



Synthesis Of Selected Nanomaterials And Nanorods Using Soft Chemical Route

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ABSTRACT:

In the synthesis of the materials, the used precursors were dissolved in distilled water and stirred by a magnetic stirrer to get a clear solution. A capping agent was used to arrest the agglomeration. Using cold centrifuge, the resulting precipitate was separated from the final solution and washed several times by methanol to remove the impurities present in the sample and then dried in vacuum at room temperature to obtain the nano materials in powder form. In this article, synthesis of several nanomaterials and nanorods using soft chemical route has been highlighted.

Keywords: Synthesis, Nanomaterials, Nanorods, Soft Chemical Route.

INTRODUCTION:

Nanomaterials have become a fascinating class of materials that are highly sought after for a variety of real-world uses. The length of a nanometer can be visualized as five silicon atoms or ten hydrogen atoms lined up, each of which is one nanometer in length. If a material's size or one of its dimensions is between 1 and 100 nm, it is referred to as a nanomaterial. It is difficult to pinpoint the precise timeline of human use of nanoscale items. The use of nanomaterials, however, has a long history, and humans have inadvertently employed them for a variety of purposes for a very long time. Asbestos nanofibers were used by humans to strengthen ceramic mixes about 4500 years ago. PbS nanoparticles were known to the ancient Egyptians some 4,000 years ago, and they were utilised in an ancient hair-dyeing technique. Another noteworthy historical example is the Lycurgus Cup. It is a dichroic cup made in the fourth century AD by the Romans. In direct light, it has a jade-like appearance, yet in transmitted light, it has a translucent ruby hue. Depending on the light that is incident, it has different colorations. Due to the presence of Ag and Au nanoparticles, these color differences are visible. Richard Adolf Zsigmondy originally used the word "nanometer" in 1914. The term "nanotechnology" was first used in a speech given in 1959 at the annual meeting of the American Physical Society by the American scientist and Nobel Prize winner Richard Feynman. This is regarded as the first scholarly presentation on nanotechnology. There's Plenty of Space at the Bottom was the

title of the lecture he gave. The idea, "Why can't we write the full 24 volumes of the Encyclopedia Britannica on the tip of a pin?" was brought up during this discussion. The goal was to create molecularly scaled, smaller devices. In this address, Feynman argued that the inadequacy of our tools and methods—rather than the rules of nature—limits our ability to conduct research at the atomic and molecular levels. The idea of contemporary technology was so firmly planted. He is frequently regarded as the originator of contemporary nanotechnology as a result. Possibly the first person to use the phrase "nanotechnology" was Norio Taniguchi in 1974. Nanotechnology, according to Norio Taniguchi, primarily entails the processing, separation, consolidation, and deformation of materials by a single atom or molecule. Until the 1980s, nanotechnology was merely a topic for debate, but it had already begun to take root in academics' thoughts as a viable field for advancement. The development of numerous spectroscopic methods has accelerated nanotechnology research and invention. In 1982, IBM researchers created scanning tunneling microscopy (STM), which made it possible to capture images of individual atoms on "flat" (i.e., non-tip) surfaces. Since its creation in 1986, atomic force microscopy (AFM) has emerged as the most important scanning probe microscope method. Measurements of electrostatic and magnetic forces were spurred by the desire to create hard discs with high storage densities. As a result, Kelvin-probe, electrostatic, and magnetic-force microscopy were developed. Nowadays, nanotechnology is developing quickly and entering practically all areas of materials chemistry. Thanks to the daily advancements in the field of nanotechnology, powerful characterization and synthesis technologies are now accessible for creating nanomaterials with better-controlled dimensions. An excellent example of an emerging technology is nanotechnology, which provides designed nanomaterials with the huge potential to produce goods with significantly better performances. Nanomaterials are currently used in a variety of commercial products, including scratch-resistant paints, surface coatings, electronics, cosmetics, environmental cleanup, sporting goods, sensors, and energy storage devices. The exact definitions of nanomaterials and the terminology used in conjunction with them are still up for debate. Because of this, there is a ton of opportunity for the interpretation and classification of nanoparticles. The term "nanomaterials" is not easily defined. Due to the lack of a precise definition in the literature, nanomaterials are understood differently. Several scientists have used the term "nanomaterial" to describe anything with a size of a few nanometers or less than a few tens of nanometers, and some have even used it to describe anything with a size of less than a micrometer. Nanomaterials' particular composition, shape, and size determine their physical and chemical properties. The size, shape, and other characteristics of nanomaterials affect their effects on human health and the environment. It is difficult to locate a single, broadly acknowledged definition of nanoparticles, and the scientific community is still debating a precise definition of nanomaterials.

Certain electrical characteristics are present in semiconductors. A substance is referred to as a conductor or an insulator depending on whether it conducts electricity or not.

Semiconductors are materials that fall halfway in between. Semiconductors are used to make integrated circuits (ICs) and electronic discrete components like transistors and diodes. Germanium and silicon are common types of elemental semiconductors. Of these, silicon is well-known. Most ICs are made of silicon. Examples of typical semiconductor materials are indium antimonide and gallium arsenide. Several technological products as well as the societal infrastructure that supports our daily lives now depend on semiconductors.

The operation of air conditioners at a pleasant room temperature, increased auto safety, laser therapy in cutting-edge medical care, and many more applications depend heavily on semiconductors. Also, the advancements in semiconductor technology have facilitated system efficiency, downsizing, and energy savings, all of which contribute to a safe, comfortable existence today and a successful future tomorrow. Semiconductors were first identified in the 19th century. The transistor was created in the 1940s. Radios, which had previously required Hoover tubes, were drastically scaled down and made portable. Silicon is a well-known semiconductor. Semiconductor devices, which include the IC, a transistor-based integrated circuit, are used in electronic components. Semiconductor devices are crucial electronic components that enable our daily lives and are placed within various electronics gadgets.

Semiconductors are solids that are either crystalline or amorphous and have different electrical properties. Semiconducting materials have a resistance that is halfway between that of metals and insulators [1-5]. In contrast to metals, they exhibit a negative temperature coefficient of resistance. Finally, the deliberate, controlled introduction of impurities ("doping") into the crystal structure might affect their conducting capabilities in advantageous ways [6-10]. Modern intriguing experimental approaches like as molecular beam epitaxy (MBE), metal-organic chemical vapour deposition (MOCVD), and others are used to create homo and hetero connections [11-14]. Diodes, transistors, metal-oxide-semiconductor field-effect transistors (MOSFETs), and all modern electronics and optoelectronic devices are based on the behaviour of charge carriers such as electrons, ions, and electron-holes at these junctions [15-17]. Semiconductor devices can have a variety of beneficial qualities, including the ability to transmit current more easily in one way than the other, changeable resistance, and light or heat sensitivity [18,19]. Devices composed of semiconductors can be used for amplification, switching, and energy conversion because the electrical properties of a semiconductor material can be altered by doping, electric fields, or light [20].

An item made of silicon that conducts electricity more than an insulator like glass but less than a pure conductor like copper or aluminium is known as a semiconductor. With the addition of impurities, a process known as doping, their conductivity and other properties can be changed to suit the unique requirements of the electronic component in which they are found. Many practical characteristics of semiconductor devices include changeable resistance, easier current flow in one direction compared to the other, and responsiveness to heat and light. They actually do signal amplification, switching, and

energy conversion. As a result, they are widely used in practically all industries, and the businesses that produce and test them are seen as great indicators of the state of the economy as a whole. With semiconductor components present in a variety of consumer and commercial items, including cars, computers, mobile devices, and personal electronics, the semiconductor business is a vital sector for both the U.S. and global economies.

Nanomaterials and Nanorods:

Nanomaterials have emerged as an exciting class of materials that are in high demand for a range of practical applications. The length of a nanometer can be understood through the example of five silicon atoms or 10 hydrogen atoms lined up, which is one nanometer. Materials are defined as nanomaterials if their size or one of their dimensions is in the range of 1 to 100 nm. The exact history of the utilization of nanosized objects by humans is difficult to clarify. However, the history of nanomaterial utilization is ancient, and human beings used these materials a long time ago for various applications, unknowingly. About 4500 years ago, humans exploited asbestos nanofibers to reinforce ceramic mixtures. The ancient Egyptians were familiar with PbS nanoparticles about 4000 years ago and used them in an ancient hair-dyeing formula. The Lycurgus Cup is another fascinating example from the past. It is a dichroic cup produced by the Romans in the 4th century A.D. It resembles jade in direct light, whereas it shows a translucent ruby color in the case of transmitted light. It shows color variations depending on the incident light. These color variations appear due to the presence of nanoparticles of Ag and Au. The term nanometer was first used in 1914 by Richard Adolf Zsigmondy. The American physicist and Nobel Prize laureate Richard Feynman introduced the specific concept of nanotechnology in 1959 in his speech during the American Physical Society's annual meeting. This is considered to be the first academic talk about nanotechnology. He presented a lecture that was entitled "There's Plenty of Room at the Bottom". During this meeting, the following concept was presented: "why can't we write the entire 24 volumes of the Encyclopedia Britannica on the head of a pin?" The vision was to develop smaller machines, down to the molecular level. In this talk, Feynman explained that the laws of nature do not limit our ability to work at the atomic and molecular levels, but rather it is a lack of appropriate equipment and techniques that limit this. Through this, the concept of modern technology was seeded. Due to this, he is often considered the father of modern nanotechnology. Norio Taniguchi might be the first person who used the term nanotechnology, in 1974. Norio Taniguchi stated: "nano-technology mainly consists of the processing of, separation, consolidation, and deformation of materials by one atom or one molecule." Before the 1980s, nanotechnology remained only an area for discussion, but the concept of nanotechnology was seeded in the minds of researchers with the potential for future development. The invention of various spectroscopic techniques sped up research and innovations in the field of nanotechnology. IBM researchers developed scanning tunneling microscopy (STM) in 1982, and with STM it became feasible to attain images of single atoms on "flat" (i.e., not a tip) surfaces. Atomic force microscopy (AFM) was invented in 1986, and it has become the most crucial scanning probe microscope

technique. The motivation to develop hard discs with high storage density stimulated the measurement of electrostatic and magnetic forces. This led to the development of Kelvin-probe-, electrostatic-, and magnetic-force microscopy. Currently, nanotechnology is rapidly evolving and becoming part of almost every field related to materials chemistry. The field of nanotechnology is evolving every day, and now powerful characterization and synthesis tools are available for producing nanomaterials with better-controlled dimensions. Nanotechnology is an excellent example of an emerging technology, offering engineered nanomaterials with the great potential for producing products with substantially improved performances. Currently, nanomaterials find commercial roles in scratch-free paints, surface coatings, electronics, cosmetics, environmental remediation, sports equipment, sensors, and energy-storage devices. Rigorous definitions of nanomaterials and associated terms are debatable and still not fixed. For this reason, huge room has been left around the interpretation and classification of nanomaterials. The definition of nanomaterials is not straightforward. In the literature, nanomaterials are perceived in different ways due to the absence of a rigorous definition. Many researchers have used the term nanomaterial if the size is a few nanometers or smaller than a few tens of nanometers, whereas others have even used the term nanomaterial for anything less than a micrometer. The physical and chemical properties of nanomaterials depend upon their precise composition, shape, and size. The effects of nanomaterial on health and the environment also depend upon their size, shape, etc. A single internationally accepted definition of nanomaterials is challenging to find, and a rigorous definition of nanomaterials is still under discussion in the scientific community.

Nanorods are an appealing component to study and are the best choices for various applications due to their form anisotropy (physical characteristics). The ability of the nanorods was shown to be superior to that of spherical particles. This is because the particle's enhanced aspect ratio causes a rise in the excitation of surface plasmons in nanoparticles. Due to an increase in surface plasmons, a nanoparticle's dipole moment is particularly strong. Consequently, as compared to spherical particles, an increase in surface plasmons causes an improvement in the electrical field in nanorods. One advantage of a rod-like shape was shown by Alivisatos and colleagues, who saw that partially aligned CdSe nanorods gave charge carriers an efficient, guided path to travel across the photovoltaic device and be collected. Similar to this, as the aspect ratio rose from 1 to 10, the addition of nanorods to P3HT film could raise the external quantum efficiency by a factor of 3. As the aspect ratio of nanoparticles rose, the electron accumulation enhanced. Moreover, nanorod alignment is crucial for enhancing its characteristics. The aspect ratio of anisotropic nanoparticles plays a role in the electrical conductivity of polymer composites, according to research done by the Winey group on Ag nanorods for polystyrene composites. Specifically because rod-shaped particles have a lower percolation threshold than spherical particles. It has been discovered that percolation depends on the size and form of nanoparticles. Bigger rod-shaped particles are anticipated to share many benefits with nanorods in terms of their oriental properties, both in terms of length and diameter. Last but not least, compared to isotropic

(homogenous and uniform) particles, nanorods have greater advantages. It can be said that nanorod aspect ratio, volume fraction, polydispersity, and orientation have a significant impact.

Many nanorods, including carbon nanorods, ZnO nanorods, gold nanorods, and magnetic nanorods, have been thoroughly researched. Recently, other methods for creating the nanorods have been suggested. It can be categorised as bottom-up or top-down techniques, physical or chemical methods, or both. Thermal hydrolysis, the hydrothermal route, sol-gel, vapour condensation, spray pyrolysis, pulse laser decomposition, laser ablation, thermal evaporation, pulse combustion-spray pyrolysis, electromechanical, low energy beam deposition, ball milling, chemical vapour deposition, laser ablation, chemical reduction, co-precipitation, the hybrid wet chemical route, physical evaporation, electrophoretic deposition, and radio frequency Normally, nucleation growth is controlled to produce nanorods rather than transverse growth.

Due to their physical (particle size, shape, huge surface area, and larger pore size distribution) and chemical characteristics, carbon nanorods have garnered a lot of attention over the past few decades. "Carbon nanorods" and "diamond nanorods" are other names for nanorods formed of carbon. With sp³ carbon hybridization, diamond nanorods have a crystalline structure similar to diamond. The inert atmosphere's composition and pressure have a significant impact on the yield and purity of carbon nanorods produced. With the introduction of various functionalities into the carbon nanorods' pore surfaces, the physicochemical properties of the carbon nanorods generally improved. It will enable numerous applications, including those in supercapacitors, water treatment, and catalysis, among others. In addition to their use as fillers and high performance electrode materials, carbon nanorods are widely used as anodic materials in batteries. Many synthesis techniques have been put forth up to this point, and they can be categorised as "bottom up" (using tiny molecules or colloidal solutions for synthesis) or "top down" (like starting with bigger structures). The top-down approach, which produces carbon nanorods using electrochemical and straightforward chemical etching. In the meanwhile, bottom-up approaches such as synthesis in solution with template assistance, metal assistance, the hydrothermal route, vapour deposition (CVD), and other methods are also used.

Recent developments in the production of carbon nanorods from metal-organic frameworks were highlighted in light of a recent finding (MOFs). MOFs, a group of crystalline and porous materials, have drawn a lot of interest because of both their intriguing architectural designs and their advantageous characteristics. MOFs could be created by combining organic and inorganic materials. Although MOFs are known to be excellent porous materials, their initial shape may partially or completely collapse during the thermal conversion of MOFs into carbon compounds. For these reasons, self-scarification and morphology-preserving thermal transformation of MOF-74 results in the production of nonhollow (solid) 1-D carbon nanorods with moderate aspect ratio, large surface area, and good performance capacitor electrodes.

Microcrystalline MOF-74 was created when zinc nitrate and 2,5-dihydroxyterephthalic acid were combined in N, N-dimethylformamide (DMF) using the conventional hydrothermal technique. Scanning and transmission electron microscopy (SEM) images of the reaction between those components at room temperature in the presence of salicylic acid as a modulator revealed the creation of rod-shaped MOF-74 (MOF-74-Rod, 30-60 nm broad, 200-500 long) (TEM). Via the stabilisation of the active metal sites on the MOF crystal surface, the addition of salicylic acid steered MOF development in a rod-shape morphology.

Synthesis of II-VI Semiconductor (CdSe/CdTe) Nanomaterials:

In the synthesis of CdSe/CdTe nanoparticles, the precursors used were cadmium acetate ($(\text{CH}_3\text{COO})_2\text{Cd}$, $2\text{H}_2\text{O}$), Merck), sodium selenite ($(\text{Na}_2\text{SeO}_3, 5\text{H}_2\text{O})$, Loba chemie) and sodium tellurite ($(\text{Na}_2\text{TeO}_3)$, Loba chemie). Mercapto ethanol ($(\text{C}_2\text{H}_6\text{OS})$, SRL) was used as the capping agent. The cadmium acetate solution was prepared by dissolving cadmium acetate in distilled water with stirring by a magnetic stirrer. Sodium selenite and sodium tellurite solution was prepared by dissolving sodium selenite and sodium tellurite in distilled water. Mercapto ethanol solution was prepared by diluting mercapto ethanol into distilled water. First of all, the mercapto ethanol solution was mixed with sodium selenite and sodium tellurite solution to arrest the agglomeration of CdSe/ CdTe nanoparticles during precipitation. This solution was poured in the cadmium acetate solution drop-wise and the resulting solution was stirred for 3 hours at 50°C . Using cold centrifuge the resulting precipitate was separated from the final solution and washed several times by methanol to discard any impurity from the solution. Finally the resulting precipitate was dried in vacuum to obtain CdSe/CdTe nanoparticles in powder form. Differential scanning calorimetry (DSC) measurement of the sample was carried out using a TGA/DSC (Mettler Toledo) set up in the temperature range from 30°C to 400°C for the heating rate of $10^\circ\text{C}/\text{min}$, $20^\circ\text{C}/\text{min}$, $30^\circ\text{C}/\text{min}$ and $40^\circ\text{C}/\text{min}$ to get the transition temperature at which the material should be sintered. The sample was heated at 300°C ($>T_g$, the glass transition temperature) for 2 hours to obtain the crystallization phase of CdSe and at 400°C ($>T_g$, the glass transition temperature) for 2 hours to obtain the crystallization phase of CdTe. This sintered material was used for further characterization. In some of the characterization sintered powder sample was used and, in some measurement, the powder of CdSe was pelletized into a disc of thickness 2.75 mm and diameter 8.03 mm using a pressure of 4 tons.

Synthesis of Fe (5% and 10%) doped CdSe Nanomaterials:

To prepare nanoparticles of Fe doped (5% and 10%) i.e. $\text{Cd}_{0.95}\text{Fe}_{0.05}\text{Se}$ (5 % Fe doped) and $\text{Cd}_{0.9}\text{Fe}_{0.1}\text{Se}$ (10 % Fe doped) henceforth referred as CdFeSe1 and CdFeSe2, iron (III) chloride ((FeCl_3) , solution was prepared using FeCl_3 in distilled water and then the mixture was poured into cadmium acetate solution. After that the two solutions (one is cadmium acetate solution mixed with iron chloride solution and another is sodium selenite solution mixed with mercaptoethanol solution) were mixed thoroughly as per

the sequence mentioned earlier using cold centrifuge at a temperature 50 °C for 3 hours. Using cold centrifuge the resulting precipitate was separated from the final solution and washed several times by methanol to discard any impurity from the solution. Finally the **resulting precipitate was** dried in vacuum to obtain CdFeSe1 and CdFeSe2 nanoparticles in powder form. DSC measurement of the sample was carried out to get the transition temperature at which the material should be sintered. The sample was heated at 300 °C ($>T_g$, the glass transition temperature) for 2 hours to obtain the crystallization phase of the samples. This sintered material was used for further characterization. In some of the characterization sintered powder sample was used and in some measurement, the powder of CdSe was pelletized into a disc of thickness 2.72 mm and diameter 8.05 mm using a pressure of 4 tons.

Synthesis of Co (2%, 5% and 10%) doped CdSe Nanomaterials:

To prepare nanoparticles of Co (2%, 5% and 10%) i.e. Cd_{0.98}Co_{0.02}Se (2 % Co doped) Cd_{0.95}Co_{0.05}Se (5 % Co doped) and Cd_{0.9}Co_{0.1}Se (10 % Co doped) henceforth referred as CdCoSe1, CdCoSe2 and CdCoSe3, cobalt (II) nitrate [Co(NO₃)₂, 6H₂O] solution was prepared using Co(NO₃)₂, 6H₂O in distilled water and then the mixture was poured into cadmium acetate solution. After that the two solutions (one is cadmium acetate solution mixed with cobalt nitrate solution and another is sodium selenite solution mixed with mercaptoethanol solution) were mixed thoroughly as per the sequence mentioned earlier using cold centrifuge at a temperature 50 °C for 3 hours. Using cold centrifuge the resulting precipitate was separated from the final solution and washed several times by methanol to discard any impurity from the solution. Finally the resulting precipitate was dried in vacuum to obtain CdCoSe1, CdCoSe2 and CdCoSe3 NPs in powder form. DSC measurement of the sample was carried out to get the transition temperature at which the material should be sintered. The sample was heated at 400 °C ($>T_g$, the glass transition temperature) for 2 hours to obtain the crystallization phase of the samples. This sintered material was used for further characterization. In some of the characterization sintered powder sample was used and in some measurement, the powder of CdSe was pelletized into a disc of thickness 2.65 mm and diameter 8.01 mm using a pressure of 4 tons. .

Synthesis of Ni (5%, 7% and 10%) doped CdTe Nanomaterials:

To prepare nanoparticles of Ni (5%, 7% and 10%) i.e. Cd_{0.95}Ni_{0.05}Te (5 % Ni doped) Cd_{0.93}Ni_{0.07}Te (7 % Ni doped) and Cd_{0.9}Ni_{0.1}Te (10 % Ni doped) henceforth referred as CdNiTe1, CdNiTe2 and CdNiTe3, nickel chloride ((NiCl₂, 6H₂O)) solution was prepared using NiCl₂, 6H₂O in distilled water and then the mixture was poured into cadmium acetate solution. After that the two solutions (one is cadmium acetate solution mixed with nickel chloride solution and another is sodium tellurite solution mixed with mercaptoethanol solution) were mixed thoroughly as per the sequence mentioned earlier earlier using cold centrifuge at a temperature 50 °C for 3 hours. Using cold centrifuge the resulting precipitate was separated from the final solution and washed several times by methanol to discard any impurity from the solution. Finally the resulting precipitate was

dried in vacuum to obtain CdNiTe₁, CdNiTe₂ and CdNiTe₃ NPs in powder form. DSC measurement of the sample was carried out to get the transition temperature at which the material should be sintered. The sample was heated at 400 °C (>T_g, the glass transition temperature) for 2 hours to obtain the crystallization phase of the samples. This sintered material was used for further characterization. In some of the characterization sintered powder sample was used and in some measurement, the powder of the samples was pelletized into a disc of thickness 2.76 mm and diameter 8.05 mm using a pressure of 4 tons.

Synthesis of CdSe Nanorods:

In the synthesis process, cadmium acetate, ((CH₃COO)₂Cd, 2H₂O (Merck)) and sodium selenite, (Na₂SeO₃, 5H₂O (Loba chemie)) were used as precursors for cadmium and selenium ions respectively. Mercapto ethanol, (C₂H₆OS, (SRL)) was used as capping agent. To prepare the CdSe nanorods, cadmium acetate solution was prepared by dissolving cadmium acetate in distilled water and stirred by a magnetic stirrer to get a clear solution. Sodium selenite solution was prepared by dissolving sodium selenite in distilled water. Mercapto ethanol solution was prepared by diluting mercapto ethanol into distilled water. First of all the mercapto ethanol solution was mixed with sodium selenite solution to arrest the agglomeration, during precipitation. The later solution was poured in the cadmium acetate solution drop-wise and resulting solution was stirred for 3 hours at 50°C. After that the solution was heated at a temperature of 100°C for 30 minutes. Using cold centrifuge at 10,000 rpm, operated at a temperature of 5°C for 7 min each time, the resulting precipitate was separated from the final solution and washed several times by methanol to remove the impurities present in the sample and then dried in vacuum at room temperature for 15 hours to obtain CdSe in powder form. Differential scanning calorimetry (DSC) measurement of the sample was carried out using a TGA/DSC (Mettler Toledo) set up in the temperature range from 30°C to 400°C for the heating rate of 10 °C/min, 20 °C/min, 30 °C/min and 40 °C/min to get the transition temperature at which the material should be sintered. The sample was heated at 300°C (>T_g, the glass transition temperature) for 2 hours to obtain the crystallization phase of CdSe nanorods. This sintered material was used for further characterization. In some of the characterization sintered powder sample was used and in some measurement, the powder of the samples was pelletized into a disc of thickness 2.76 mm and diameter 8.05 mm using a pressure of 7 tons.

CONCLUSION:

People have accidentally used nanomaterials throughout history. In academia, Feynman's well-known lecture 'There's Plenty of Space at the Bottom' popularized the idea of contemporary nanotechnology. Since then, nanotechnology has made significant progress and is constantly spreading into new fields. Materials that have any dimension between 1 and 100 nm are typically referred to as nanomaterials. Nanomaterials are created using two main techniques: Top-down procedures, which include a variety of

techniques such as mechanical milling, electrospinning, lithography, sputtering, arc discharge, and laser ablation, are one of the key approaches. The second way uses bottom-up techniques such as reverse micelle, solvothermal and hydrothermal, sol-gel, and chemical vapour deposition (CVD). A variety of distinctive characteristics that distinguish nanomaterials from their bulk counterparts have been demonstrated. High surface area, magnetism, quantum effects, antibacterial activity, and high thermal and electrical conductivities are all characteristics of nanomaterials. Metal-based materials exhibit significantly high catalytic activity at the nanoscale. By dispersing these catalysts on 2D sheets of other nanomaterials, it is possible to improve their dispersion and, hence, the overall performance of metal-based catalysts. Nanoporous materials, core-shell materials, ultrathin 2-dimensional nanomaterials, carbon-based nanomaterials, and metal-based nanomaterials are all members of the nanomaterial family. A fascinating subset of these are the carbon-based nanomaterials, which include graphene, fullerenes, carbon nanotubes, carbon-based quantum dots, and carbon nanohorns. Moreover, the surfaces of carbon-based nanomaterials can be further functionalized to adjust their characteristics for specific uses. Due to their large surface areas, quick charge transfer capabilities, and great mechanical strength, CNTs and graphene are well-known members of the family of carbon-based nanomaterials and have been thoroughly investigated for a variety of applications. In the areas of sensing, nanomedicine, and bioimaging, carbon quantum dots have drawn a lot of interest. Due to their numerous novel qualities, ultrathin 2D materials have attracted a lot of interest since graphene was isolated from graphite in 2004. Due to this, a number of ultrathin nanomaterials, such as silicene, borophene, antimonene, MXenes, 2D MOF nanosheets, and boron nitride nanosheets, have been described. Despite the experimental evaluation of ultrathin 2D materials still being in its early stages and despite their exceptional qualities, these materials are being swiftly investigated for practical applications. The development of nano-catalysts using a variety of metal-based nanostructured materials has become a popular topic of research. Large surface areas, a large number of binding sites, and intricate surface textural features are all features of nanoscale catalysts. The thermodynamics and kinetics of transportation are favored during heterogeneous reactions by all of these characteristics, as well as the tiny size. In energy conversion and storage devices, layered metal-oxide-based materials are being investigated as electrode materials. Nanoscale modifications are being made to semiconductor metal oxide materials to improve their capacity to catalyze water and generate sustainable energy. As a result of well-organized nanostructures, more emphasis is currently being placed on creating nanomaterials with controlled morphologies and nanoscale dimensions. Some commercially available gadgets have already been introduced thanks to nanotechnology. There will likely be much more advancement as nanomaterials are incorporated into next-generation devices to meet the high energy demands of the future and take a more active part in biosensors and nanomedicines to combat both known and undiscovered diseases. Abraxane and Doxil are two examples of artificial nanoparticles that are employed in biomedical applications. These nanoparticles are treatments with clinical approval. TiO₂ particles with a submicron size are a crucial feature of white paints.

Commercial sunscreens contain nanoparticles of zinc oxide and titanium oxide. Titanium is industrially manufactured in enormous amounts each year. Color pigments with crystal sizes smaller than 40 nm are now used in commercial LCDs to improve color purity, brightness, and contrast for applications based on high-definition television. With the exception of a few specific cases, the majority of nanomaterials are being developed for lab-scale uses, and significant work is needed to get them to the commercial market. Finding alternatives to the usage of endangered and resource-limited materials in the manufacturing of nanomaterials is another significant difficulty linked with contemporary nanotechnology. Out of 118 elements, 44 will have supply restrictions in the upcoming years. The list of essential elements includes rare-earth elements, precious metals, and phosphorus. It is imperative to lessen reliance on vulnerable and important resources. For instance, efforts are being made to switch out essential lithium ions with more accessible metal ions in batteries. Carbon-based nanomaterials are an excellent option for large-scale synthesis for a variety of applications because carbon sources are widely available. The use of crucial components in many applications can be reduced with the use of core-shell-based morphologies. Water purification and wastewater recycling can both benefit from the active participation of nanotechnology. With more knowledge and swift advancements in nanotechnology, future problems facing contemporary civilization can be resolved.

From the above synthesis using soft chemical route, the expected results have been achieved.

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