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Achieving exceedingly constructional characterization of magnesia-yttria (MgO-Y_2O_3) nanocomposite obtained via oxalate precursor strategy

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ABSTRACT

Magnesium yttrium oxide (MgO-Y_2O_3) nanocomposites have been purposefully tailored using an oxalate precursor pathway. Commonly, MgO-Y_2O_3 nanocomposites possessed a significant technological challenge in electroceramics; particularly remarkable as the anode material for solid oxide fuel cells (SOFC). In this regard, different weight ratios, % of MgO and Y_2O_3 including (20:80), (50:50) and (80:20) were fabricated based on oxalic acid as a fuel in acidic medium. Indeed, the impact of the annealing temperature on the phase composition, crystallite size, morphology and optical properties was investigated using X-ray diffraction, field emission electron microscope (FESEM), TEM, FTIR and UV–VIS-NIR spectrophotometer. The FESEM results showed the nanocomposite had a cubic like structure with the fine grain sizes of 0–150 nm because of the rapid solidification. The band gap energy was found to be 4.83, 5.10 and 5.08 eV with increasing the ratio of Mg^{2+} ion from 20 to 50 and 80, respectively. Eventually, our currently studies consider to be an important achievement to investigate and recognize the features of the MgO-Y_2O_3 system for different applications involving microwave systems, advanced displays (field emission display, plasma display, electroluminescent display), ultra-fast sensors, durable, infrared windows and lasers.

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1. Introduction

Materials containing magnesium ions are considered as the ideal candidates for the different applications including reducing of greenhouse gas emission because of their lightweight and low cost attainable. These advantages enable magnesium materials replaced the conventional steel in the passenger vehicles with the internal combustion engines and reducing consumption inside the vehicles to control the greenhouse gas emissions. Meanwhile, the very low density of Mg^{2+} ions drives it to be a viable material for light weighting given that it is lighter than aluminum by one-third and steel by three-fourth. Despite these advantages, magnesium materials have certain drawbacks like low elastic modulus and ductility. The disadvantages of these materials can be circumvented with composite technology by incorporating other different materials in the composition [1,2]. Accordingly, many efforts have been performed to fabricate Mg based nanocomposite powders using ease ways with extremely high yield [3–5]. In this context, different types of particulates (metals and ceramics) with different length scales are produced [6–12]. Particulates reinforcement in nano length scales, such as alumina and yttria, have exhibited the potential to enhance the amalgamation of tensile strengths as well as the ductility of MgO powders [3,4,12]. Besides, it was very important issue to have a deep look inside not only the structure of the magnesium materials itself but also to understand the composition of it. Meanwhile, it is very substantial to recognize the deformation that occurred during the formation of nanocomposites between Mg^{2+} ion and the other metal ions with different types and reinforcements.

There are the few studies focused on the properties and the features of magnesium-based nanocomposites. Limited studies exist only on reinforced magnesium alloys such as AZ31, AZ31B, and AZ91, which consist of different metals in their composition with Mg as the major element [13–16]. Recently, yttrium oxide (Y_2O_3)

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has attracted attention as a material with outstanding spectral features with the large range of promising applications [17,18]. Therefore, it is significantly desirable to combine the properties of these two magnificent materials like the low optical absorption as well as the high mechanical and thermal features in order to obtain new class of composites with outstanding performance. Thus, MgO-Y_2O_3 nanocomposite materials are achieved to increase the optical properties of yttria and to increase the thermal shock resistance properties of magnesia with superb mid-infrared transparency and enhanced mechanical features to be utilized as infrared window materials [19]. Furthermore, the improvement of the mechanical properties of MgO-Y_2O_3 nanocomposite ceramic materials could be attained by limiting the phase domain size at the nanoscale. Subsequently, the light scattering is minimized at the two-phase grain boundaries [20]. From the best of our knowledge, the optical properties of MgO-Y_2O_3 as binary oxide system at different molar ratios is not mentioned elsewhere. However, the optical properties of MgO-TiO_2 is previously studied showing shift in the absorbance peaks with enhancing the MgO ratio [21]. Analogically, photoluminescence properties (PL) of Y-doped (0.001, 0.01 and 0.1%) MgO samples by using a Spark plasma sintering (SPS) is previously studied [22].

Herein, we develop for the first time a new class of MgO-Y_2O_3 nanocomposite with different molar ratios (20, 50 and 80 wt% MgO) using a facile organic acid precursor based on oxalic acid as a chelating agent and as a fuel. The phase feature, structure morphology and the optical properties of the tailored materials with different magnesia to yttria content were investigated and reported.

2. Experimental section

2.1. Material and study methods

All the chemicals employed in this study such as magnesium chloride hexahydrate ($MgCl_26H_2O$, CAS: 7791-18-6, 99.0%, Merck), yttrium nitrate hexahydrate, (Y $(NO_3)_3{\cdot}6H_2O$ CAS: 13494-98-9, 99.9% metals basis, Sigma Aldrich) and oxalic acid as source of organic acid (CAS: 6153-56-6, organic 98%, Sigma Aldrich) were of analytical grade and incorporated in the work without further purification. Deionized water was used in every step of the experiments.

2.2. Procedures for preparation of MgO-Y_2O_3 nanocomposite

Magnesium yttrium oxide (MgO-Y_2O_3) powders were elaborated using aqueous solutions of magnesium chloride hexahydrate and yttrium nitrate hexahydrate with different molar ratios (20, 50 and 80%). Oxalic acid acts as an organic precursor and as fuel was inserted to the solution based on the concentration ratio of Mg^{2+} and Y^{3+} ions then following as mentioned elsewhere [23–25]. After that, stirring of the formed solution was gently occurred and then evaporated at 80 °C until a clear, viscous gel was obtained. After that, the gel was dried at 110 °C for 24 h. Eventually, the dry precursors were heated at a rate of 10 °C/min in static air at different temperatures from 200 to 1000 °C where they were maintained for 2 h.

2.3. Physical characterization

2.3.1. XRD studies

Bruker AXS diffractometer (D8-ADVANCE Germany) with Cu Kα (λ = 1.54056 Å) radiation, operating at 40 kV and 40 mA was applied to detect the X-ray powder diffraction (XRD) peaks for the produced samples. The diffraction data were recorded for 2θ values between 10° and 80° and the scanning rate was 3° min^{-1} (or 0.02°/0.4 s).

2.3.2. FESEM studies

Field emission scanning electron microscopy (FESEM) was utilized by a JEOL-JSM-5410 (Japan). In addition, Transmission electron microscopy (TEM) was examined with a JEOL-JEM-1230 microscope, Japan.

2.3.3. Optical measurements

The UV–Vis absorption spectrum was performed by UV–VIS-NIR-scanning spectrophotometer (JASCO-V-570 spectrophotometer, Japan) fitted with integrating sphere reflectance unit (ISN) in

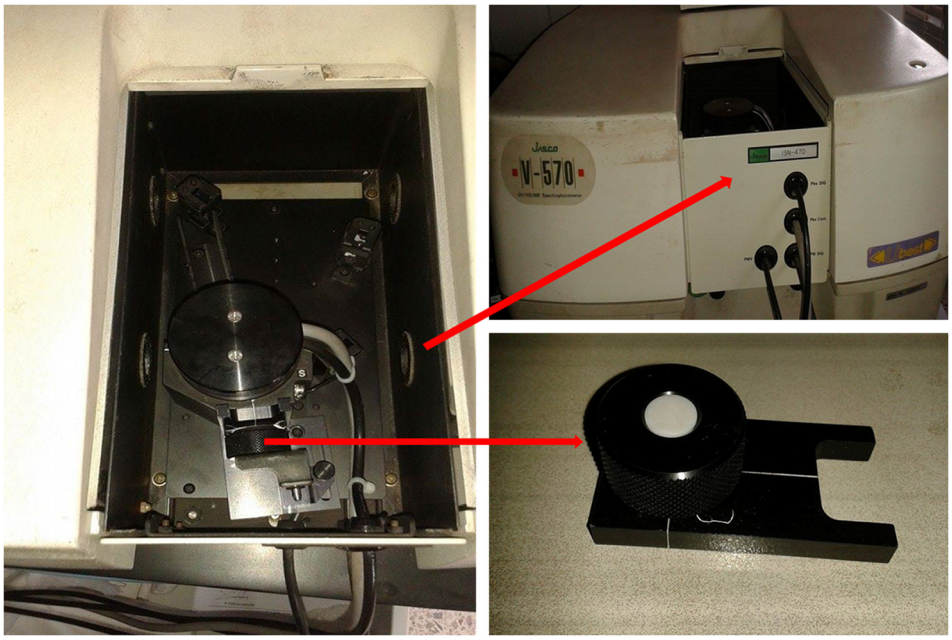

Fig. 1. The Integrated sphere unit in the UV–Vis-NIR-scanning spectrophotometer (JASCO V-570 spectrophotometer, Japan).

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