can be controlled by controlling the grain size and porosity, thus making the ceramics suitable for a wide range of applications in sensing and filtering technologies. The increase in the scattering rate of nanomaterials can reduce the sintering temperature of the material, and this enhanced dispersion can be used to make oxygen sensors and fuel cells at lower temperatures than current systems. Nanoceramics are also ideal materials for joining ceramics, as the high dispersibility and superplasticity of nanoceramics overcome common problems of ceramic joinings, such as dispersive structures at high temperature and pressure. The excellent connection performance of soft magnetic can be used to produce general choke coils, saturable reactors, high-frequency converters and magnetic heads. The magnet-tocaloric effect of nanocomposites can transfer heat from one thermal reservoir to another so that the effect can be used as magnetic refrigeration, that is, replacing the currently used compressed gas with a solid magnetic substance, which can avoid carbon The harm caused by the fluorine atmosphere, and the cooling effect is also better. Nanomaterials also have potential uses, such as nano metallic materials, nano semiconductor materials, nanocatalysis materials, nanocomposite materials, nanopolymer materials, etc. The research on the structure and properties of nanomaterials will be broadened and deepened with the improvement of preparation methods and the birth of new nanomaterials. Research in this area requires the close cooperation and collaboration of materials science, basic disciplines such as physics and chemistry, and chemical engineering. Nanomaterials will certainly have very broad and attractive development prospects as an emerging material category.

7. Conclusion

The main problems encountered in the analysis of nanomaterials are the inhomogeneity of size and structure and the difficulty of controllable manipulation of individual small-sized materials. For different systems, it is necessary to select methods suitable for structural analysis and performance research. At present, the research on the intrinsic properties of nano-elements is still a very challenging research topic. Improving microfabrication and directional synthesis technology is an indispensable prerequisite to having a great breakthrough in this field.

Nanomaterial is a new type of material developed in the mid-1980s, and its unique structure makes it show unique and excellent properties. Although much research has been done on nanomaterials' preparation, structure, and properties, much work still needs to be done in basic theory and application development. Although there are many methods for preparing nanomaterials, most of them remain in the laboratory stage, and few of them can be industrialized, with high energy consumption, high cost and wide particle size distribution. The result of the development of nanomaterials technology will directly extend the ability of human beings to transform nature into molecules and atoms. Therefore, the development and application of nanotechnology will have a significant and far-reaching impact on the development and progress of human society.

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