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Structural and thermoluminescence properties of magnesium oxide by exposed to beta radiation

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ABSTRACT

In this research, magnesium oxide nanoparticles were produced through the chemical spray pyrolysis technique by using magnesium chloride and deionized water at room temperature. Structural characterization of magnesium oxide was carried out by x-ray diffraction system, the pattern confirmed that the prepared magnesium oxide sample has a pure MgO phase with (2 0 0) orientation. Scanning electron microscopy images (SEM) showed that the surface was covered by spherical and irregular shapes in different sizes on the nanoscale ranging between 50 nm and 100 nm. UV–Vis spectroscopy system was used to estimate the band gap energy; it was equal to 3.7 eV. In addition, we investigated the thermoluminescence and dosimetric characterization of magnesium oxide by studying the TL glow curve intensity. The results exhibited that the intensity of TL is increased with increasing of absorbed dose as a function of the temperature. According to the obtained results, MgO is a promising material as a TLD device.

1. Introduction

In the last decades, thermoluminescence dosimetry (TLD) in the radiation protection field has developed; it is considered the great and significant dosimetric method to measure the absorbed dose to humans whether in the medical or industrial sector and personal monitoring. The reasons which make TLD dosimeter employed in the radiation protection aspect due to nearly soft tissue-equivalent, simple configuration, reproducibility, low fading. good repeated readouts and accurate detection (Srivastava et al., 2017), (Damulira, 2022). Magnesium oxide (MgO), also known as magnesia is promising material in semiconductor technology with a wide range of properties that make it suitable for various applications because of its unique properties such as its high melting point of around 2800 °C, an excellent thermal insulating properties, which make it useful for thermal insulation products.

Recently, MgO is used in new technology applications due to the high optical transparency in a wide wavelength range. Moreover, MgO is a promising candidate for lighting industry, optical systems and laser technology. MgO has relatively high sensitivity to ionizing radiation, allowing it to detect even low levels of radiation exposure accurately, as well as can be exposed to a wide range of temperatures during the heating process, allowing for flexibility in the measurement protocol (Sathyamoorthy & Luthra, 1978), (Soliman, 2009), (Mhetre et al., 2022), (Devaraja et al., 2015).

There are various techniques for production of MgO films, such as sol–gel synthesis (Yoon et al., 1997), metalorganic molecular beam (Niu & Hoerman, 2000), pulsed laser deposition (Aadim, 2018) epitaxy and chemical vapor deposition (Sung et al., 2000). In our research, we used the spray pyrolysis deposition technique since it has many advantages. It does not require an expensive equipment of vacuum or high-quality substrates, the process of deposition is speed and many of layers can be produced.

The main goal of this work is synthesizing of MgO nanoparticles by chemical spray technique and studying their structural, thermoluminescence and dosimetric properties for radiation dosimetry application purpose.

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2. Experimental details

The chemical spray pyrolysis technique was used to synthesize magnesium oxide nanoparticles. 0.2M of magnesium chloride hexahydrate ($MgCl_2.6H_2O$) was used and dissolved in 50 ml of deionized water, and the appropriate weight for each component was measured by a sensitive electronic balance device (Model; Sartorius Group 2004), and then the precursor solution kept on the magnetic stirrer at 75 °C for I hour until homogenized and became evident. Glass substrates were cleaned by ultrasonic cleaning system by pure water, ethanol and acetone respectively for 1 h; the deposition temperature was kept to 400 °C. The process of fabrication of MgO briefly can be clarified in Fig. 1.

The phase identification was conducted by X-Ray diffraction (XRD) system. The morphology properties and particle size of the samples were examined by Scanning Electron Microscope (SEM). The band gap energies of the samples were measured in the wavelength range of 200 nm–1000 nm by using a UV–Vis spectrophotometer (Model -Jasko-V770 Spectrophotometer). 25 mg of MgO as a powder has been used for thermoluminescence and dosimetric characterization by TLD reader model Harshaw 3500 analyzer.

3. Results and discussion

3.1. X-ray diffraction measurements

X-ray diffractometer with Cu-Kα radiation with wavelength 1.54060 Å and 2θ ranged from 20° to 80° resolution, has been used to study the structural properties of MgO nanoparticles and to identify the crystal phase. Fig. 2 shows the x-ray diffraction pattern of MgO, which confirms a cubic structure and the diffraction peaks were found at 2θ value of 36.9°, 42.9°, 62.2°, 74.6° and 78.6° with attributes (111), (200), (220), (311) and (222) respectively. The structure sample was pure with no unwanted impurities or secondary phases. It is consistent with the library code value of MgO (Pattern: COD 9000501). And agreement with literature reported (Rao et al., 2015, pp. 8–9).

3.2. Surface morphology analysis by scanning electron microscopy (SEM)

Morphology and chemical composition of the magnesium oxide surface examined by FEI Quanta FEG 250 Scanning Electron Microscope (SEM), which attached with energy dispersive spectroscopy system (EDS). The measurements have been done by SEM and obtained results were exhibited in Fig. 3.

Fig. 3-a shows the SEM morphology a general shape of surface at lower magnification20000 showed spherical and irregular shapes in different sizes, and Fig. 3-b is at high magnification 100000 these particles have sizes at nanoscale ranging from 50 nm–100 nm. Our result is in agreement with literature reported in Ref. (Park et al., 2006).

3.3. EDS measurements of MgO

Energy dispersive spectroscopy system (EDS) which followed by SEM measurements was also used in this work. It has been used to determine the chemical composition of magnesium oxide. The weight percentage for each element id given in Table 1 and EDS spectrum image of MgO displayed in Fig. 4.

The effective atomic number of MgO was calculated to be **11.4** using the well-established formula (Eq. (1)) (Singh & Badiger, 2014). The information is obtained from Table 1.

$$Z_{eff} = \sqrt[2.94]{(f_1 x (Z_1)^{2.94} + f_2 x (Z_2)^{2.94} + \ldots)} \quad (1)$$

Where: f_n is the fraction of the total number of electrons associated with each element and Z_n is the atomic number of each element.

3.4. UV–Vis measurements of MgO

The optical properties were examined by UV–visible (UV–Vis) spectrophotometer (Model -Jasko- V770 Spectrophotometer) to calculate band gap energy and the optical characterization of MgO was performed by absorbance spectrum at a wavelength ranging from 200 to 1000 nm. The band gap value of MgO was calculated by using the thickness obtained from SEM measurements. For this calculation, the Tauc relationship (Arif et al., 2015) has been used as follows:

$$(\alpha h\nu) = A\,(h\nu - E_g)^n \quad (2)$$

Where: α; is the absorption coefficient, *A;* the constant, *h;* the Planck's constant, E_g; the optical band gap, and *n* the 1/2 for direct band gap semiconductors.

As shown in Fig. 5, an extrapolation of $(\alpha h\nu)^2$ on y-axis versus photon energy ($h\nu$) on the x-axis gives the value of the optical band gap. According to this mathematical calculation, we calculated the bad gap value of MgO as 3.6 eV it is in agreement with previous studies (Diachenko et al., 2016), (Rao et al., 2018).

3.5. Thermoluminescence readout and dosimetric properties of MgO

TL measurements were conducted by TLD reader model Harshaw 3500 analyzer, connected to a PC to record and process the data during

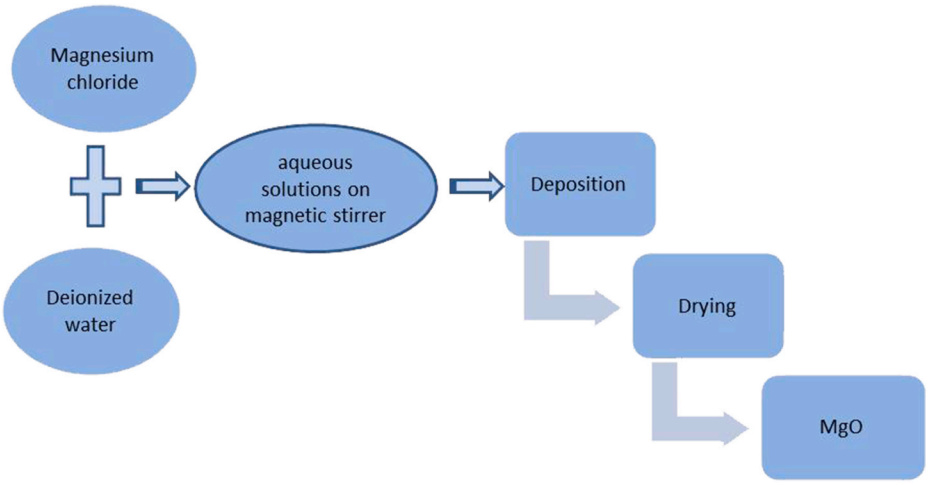


Fig. 1. Fabrication of MgO nanoparticles process.

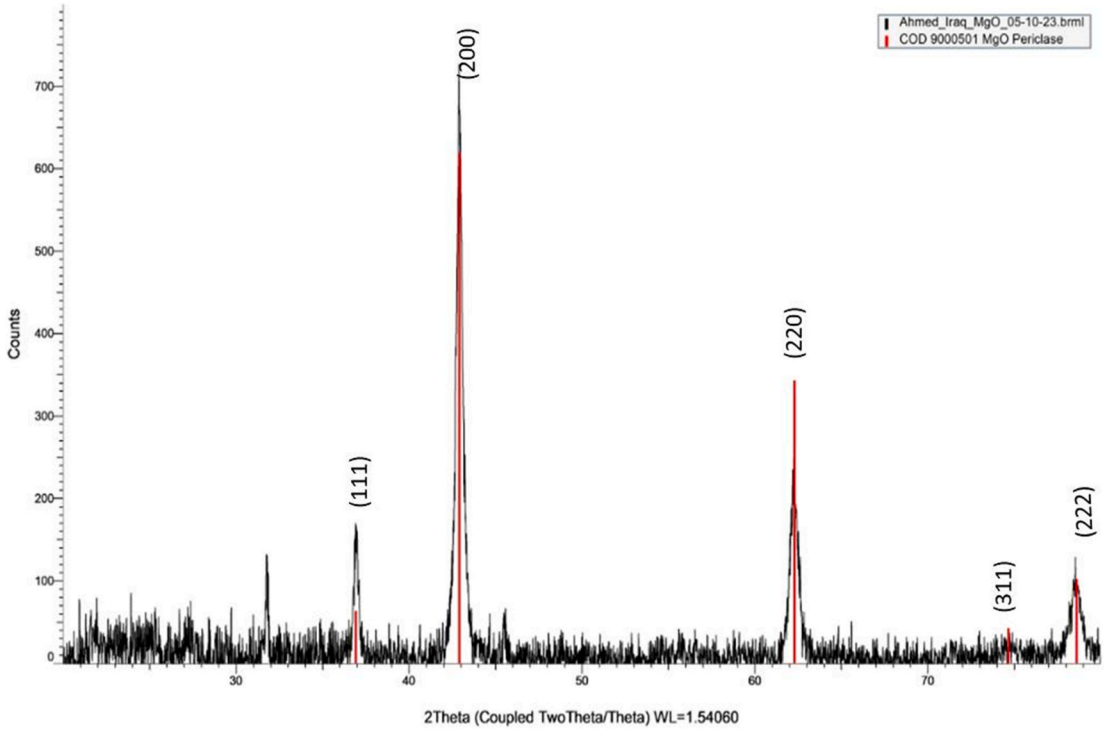


Fig. 2. XRD diffraction patterns of MgO.

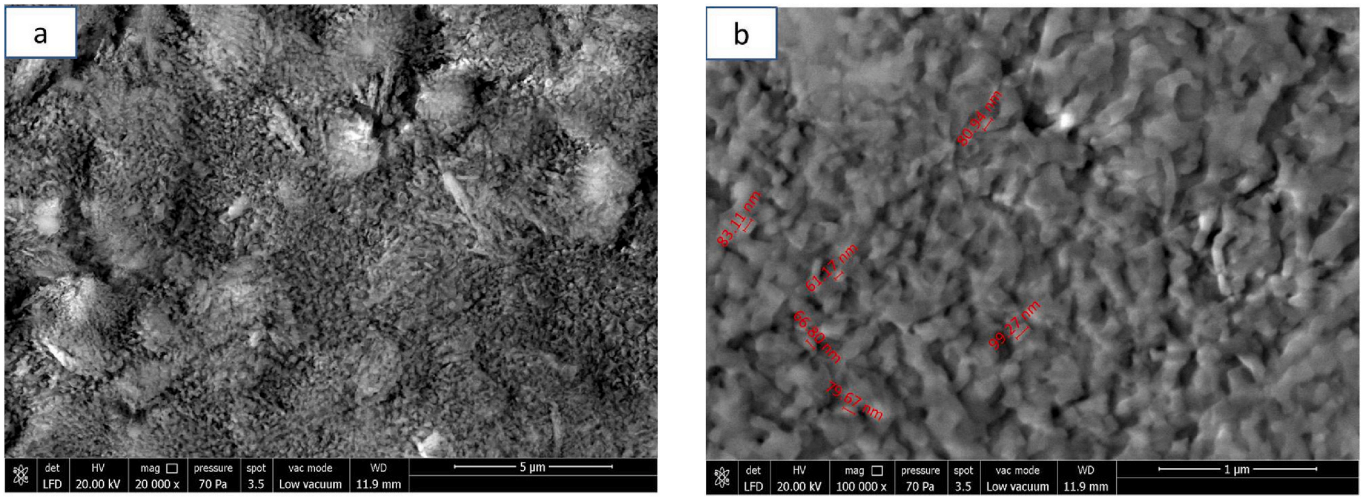


Fig. 3. SEM image of MgO material for a) general shape of surface, b) as high magnification.

Table 1
EDS analysis of chemical components for MgO as grown.

chemical components	O	Cl	Mg
Weight percentage	35.92	8.28	55.81

the experiment. The TL signal has been collected at room temperature up to 350 °C by heating rate of 10 °C/s. The measurements were perfromed in nitrogen atmosphere in order to decrease the spurious phenomena and the background. Thermoluminescence and dosimetric properties were studied by examining the sensitivity of the samples toward the radiation when exposed to beta source ^{90} Sr/Y and observation of TL glow carve intensity and displayed in Fig. 6, and the dose response curve in Fig. 7 respectively.

Fig. 6 shows the TL response area per unit of mass (ar.un) of the MgO sample exposed to different doses of radiation ranging from 12 Gy to 216 Gy. Five reading for a MgO sample was taken for each dose, and the average reading was recorded. It can be seen that the intensity of TL glow curve is increased with increasing of absorbed doses and a maximum peak is observed and located at 125 °C That attribute because a higher dose results in a greater number of trapped electrons and when these trapped electrons are thermally released at higher temperatures, they emit more light, leading to a higher intensity of the TL glow curve (Kadukar et al., 2017), (Tiwari et al., 2014).

Fig. 7 shows the dose response of nanoparticles MgO. It was found that the dose response curve of the MgO is linear from about 12 Gy up to 212 Gy. The TL signal continues to grow linearly due to the filling of most of the electron traps by radiation-produced free electron this characteristic is a good indicator of the suitability of MgO material used

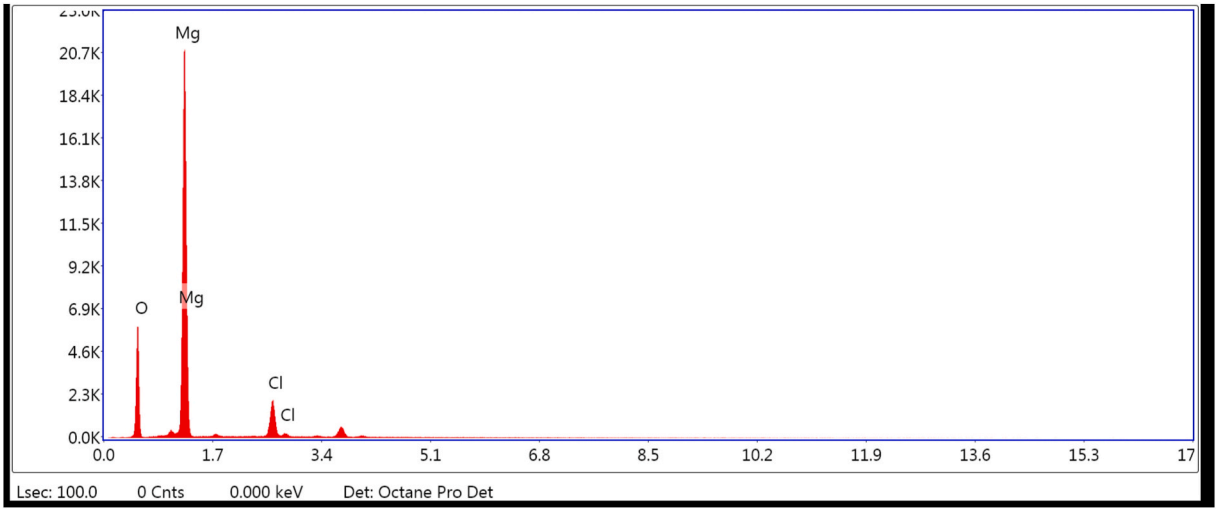


Fig. 4. EDS spectrum image of MgO.

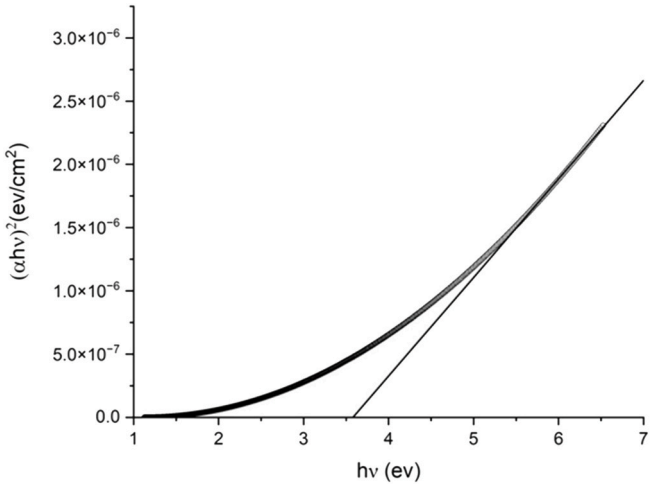


Fig. 5. Band gap energy of MgO.

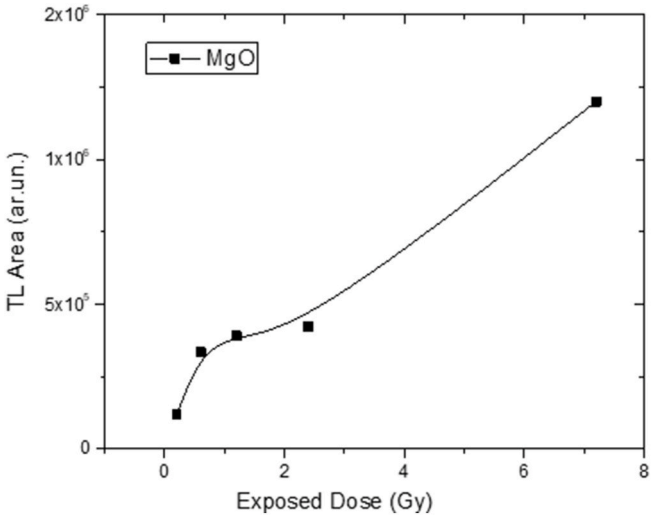


Fig. 7. Dose response curve of MgO material.

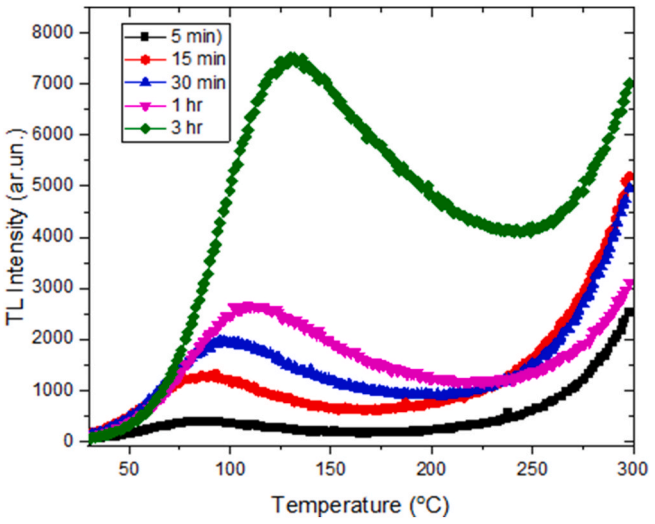


Fig. 6. Glow curves of MgO powder irradiated with ^{90} Sr/Y source at an absorbed dose of 12 Gy, obtained immediately after irradiation.

as a TLD device (Engin et al., 2010). It is also seen from other works that different types of material has been studied in material science for different purposes (Atik, 2023; Aygun & Aygün, 2023; Aytatlı, 2023; Bölükbaşı et al., 2023; Coşkun et al., 2023; Doğan, 2023; Karpuz, 2023; Malidarre et al., 2023; Oruncak, 2023; Ozhan, 2023; Rwashdı et al., 2022; Waheed et al., 2022).

4. Conclusion

In this study, MgO nanoparticles were prepared by chemical spray pyrolysis technique. XRD measurements showed that the plan displayed in cubic structure and polycrystalline in nature. The diffraction peak of cubic structure MgO nanoparticles is found at 2θ values at 2θ value of 36.9°, 42.9°, 62.2°, 74.6° and 78.6° with attributes (111), (200), (220), (311) and (222) respectively as a preferred for crystallographic orientation and never seen unwanted impurities and secondary phase in the structural of MgO. SEM analysis showed that the surface of MgO covered by spherical and irregular shapes in different sizes ranging between 50 nm and 100 nm. Optical band gap energy was estimated using UV-VIS measurements and we found that the optical band gap is equal to 3.7 Ev. Thermoluminescence and dosmetric characterization have been studied by irradiated the sample of MgO in the form of a powder by beta

source ^{90}Sr/Y with absorbed doses ranged 12–216 Gy. The results showed that TL glow curve intensity is increased with the increasing of absorbed doses as a function to the temperature. The reason for this increasing intensity could be that under irradiation the number of trapped electrons will be increased and when these trapped electrons are thermally released at higher temperatures, they emit more light, leading to a higher intensity of the TL glow curve, this characteristic is a good indicator of the suitability of MgO material which used as a TLD device.

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