Synthesis and Applications of MgO and its Nanocomposites: A Review

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***Abstract*: One of the alkaline-earth metal oxides is magnesium oxide (MgO). The synthesis of MgO nanoparticles has been reported using a variety of techniques. Because of their anionic vacancies, MgO nanoparticles were of particular importance. MgO nanocomposite particles are non-toxic and flavourless, making them more suitable for use in a variety of applications. Superoxide anion, or O_2, and the alkaline effect are two characteristics that set MgO nanoparticles apart from other materials. MgO nanoparticles are employed in a wide range of fields, including windows layers, medical applications, photocatalysis antimicrobial applications, optical sensors, gas sensors, and biomedical applications due to this property. The sensitivity, selectivity, stability, and limit of detection of their nanocomposites are higher than those of pure MgO nanoparticles. The various synthesis, characterization, and application methods for MgO nanoparticles and MgO nanocomposites have been compiled in this review.**

Keywords: Alkaline earth metals, synthesis, **nanoparticles** ***biomedical, nanocomposites.***

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1. Introduction

A semiconductor metal oxide gas sensor is a device that uses the principles of material science, process optimization, and sensing to turn information about an unidentified analyte into other signals. A lot of people are interested in the development of gas nanosensors as a practical way to find out what harmful gases are around. However, problems like poor selectivity, low response, and high activity temperature, among others, restrict their development and application [1, 2]. The formation of nanocomposites is a topic of research to reduce these problems. By adding two metal oxides during synthesis and using various techniques, the nanocomposites can be formed [3, 4].

When two semiconductors with different band gap widths touch, they interact in a transition region called a heterojunction [5]. As we all know, there are two types of semiconductors: n-type semiconductors and p-type semiconductors. Therefore, there are two categories of heterojunctions: homogeneous heterojunctions (n-n and p-p heterojunctions) and heteromorphic heterojunctions (p-n heterojunctions). Nanocomposites can be found in a variety of structures, including nanoparticles, nanosheets, hollow microspheres that resemble flowers, nanofibers, and nanorod [5, 6]. Because the two different materials have different chemical and physical properties, such as band structure, dielectric constant, crystalline structure, and electronegativity, the mismatch phenomenon at the interface gives the heterojunction a number of new properties that have led to a lot of research on heterogeneous materials and devices [5, 7].

MgO is an n-type semiconductor. The wide-bandgap of MgO is ~7 eV. It has a low electron affinity. MgO is mostly suited for electron emission applications, especially in a plasma environment. Recently, MgO has been studied extensively in different areas due to its stable secondary electron emission and protective layer for plasma-related devices.

MgO has a halite or cubic structure and a lattice arrangement of Mg2+ ions and O_2^- ions in ionic bonding [5, 8].

The main aim of the present research is to brief information of synthesis, characterizations and applications of MgO nanoparticles and its nanocomposites.

2. Synthesis methods of MgO nanoparticles and its nanocomposites

Nanocomposites of MgO can be prepared through different synthesis approaches, such as the bottom-up approach and the top-down approach. These are the two major approaches for the synthesis of nanoparticles in the field of material science. By using these two approaches, the physical, chemical, and electrical properties of the host material can be modified. The structural parameters like specific surface area, bandgap, crystallite size, and morphology can be achieved depending on the reaction conditions, the basic starting materials, or their concentrations during synthesis.

In the bottom-up and top-down approaches, many methods are involved. Physical, chemical, and biological are the three common methods used to synthesize nanoparticles. Each and every method has some advantages and disadvantages. According to a literature survey, the biological or green synthesis method is better than physical and chemical methods because it is eco-friendly, non-toxic, less expensive, and a biodegradable method.

The various synthesis methods and reported results by different researchers are elaborated in this section as follows:

Suresh et al. [10] used an extract of Nephelium lappaceum L. and double-distilled water for green synthesis, whereby magnesium nitrate was used as a precursor. They verified the cubic structure of MgO by the investigations that were carried out, and the average crystallite size was determined as 55 nm, which agreed very well with the SEM measurements. The grain size was obtained in between of 60–70 nm. Vargheese et al. [11] synthesized MgO by using Trigonella foenum-graecum extracted in double-distilled water using magnesium nitrate as a precursor. The average crystalline size determined from XRD was around 14 nm. It is evident from the SEM measurements that the particles prepared in this way had a mixture of fine, spherical structures. Mustuli et al. [12] focused on the production of nanostructured nanoparticles with the sol–gel method, also found that using magnesium acetate tetrahydrate together with a complexing agent in the form of oxalic acid and tertiary acid could inhibit crystal growth to achieve a thermally stable nanostructure with uniform nanoparticle size distribution. Boddu et al. [13] synthesised MgO nanoparticles with a coralline structure by starting with magnesium ribbons. In this instance, hydrolysis, supercritical drying, and thermal activation came first, then a solution of magnesium methoxide. This process produced particles of the mentioned structure with dimensions of 200–300 nm. Dercz et al. [14] looked at the structure of a nanopowder made from MgO xerogel by first mixing magnesium methoxide with methanol and then toluene. Applying the procedure reported in this study, an average crystallite size of 7.5 nm and a specific surface area of 138 m^2/g were achieved. Karthikeyan et al. [15] also looked at how the amount of PEG affected the way the co-precipitation method made MgO NPs. Magnesium nitrate was again used as a precursor and sodium hydroxide as a precipitation agent. The crystallite size determined by XRD shows that using PEG is almost twice as large as using pure MgO (8.62 nm vs. 14.76–15.78 nm). There are also visible differences that are due to the presence of PEG in terms of morphology. Pure MgO had a spherical shape, and PEG-modified MgO had a flake-like structure. Devaraja et al. [16] described the properties of a nanocrystalline MgO powder that had been prepared from magnesium nitrate hexahydrate and sodium hydroxide. Their presented procedure resulted in porous magnesium oxide particles with an average crystallite size of 25 nm. Among the other reported properties of the synthesized particles was the optical energy bandgap is 5.5 eV. Balakrishnan et al. [17] synthesized MgO using the solution combustion method. They used magnesium nitrate as an oxidizer and urea as fuel. Using this method, they produced MgO with a cubic structure and crystallite size around 22 nm, as seen from the XRD results. Through SEM analysis, the authors found that the particles are spherical and their size is uniform. Interestingly, compared to other studies, the synthesized particles have a bandgap of only 2.9 eV. Ranjan et al. [18] used a modification of this process in which glycine was used as fuel and magnesium nitrate was the precursor. From the XRD results, they determined the crystallite size to be 20.76 nm. Mashad et al. [19] prepared MgO particles using the co-precipitation method by observing the effect of different reaction conditions, such as temperature, pH, and the molar ratio of the precursor (magnesium nitrate). Using the procedure presented in their work, they formed nanoparticles and nanorods with a relatively high specific surface area (231 m2/g for nanoparticles and 176 m2/g for nanorods) and a particle size of 50 nm. The results show that there is an effect of a polyethylene glycol (PEG) template and pH on particle morphology. Frantina et al. [20] prepared MgO particles by calcination of magnesium carbonate, which they first synthesized by mixing ammonium carbonate and magnesium chloride. The XRD results show an average crystallite size of 24 nm for a cubic structure. The spherical morphology of the particles was determined by scanning electron microscopy (SEM), with insignificant differences in particle size (an average of 50.9 nm). Fatiquin et al. [21] tried to make MgO by starting with magnesium chloride and adding Moringa oleifera as a reagent. Their efforts resulted in particles with a crystalline size of around 21 nm. These particles, according to TEM, exhibited a cubic structure and ranged in size between 2 and 50 nm. Nguyen et al. [22] made MgO particles from the flower, bark, and leaf extracts of Tecoma stans L. and a magnesium nitrate precursor. Depending on the extract used, the resulting particles were either round or hexagonal, and the average size of the crystals was between 20 and 50 nm. The authors found that the flower extract was the most promising, mostly because the synthesized particles were able to absorb a lot.

The creation of the MgO nanocomposite has drawn considerable interest. Both top-down and bottom-up methods were used to synthesize numerous MgO nanocomposites. By employing a solvothermal technique, Alla et al. [23] synthesized CuO-MgO nanocomposites and investigated the catalytic uses for these materials. According to the results of this method, it was discovered that the catalytic activity increased as the amount of CuO in the nanocomposite did. Ma, H. J. et al. [24] synthesized an Y_2O_3-MgO nanocomposite by sintering ceramic powder. Excellent mechanical, thermal, and optical characteristics can be seen in the prepared nanocomposite. The authors reported the fluorescence spectrum and cross-section values of the Y_2O_3-MgO nanocomposite in order to evaluate its potential as a laser gain medium. At high Er3+ ion dopant concentrations, the Er:Y_2O_3-MgO nanocomposite also exhibits excellent mechanical and thermal properties. Y_2O_3-MgO nanocomposite ceramics are promising candidate materials, according to the results, for use as high-power infrared laser hosts. By using a microwave-assisted technique, Kannan, K., et al. [25] prepared a CdO-MgO nanocomposite. The oxides of magnesium and manganese, MgO and MnO2, were made using the conventional method of mixing and grinding with various mixing ratios. According to the authors, the homogeneous structure of MgO-MnO_2 NCPs was confirmed by the analytical results, which also pointed to the high efficiency of the MgO-MnO_2 nanocomposite compared to individual oxides (MgO and MnO_2). The NCPs particle size distribution results, which ranged from 16.4 to 100 nm, make them promising for use in biomedical and medical applications. Using a straightforward precipitation method, Azhari, A., et al. [26] synthesized MgO-Fe_2O_3 nanocomposite and investigated the formation of magnesioferrite spinel as a result of a solid-state reaction occurring at a very low temperature. Using the sol-gel and ultrasound methods, Wang, H., et al. [27] synthesized Ag_2S-MgO/graphene oxide nanocomposites and investigated their structural, highly photocatalytic, and antimicrobial activities. The author stated that MgO, Ag2S-MgO, and Ag_2S-MgO/GO are distinguished by having average crystallite sizes of 24.2, 29.3, and 33.1 nm, respectively. Ag_2S-MgO, MgO, and Ag_2S-MgO/GO have band gaps of 4.08, 3.25, and 2.82 eV, respectively. Rhodamine B (RhB) showed the highest photo-degradation rate in Ag_2S-MgO/GO nanocomposites under UV light (98.8%) and visible light (64.8%) over the course of 60 minutes. Bacillus vallismortis, Escherichia coli, Aspergillus flavus, and Trichoderma viride were used to test the prepared nanomaterials' antibacterial and antifungal abilities. By significantly reducing the amount of bacteria and fungi in the medium after the addition of the Ag_2S-MgO/GO nanocomposites, the beneficial antibacterial and antifungal performance of these materials was further demonstrated. Huang, Y. Z., et al. [28] used chitosan, $CaCO_3$/MgO nanocomposites made from eggshells, and these other materials to make a biomimetic scaffold for bone regeneration. Eggshells are a type of natural biomaterial, and one of their main inorganic components is $CaCO_3$. Here, we made eggshell particles coated with MgO nanoparticles and then they chemically linked the $CaCO_3$/MgO nanocomposite with bone morphogenetic protein 2 to produce a bio-inspired active scaffold. The results showed that the new composite scaffold made of $CaCO_3$, MgO, CMC, and BMP2 was stronger than the CMC scaffold in terms of modulus and compressive strength. It's interesting to note that the composite scaffold has a lot of room for osteogenic differentiation and mineralization. Liu, L., and colleagues [29] synthesized highly-infrared transparent Y_2O_3-MgO nanocomposites using a colloidal technique and spark-plasma sintering. Spark-plasma sintering, according to the author, is a potent method for creating fine-grained, dense, transparent ceramics that are suitable for making IR-transparent Y_2O_3-MgO composite ceramics from pre-commercial starting powders.

3. Applications of MgO nanoparticles and its nanocomposites

Figure 1 shows the different applications of MgO nanoparticles and its nanocomposites

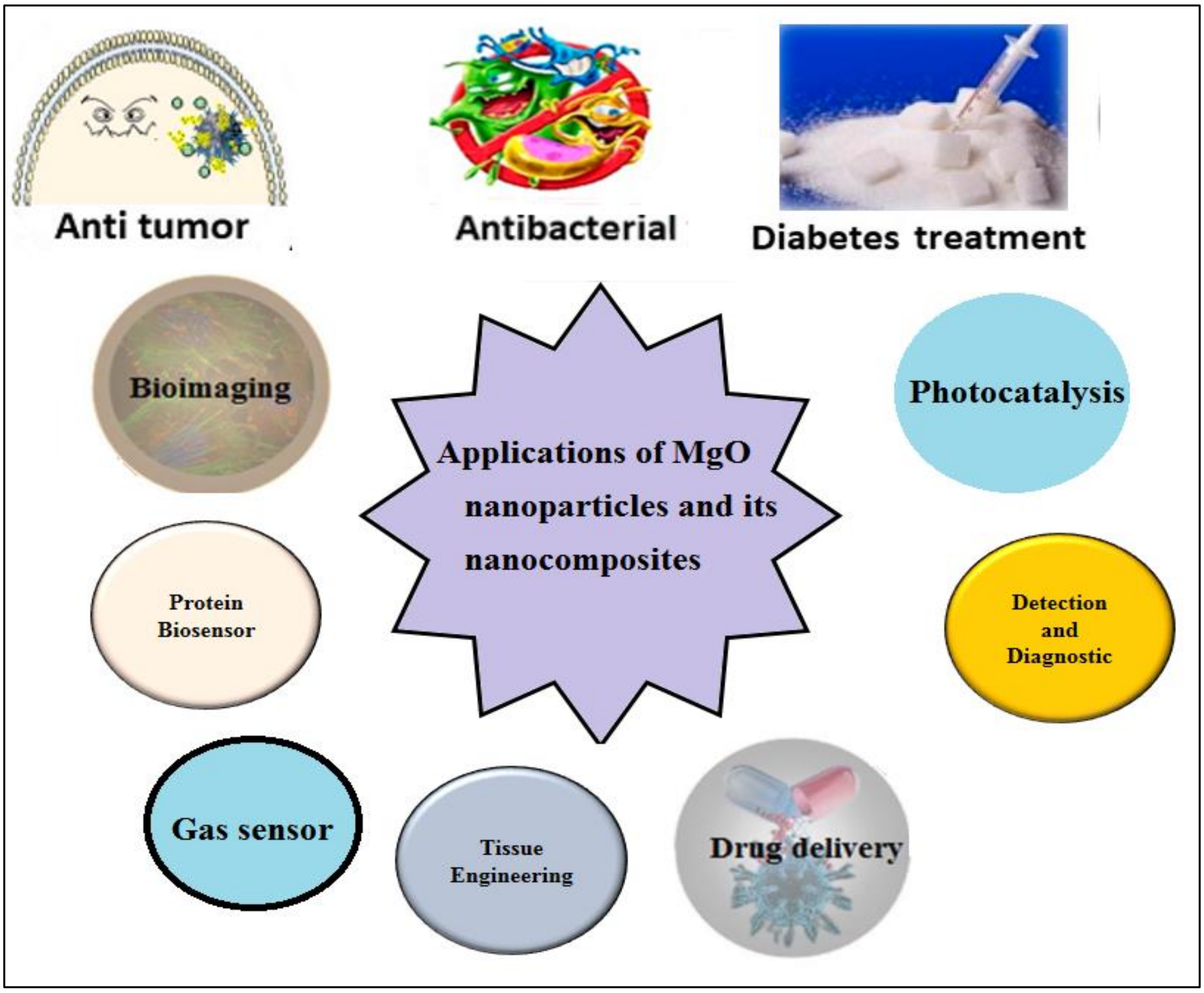

Figure 1: Applications of MgO nanoparticles and its nanocomposites

Conclusions and future scope

This review discusses the synthesis of MgO nanoparticles and their nanocomposites as well as their current uses in a range of applications. This paper will help the research scholars who are working on MgO nanoparticles and their nanocomposites in the future. More research is required to ascertain how these nanocomposites might be applied in farming as well as in the environment since there aren't many reports on the use of MgO nanoparticles and nanocomposites in the fields of farming and ecology.

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