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REVIEW ARTICLE

Green Synthesis of CoO Nanoparticles and their astounding Applications

Chandra Mohan Rajoria[1], Suresh Kumar Verma[1], Ravi Dutt Sharma[2]
1. Department of Chemistry, Girls College, Chomu, Jaipur, Rajasthan, India
2. Department of Pure Sciences, CETVET, Fiji National University, Republic of Fiji

ABSTRACT
This review paper describes the formation of cobalt oxide nanoparticles (CoONPs) with and without a green capping agent. The capping agent used here is carrageenan among the various polysaccharides. CoONPs were prepared without and with capping agent carrageenan. Both the procedure was followed by calcination at 400°C for 2 hours. The cobalt oxide nanoparticles have been characterized by UV-vis and FTIR spectrum. The synthesized cobalt oxide nanoparticles are subjected to band gap determination in view of photocatalytic and biomedical property of nanoparticles. The capped cobalt oxide nanoparticles show better band gap.
KEYWORDS: *Cobalt Oxide nanoparticles, carrageenan , band gap energy , FTIR , UV-vis*

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INTRODUCTION

Both natural and man-made nanoparticles can be found in the environment. Various nanoparticles are not only the result of contemporary technology, but also of natural phenomena like forest fires and volcano eruptions, in addition to commercially generated nanomaterials. Ultrafine sand grains of a mineral origin (such as oxides or carbonates) are also examples of naturally occurring nanoparticles. The burning of diesel fuel (ultrafine particles) or grilling accidentally produces large amounts of nanoparticles. Their submicroscopic size gives them special material properties. A vast range of substances, including as metals, metal oxides, dendrimers, and polymers, can be used to create these particles. The nanoparticles' special qualities, which result from their small size and high surface area to volume ratio, make them useful in a variety of fields, including electronics, energy, medicine, and catalysis. Numerous techniques, including as chemical synthesis, physical vapour deposition, and material synthesis with template assistance, can be used to create the nanoparticles. These days, nanoparticles are employed, for example, in the production of transparent sunscreens, stain-repellent textiles, self-cleaning windows, anti-graffiti coatings for walls, scratch-proof eyeglasses, paints that don't fracture, and ceramic coatings for solar cells. 'Smarter' surfaces and systems can be made stronger, lighter, cleaner, and with the help of nanoparticles.
The generated nanoparticles are useful in numerous applications and have a significant role in nanotechnology. This comprises dispersions in fluids (like ferrofluids), as ultrafine powder for thin films, as gases (like aerosols), or embedded in solid materials (like nanocomposites). Nanoparticles can be categorised in a variety of ways: Man-made or natural? By-products or produced? Is it inorganic or organic? via functionalization, surface characteristics, size, or form. The nanoparticles' diversity is significant. Their characteristics and uses are different. The nanoparticles differ not only in size but also in form, surface properties, chemical makeup, and manufacturing process.

DIFFERENT TYPES OF NANOPARTICLES

Depending on their size, shape, physical characteristics, and chemical makeup, nanoparticles can be divided into several categories. These nanoparticles include those based on carbon, ceramic, metal, semiconductors, polymers, and lipids. The two primary categories of nanoparticles are often classified as organic and inorganic. Micelles, dendrimers, liposomes, and compact and hybrid polymeric nanoparticles are all included in the first category. The second group consists of metal nanoparticles, silica, fullerenes, and quantum dots. Nanoparticles can also be categorised according to their size, shape, and chemical makeup. Based on physical and chemical characteristics, some of the important classes of nanoparticles are:

Carbon-based: Fullerenes, carbon nanotubes, graphene, and carbon dots are examples of carbon-based materials.These materials' exceptional strength, structure, electron affinity, electrical conductivity, and adaptability make them very interesting.

Ceramic Because of its uses in photocatalysis, catalysis, dye photodegradation, and imaging, these inorganic nonmetallic solids are attracting a lot of interest from researchers.

Semiconductor –

Semiconductor materials have large bandgaps and characteristics in between those of metals and non-metals. Their characteristics are significantly altered by bandgap tuning. As a result, they are crucial components for electronic devices, photocatalysis, and photooptics.

Polymers –

For a variety of uses, such as surface coating, sensor technology, catalysis, and nanomedicine, scientists have created a number of methods for creating polymeric nanoparticles.

NANOPARTICLE DIMENSIONS :

The amount of dimensions that fall outside the nanoscale (100 nm) range is how scientists categorise nanomaterials. Since no dimension in zero-dimensional (0D) nanomaterials is more than 100 nm, all dimensions are measured within the nanoscale. Nanoparticles are the most prevalent type of 0D nanomaterial. One dimension lies outside the nanoscale in one-dimensional (1D) nanomaterials. Nanowires, nanorods, and nanotubes are all members of this class. Two dimensions are outside the nanoscale in two-dimensional nanomaterials (2D). This class comprises graphene, nanofilms, nanolayers, and nanocoatings and is characterised by plate-like structures. Materials that are not limited to the nanoscale in any dimension are known as three-dimensional (3D) nanomaterials. Bulk powders, nanoparticle dispersions, nanowire and nanotube bundles, and multi-nanolayers can all be found in this class.

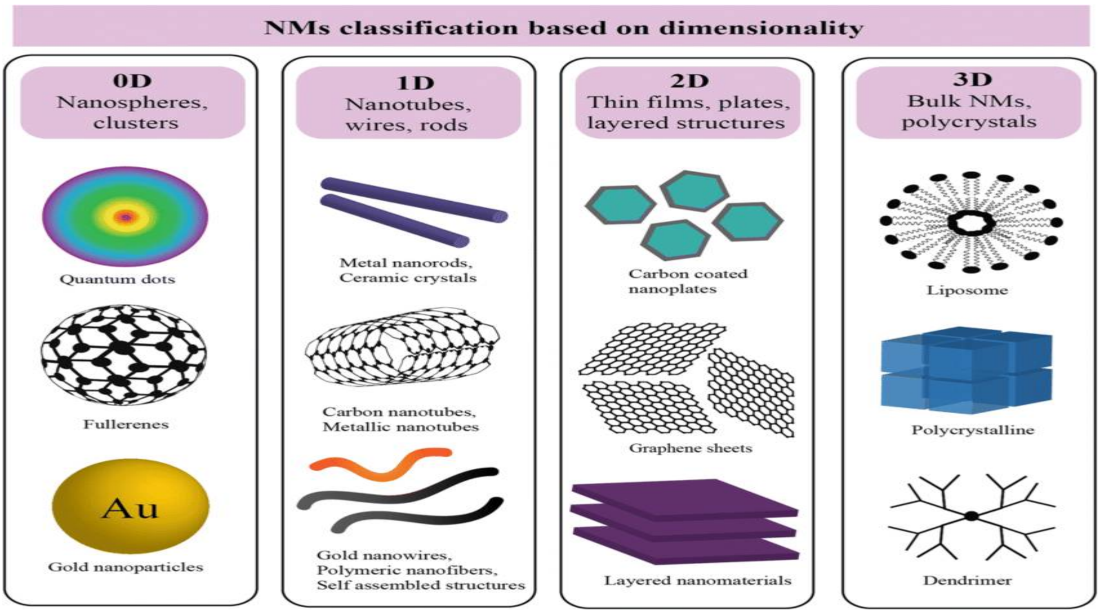

Figure 1: Nanoparticles dimensions

CHARACTERISTICS OF NANOPARTICLES:

Determining the physicochemical characteristics of nanoparticles and investigating the connections between their structure and function remain difficult tasks for researchers. Their capacity to thoroughly explore the nanoscale domain is a significant limitation: distinct characterisation methods only give a partial view of the characteristics of the nanoparticles because they are based on distinct physical properties. Even more difficult is the fact that the characterisation techniques themselves may have a direct impact on the nanoparticle amounts that are measured. From micelles to metal oxides, from polymers to big macromolecules, nanoparticles come in a variety of chemical forms. The chemistry of each of these materials is entirely distinct and can be examined using a range of techniques, such as solid-state NMR, optical spectroscopy, X-ray fluorescence and absorbance, and Raman spectroscopy. However, the nanometer-scale size of nanoparticles frequently dictate their behaviour. In order to completely comprehend and forecast the behaviour of nanoparticles, it is essential to examine their size, shape, surface charge, and porosity throughout the characterisation process.

APPLICATION OF NANOTECHNOLOGY :

Applications of nanotechnology often include energy, medical, and industrial applications. These include more ecologically friendly, higher density hydrogen fuel cells, medicinal drug delivery, and more robust building materials. Nanoparticles and nanodevices have found applications in nanoscale electronics, cancer therapies, vaccinations, hydrogen fuel cells, and nanographene batteries due to their great degree of versatility through alteration of their physiochemical properties.[1] The use of smaller materials in nanotechnology enables manipulation of molecules and substances at the nanoscale level, which can improve materials' mechanical qualities or provide access to parts of the body that are not readily accessible by hand. [1][2][3]

Application as catalyst :- Nickel, lead, silver, and platinum have all been employed as unique metal catalysts in chemical processes. However, the dissociative adsorption of hydrogen and oxygen molecules cannot occur on the surface of gold below 200 °C.[4] Because gold nanoparticles are not reactive in hydrogenation and oxidation reactions, gold is utilised as a catalyst in these processes. Nevertheless, Haruta found that gold nanoparticles function well as a catalyst.[5] Cluster structures include this state. The quantum size effect was observed in the physical properties. metals that are capable of forming atmosphericly unstable clusters. But because gold clusters are so stable, gold particles can be employed as catalysts. As the size of the gold nanoparticle decreases in catalysed oxidation reactions, the catalytic activity increases.

Application in food and agriculture :- New methods for desalination and water purification were made possible by nanotechnology, but they will be more cost-effective. The food sector can also be developed through the use of nanotechnology. For instance, new functional materials and tools for food preservation and biosecurity are created through the use of nanotechnology. The Bayer Company used nanotechnology to introduce airtight plastic packaging. This plastic packaging preserves food. Nanotechnology can be used to make genetic changes to the agricultural plant's constitution.

Applications in energy harvesting :- NPs are commonly employed in photo-electrochemical (PEC) and electrochemical water splitting processes to produce energy [6]. Solar cells [7] and piezoelectric generators [8] also very advance options [9] to produce energy other than reduction, water splitting [10], the electrochemical CO_2 [11] and from fuels [12]. At nanoscale level [13], NPs can also store the energy [14] into different forms [15]. That is why they also use in energy storage [16] applications. Using piezoelectric technology, nanogenerators can now transform mechanical energy into electrical energy, but this is an unusual method of energy production.

Application in micro wiring:- The most effective method for producing printed wiring boards in the electrical industry is metal nanoparticle paste.[17] The melting point of metal nanoparticles is lower than that of bulk metals. Circuit creation on polymer-based materials is achievable with traditional electric conduction paste. The thickness of wire is reduced to a nano level if particles at the nanoscale are employed. The ink-jet technique is crucial for the creation of nanoscale circuitry. Unlike widely used conventional processes like vacuum evaporation and photolithographic procedures, the ink-jet technology is less costly and takes less time. Gold can be used to produce metal nanoparticle paste. Due to the high cost of gold, copper is employed as a replacement. Nanoparticles of copper are employed as antioxidants.

Application in electronics: - Over the past several years, there has been an increase in interest in the development of printed electronics due to its great promise for lower costs than traditional silicon printing methods. It is anticipated that electronics printed with various inks will flow quickly. Additionally, CNTs as well as organic and ceramic nanoparticles may be present in these inks.[18] One dimensional semiconductor and metals have distinctive structural, electrical [19] and optical properties [20] which provide the key structural blocks for the development of electronic, photonic materials and sensors [21]. These days, the electrical industry is gradually discovering novel semiconducting materials. Nevertheless, transistors and diodes—even tiny chips—are being used in place of evacuated tubes [22].

Application in medicine: - Nanoparticles have very useful applications in medicine like: used in Fluorescent biological labeling [23], in drugs [24] and gene delivery [25], in biological detection of pathogens [26], useful in finding of proteins [27], in probing of the DNA structure [28], for tissue and cell engineering [29], used for tumor destruction through heating (hyperthermia) [30], helpful for separation and purification of biological cells and molecule [31].

METAL OXIDE NANOPARTICLES

With an electronic structure that can display metallic, semiconductor, or insulator features, metal oxides can take on a wide range of structural geometries, giving them a diversity of chemical and physical properties. Consequently, the most crucial functional materials for chemical and biological sensing and transmission are metal oxides. Furthermore, they are great candidates for electrical and optoelectronic applications due to their distinct and adjustable physical characteristics. Because of its prospective uses as well as scientific interest, nanostructured metal oxides have been the subject of extensive research. [32,33]

COBALT OXIDE NANOPARTICLES:

CoO, crystallizing in the rock salt structure, is antiferromagnetic (TN ~ 298 K) and electrically insulating.[34] Although there are a few reports in the literature on the preparation of CoO in bulk form, this material is difficult to obtain in pure form by simple methods, often being contaminated with Co_3O_4 or Co metal.Gravelle et al.[35] synthesized bulk CoO by heating an aqueous solution of $Co(OH)_2$ at 273 °C under vacuum, obtaining CoO mixed with Co_3O_4. El-shobaky et al.[36] prepared CoOx (x > 1) by decomposing $Co(CO_3)_2$ under reduced pressure around 900 °C. CoO nanoparticles in the 10-80-nm range have been prepared by heating the gel precursor obtained by drying a solution of $Co(NO_3)_2$ and poly(vinyl alcohol) at 225 °C in a H2 atmosphere.[37] Flipse et al.[38] have deposited CoO nanoparticles on a Si (100) substrate by spin coating an alcoholic solution of $Co(CH_3COO)_2$ followed by calcination in air at 477 °C. Decomposition of $Co_2(CO)_8$ in toluene in the presence of the surfactant Na(AOT) at 130 °C in air results in CoO nanocrystals mixed with Co and Co_3O_4.[39] Jana et al.[40] have recently obtained Co_3O_4 nanoparticles by the pyrolysis of fatty acid salts of cobalt in a hydrocarbon solvent under an argon atmosphere. Glaspell et al.[41] have recently prepared CoO nanoparticles from Co metal by laser vaporization condensation under carefully controlled partial pressures of O_2. Clearly, part of difficulty in preparing pure CoO is because of the greater stability of Co_3O_4 and the readily reducibility of CoO to Co metal. Nanocrystals of CoO are even more difficult to prepare because of the additional problems associated with surface oxidation.[42]

APPLICATION OF COBALT OXIDE NANOPARTICLES

In micro-electronics, as magnetic nanoparticles with a wide range of uses in microbatteries, nanowires, and specific alloy and catalyst applications, as well as in catalysis, superconductors, electronic ceramics, and other fields as an important inorganic material, as catalysts and catalyst carriers, as electrode active materials, for colourants and pigments in glass and porcelain, as oxidants in the chemical industry, as carbides, in temperature and gas sensors, as electrochromic devices, in enamels, solar energy absorbers, etc.

CONCLUSION

Cobalt oxide nanoparticles were obtained by the calcinations of $Co(OH)_2$. $Co(OH)_2$ obtained with capping agent carrageenan is greenish blue in color whereas $Co(OH)_2$ obtained without capping agent is pink in color. CoONPs@carrageenan are black in color and have rough texture while CoONPs@carrageenan are black in color having crystalline texture. This was identified through their appearance. The band gap energy was observed to be increase significantly in CoONPs@carrageenan. This is due to the reason that band gap energy increases with the decrease in size of nanoparticles. This is due to the quantum confinement effect. The size of nanoparticles decreases due to capping effect which results in increase of band gap energy. However, it's important to note that the relationship between band gap and size of nano particles can be more complex, depending on the specific material and the environment in which it is measured.

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