

# Flame Synthesis of Magnesium Oxide Nanoparticles for Photocatalytic Degradation of Aqueous Methylene Blue Dye

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## Abstract

Magnesium oxide (MgO) nanoparticles were prepared using a straightforward Flame Synthesis technique, and their photocatalytic potential against methylene blue (MB) dye was examined. XRD, UV-visible spectroscopy, FESEM, and EDX analysis are used to characterize the produced samples. MgO contains pure cubical phases, according to XRD measurements. FESEM study reveals that pure MgO nanoparticles have irregular, nanocubical, and nanoclustered morphologies. The prepared sample is free of contaminants according to the EDX data. A red shift in the wavelength-dependent absorbance curve was verified by UV-visible spectroscopy analysis. It is shown that MgO degrades MB with an efficiency of 88%.

**Keywords:** MgO Nanoparticles, Flame synthesis, photocatalysis, MB degradation.

## 1. Introduction

One of the key components of the sustainable development goals is the detoxification of organic contaminants from the environment[1]. Recently, there has been a lot of interest worldwide in the thorough and efficient removal of harmful organic contaminants from wastewater[2]. Our natural environment is seriously threatened by the dangerous and damaging dye effluents that are emitted by the pulp, paper, and textile industries in particular[3]. Persistent and non-biodegradable azo dyes, which are carcinogenic and can, have detrimental effects on humans and aquatic species, make up the majority of dye effluents[4]. The great stability and complex structure of the dyes make traditional and customary wastewater treatment methods ineffective[5]. Consequently, the application of metal oxides as semiconductor photocatalysts for the complete elimination of various hazardous environmental contaminants has proven to be highly beneficial throughout time[6]. Semiconductor photocatalysis is a cutting-edge approach to wastewater treatment that opens up a lot of possibilities for harnessing naturally accessible resources[7]. With an emphasis on their morphology and size, this method is commonly used to design, characterize, and explore the photocatalytic potential of nanostructured materials[8]. The potential uses of metal nanoparticles, porous metal oxides, carbon nanomaterials, and their composites in electrocatalysis have been thoroughly investigated[9].

Over the years, a number of metal oxide nanoparticles, including ZnO, SnO<sub>2</sub>, MnO<sub>2</sub>, MgO, and graphitic nanomaterials, have been used as efficient photocatalysts to break down organic pollutants in water and air[1]. Furthermore, nanoparticles have garnered enough attention to be regarded as a feasible material for modifying existing methods[10]. Numerous nanoparticle-based formulations, including insecticides, herbicides, fungicides, and fertilizers in nano-form, have been thoroughly studied for the management and preservation of soil and plant health[11]. It is generally known that physical and chemical methods are used to produce metal oxide nanoparticles in particular[12,13]. These methods necessitate complicated procedures, high temperatures, vacuum conditions, and specialized chemicals and equipment[3]. Additionally, the synthesis of nanomaterials using toxic organic solvents and deadly chemicals may increase the risks to our ecosystem and life forms[5]. Thus, creating a non-toxic and eco-friendly method for making nanoparticles is really necessary[14]. In order to develop non-toxic, inexpensive, one-step processes, scientists have concentrated their efforts on the synthesis of nanoparticles[2]. High chemical and photostability, a wide band gap, a low dielectric constant, a low refractive index, and other characteristics make magnesium oxide a versatile oxide material[3].

## **2. Materials and methods**

### **2.1. Synthesis of MgO Nanoparticles**

The nozzle delivers a mixture of oxygen and acetylene gases in an equal ratio (50:50) to create a neutral oxy-acetylene flame that will completely burn the metallic microparticles[1]. A bluish flame with a core temperature of more than 3000°C can be created by optimizing the gas flow through the nozzle with the regulator[3]. Using a powder feeder, the reactants in the form of metal powders were steadily fed into the flame core to cause combustion[2]. According to the previous study, a powder feeder with a screen was used to feed metallic magnesium powders with a grain size of around 40 µm into the bluish flame[3]. The metallic magnesium powders are quickly melted and ionized by the high-temperature flame[3]. The resulting MgO nanoparticles are subsequently deposited over the particle collector after combining with the nearby oxygen molecules[3]. The deposited MgO nanoparticles were subsequently collected using the powder collector and characterized for additional study[2].

### **2.2. Characterization**

The structural characteristics of pure MgO nanoparticles produced by flame synthesis were investigated using X-ray diffraction (XRD) [1–3,15]. Energy Dispersive X-ray Analysis (EDX) was used to analyze the chemical makeup and purity of MgO nanoparticles[1–3,15]. The optical characteristics of MgO nanoparticles in the 200–900 nm range were examined using the JASCO V-770 UV visible spectrophotometer (UV-Vis) [1–3,15]. The size, shape, and surface roughness of both flame synthesis nanoparticles were evaluated using Field Emission Scanning Electron Microscopy (FESEM)[1–3,15].

### 3. Results and Discussion

#### 3.1. Structural analysis

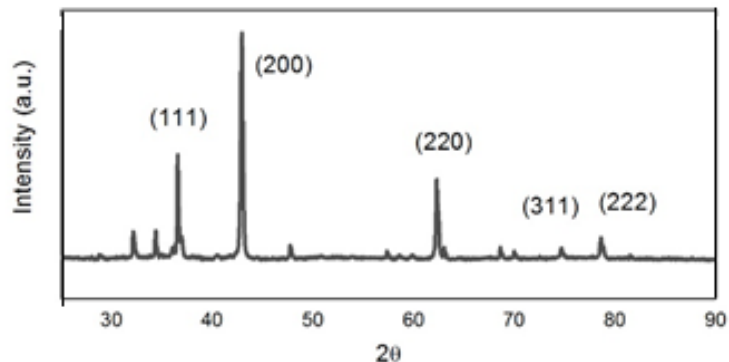


Figure 1 XRD of pure MgO nanoparticles

The phase, crystalline structure, and size of nanoparticles made using the flame synthesis process are ascertained using the XRD methodology[1–3,15]. Figure 1 displays the XRD pattern of pure MgO and Mn:MgO nanoparticles produced via flame synthesis[1–3]. The cubical structured MgO construction is confirmed by the planes (111), (200), (220), (311), and (222) matching those of JCPDS card No. 45-0946[3]. The average crystallite size (D) for MgO nanoparticles was calculated using the Debye-Scherrer equation (1), and the result was 61 nm[1–3].

$$D = \frac{K\lambda}{\beta \cos\theta} \quad (1)$$

#### 3.2. Chemical analysis

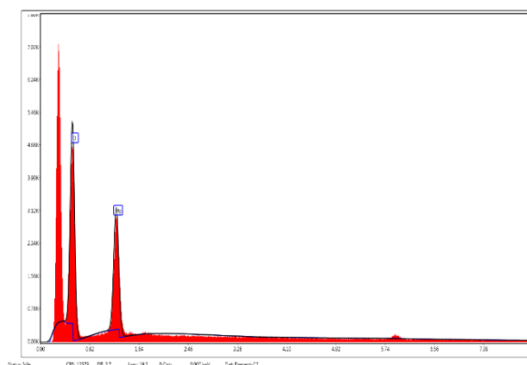


Figure 2 EDX Spectra of pure MgO nanoparticles

EDX can verify the elemental composition, chemical composition, and purity of MgO nanoparticles produced via flame synthesis[1–3].. As seen in Figure 2, the EDX spectrum of MgO displays the classic peaks for oxygen at 0.5 eV and magnesium at 1.4 eV[3]. These spectra confirm the cleanliness of the produced nanoparticles, which is one of the main benefits of the flame synthesis method[1–3].. The EDX spectra show that the MgO nanoparticles have acceptable stoichiometry. Table (1) lists the elements found in the synthesized nanomaterials along with their weight and atomic percentages[1–3]..

Element	Series	Weight Percentage	Atomic Percentage
Mg	K	37.75	28.52
O	K	62.25	71.48

Table 1: MgO EDX data

### 3.3. Surface analysis

FESEM is a great characterization method to examine the surface texture and crystalline properties of flame-synthesised MgO nanoparticles[3]. Figure 3 displays MgO nanoparticle FESEM images[3]. During the creation of MgO nanoparticles, the bulk metal magnesium powders fall onto the high-temperature oxy-acetylene flame[3]. They instantly melt and react with the oxygen to form irregular nanocubes and nanocluster structures[3].

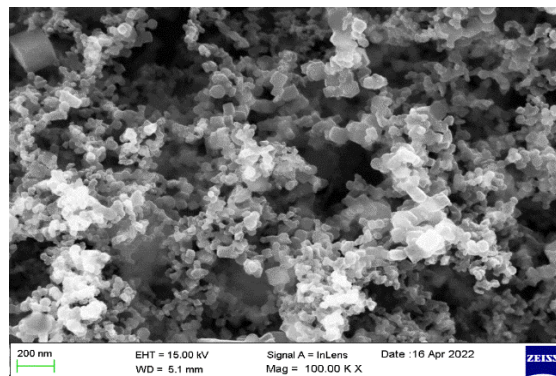


Figure 3 FESEM images of pure MgO nanoparticles

### 3.4. Optical studies

UV-Vis spectroscopy is the most effective method for analyzing the optical properties of flame synthesis nanoparticles[1,2]. Figure 4 displays the absorbance versus wavelength peaks for pure MgO nanoparticles[3]. MgO exhibits low absorbance above 250 nm and high absorbance between 200 and 250 nm[3]. The band's edge is blue-shifted and the absorbance coefficient hardly decreases, which may be explained by an increase in charge carriers and electron transfer from the valence band of oxygen's 2p states to the magnesium conduction band[3]. The band gap values of the generated nanoparticles were calculated using Tauc's plot formula, and found as 4.1 eV[3].

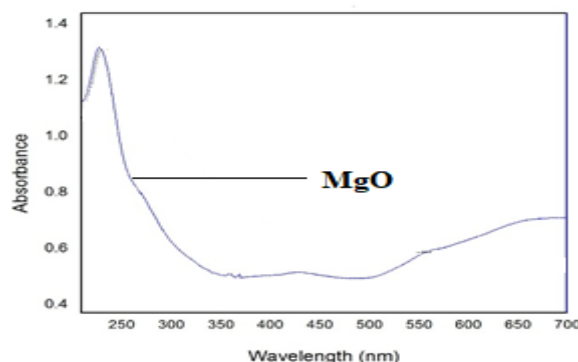


Figure 4 UV-Vis Absorbance spectra of MgO nanoparticles

#### 4. Photocatalytic Degradation of Methylene blue dye

The absorbance spectra of MB under UV light with synthetic photocatalysts present are shown in Figure 5[3]. Due to MB dye degradation at 660 nm, the absorption intensity decreases linearly with increasing irradiation time from 0 to 180 minutes[3]. Additionally, it was shown that the color of the aqueous solution gradually fades as the duration of UV irradiation increases[3]. The breakdown of MB dye in the presence of MgO nanoparticles is shown in Figure 5[3]. Before being exposed to UV light, very little photolysis was seen in the catalyst and blank test in the dark. Highly reactive  $\text{OH}^-$  (hydroxyl) and  $\text{O}_2^-$  (superoxide) radicals are produced when UV light strikes MgO because it absorbs photons and energy ( $E=h\nu$ )[1,2]. The disintegration of the MB dye solution depends on both radicals[3,16,17].

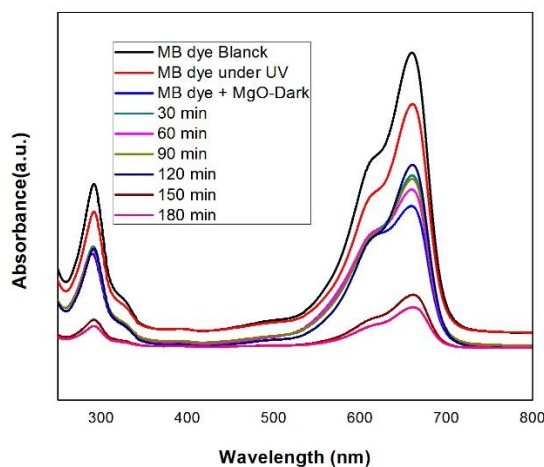


Figure 5 MB degradation in presence of MgO nanoparticles

The decolorization of the MB solution indicates that the degradation efficiency of MB dye in the presence of MgO catalyst reaches 88% after 180 minutes of UV irradiation[3]. Additionally, the longer lifespan of MgO photocatalysts and the greater conveyance of charge carriers to the substrates through an effective charge separation method are responsible for the higher MB degrading activity[3].

#### 5. Conclusion

Cubical phased MgO nanostructures were created using a one-step flame synthesis process and verified by XRD. EDX was used to verify the samples' purity. Because to higher surface level defects and reduced charge carrier recombination rates, which boost the production of extremely reactive  $\text{OH}^-$  and  $\text{O}_2^-$  radicals, the degradation efficiency approaches 88%. According to this study, one of the most capable and promising photocatalysts for high performance photocatalytic applications and the removal of hazardous organics from water resources are MgO nanoparticles produced using a simple, one-step, quick flame synthesis process.

#### Acknowledgement

#### Conflicts of interest/Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Consent for publication

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