TEST Engineering & Management

January - February 2020
ISSN: 0193 - 4120 Page No. 5854 - 5860

Synthesis and Characterization of Nano Cerium Dioxide Particles Reinforced with Magnesium Metal Matrix Particles and its Application

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Article Info
Volume 82
Page Number: 5854 - 5860
Publication Issue:
January-February 2020

Article History
***Article Received**: 18 May 2019*
***Revised**: 14 July 2019*
***Accepted**: 22 December 2019*
***Publication**: 29 January 2020*

Abstract:
The nano-sized particle's application is the result of enhanced Metal Matrix composites (MMCs) and maintenance of the matrix alloy ductility. Current research involves the production and analysis of advanced Nano-CeO_2 hybrid particles with the particles of the Magnesium metal matrix and lanthanum dioxide formed by the process of ball milling. Primarily, the powder mixtures consisting fixed weight (wt) percent of CeO_2 and Magnesium metal matrix as uniaxial cold pressed reinforcement components. In an electric muffle furnace, the green compacts are then ball milled. Microstructure and composites mechanical properties including micro-hardness, density and tensile strength were studied. Microstructure sample was examined utilizing Raman spectroscopes, Fourier transform infrared (FTIR) and X-ray diffraction (XRD) etc.. The results revealed that Nano CeO_2 hybrid particles enhance the mechanical properties.

***Keywords**: Metal matrix composites (MMC), X-ray diffraction (XRD), Fourier transform infrared (FTIR), Raman spectroscopes.*

Introduction

Metal Matrix composites (MMCs) combined with ceramic nanoparticles (> 100 mm), known as Metal Matrix Nano Composites (MMNCs), withstand the drawbacks of traditional MMCs. [1]. Relative to the relevant MMCs, the characteristics of MMNCs have increased significantly, even with a small fraction of volume of nanoparticles [2]. The nano-sized fillers are incorporated into a metal matrix since they are capable of improving mechanical and electrical properties as well as the coefficient of thermal expansion and the coefficient of friction. The carbon nanotube (CNT) strengthening dispersion effect has a positive effect on mechanical properties [3]. The hybrid composites have improved characteristics compared to single enhanced composites as they incorporate the benefits of their component enhancements [4]. Chandrakanth et al.[5] produced a hybrid copper metal matrix composite that was reinforced by microwave processing with TiC and graphite particles. In the A356 aluminum alloy's semi-solid state, distinct weight fraction of nano alumina particles are injected with argon gas and stirred by a different speeds of mechanical stirrers [6]. The method of compo casting was used to relative CeO_2 nanoparticles into the aluminum alloy and to produce nanocomposites of metal matrix with a uniform distribution of reinforcement. [7]. The ceramic nanoparticle material helps to reinforce the composites thus maintaining ductility [8]. Through adding 3.5 % of CeO_2 nanoparticles achieved the higher yield

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strength and ultimate tensile strength [9]. Shabani [10,11] developed finite element method (FEM) with an artificial neural network based genetic algorithm (ANN-GA) to model and optimize the reinforced composites of nano CeO_2 properties. Ma et al.[12] used elevated-temperature creep, X-ray diffraction, dynamic metallography compression, and tensile testing to describe Nano CeO_2 matrix composites microstructure and mechanical properties reinforced with nano matrix composites of Si – N – C. For many researchers, the preferred approach was powder metallurgy (PM) techniques [13,14]. Nano-composite specimens designed by activated plasma ball milling composites indicate structural soundness without detectable defects or clusters of secondary phase [15]. Wong and Gupta[16] have produced Magnesium composites that contain different quantities of nano-sized Cu particles using two directional ball milling microwaves. Cermet are one of application of composite added in work. Cermet are metallic (met) and ceramic (cer) composite materials Cermet is ideally built to have both a ceramic and the ideal property, like higher temperature hardness and resistance, and those of metals, like ability to undergo deformations of plastics. The metals used as boride, carbide or oxide, binders [17].usually, the metallic elements used - molybdenum, cobalt and nickel, [18]. Dependently the material's physical structure, cermet can be Metal matrix composite, but cermet usually are less than 20 percentage metal by volume. The ceramic particle are of 1 to 10 micro meter in diameter[19].

The literature indicates that comprehensive work has been done to classify and synthesize different matrix composite. There is very limited analysis of metal oxide-reinforced hybrid matrix composite transition. The current study focuses on characterizing and synthesizing the Nano CeO_2 hybrid matrix reinforced with particles of Cerium dioxide and micro lanthanum and Magnesium metal matrix produced by ball milling processes. X-ray diffraction (XRD) , Fourier transform infrared (FTIR), and Raman spectroscopes analyze and show the mechanical aspect and microstructure of the specimen.

Experimental

Ball milling

There are different types synthesis methods are there. In this study we choose ball milling. A ball milling is a grinder type used for grinding and blending material for use in paint, mineral dressing process, pyrotechnics, selective laser ball milling and ceramics. It work on principle of attrition and impact the decrease in size is done by impact as ball drop from near top of shell. CSIR, Trivandrum at-200Time, 20 Minutes, Bowl, Stainless Steel / Ceramic Ball, Zirconium / Ceramic. Ball milling is heat treatment introduced to compact powder to give strength and integrity. The ball milling temperature is below the melting point (MP) of the major component of the Powder Metallurgy material.

In ball milling(BM) method, a powder mixture of cerium oxide (0.5%) and (0.5%) AZ91D (magnesium metal matrix) milled by a Fritsch "Pulverisette 5" planetary ball mill with argon atmosphere with a 250 rpm rotation speed for 30 hrs. 10 mm in diameter balls are used and by keeping powder-to-ball weight ratio at 1 : 10. We used ethanol 1 wt% as process controlling agent for preventing extreme cold welding of these powders at the time of BM. The SUJ-2, chrome steel ball are used in BM because it have high toughness and wear resistance. So we can reduce contamination at the time of ball collisions. To avoid oxidation of the powders, loading and discharging of the powders doing inside an argon-filled glove box. The same procedure followed for lanthanum oxide by taking (0.5%) lanthanum and (0.5%) of AZ91D. The resulting powder kept in Muffle Furnace is 450o C and 1 hour. After that characterized through XRD, Raman and FTIR.

Characterizations studies

X-ray diffraction

Using X-ray diffraction (XRD) studies to analyze the phase and crystalline purity of synthesized metal alloys. X-ray diffraction sample used to use the Shimadzu instrument (XRD -6000, Japan). X-ray patterns coordinated with Cu k radiation (= 1,5406 Å) with 45 kV precise voltages and 40 mÅ presence.

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Raman measurement

The Raman spectrum was recorded on (EZ Raman, Enwave optroncs, USA) RFS 100 spectrometer with a diode-pumped Nd: YAG laser emitting 1064 nano meters and a liquid nitrogen-cooled Germanium detector. The instrument was fitted with a xy stage, a prism slide and a mirror target to focus the beams of the laser. The instrument was placed horizontally compared to standard vertical sampling arrangements; approximately. 3 to 5 ml of anodized AZ91D alloy are mounted in the middle of metal rings. The spectra are collected with a resolution of 4 cm^{-1} in 1000 to 4000 cm^{-1} with a laser power of 3.150 mW supplied by non-focused laser beams from 128 scans measured.

FTIR analysis

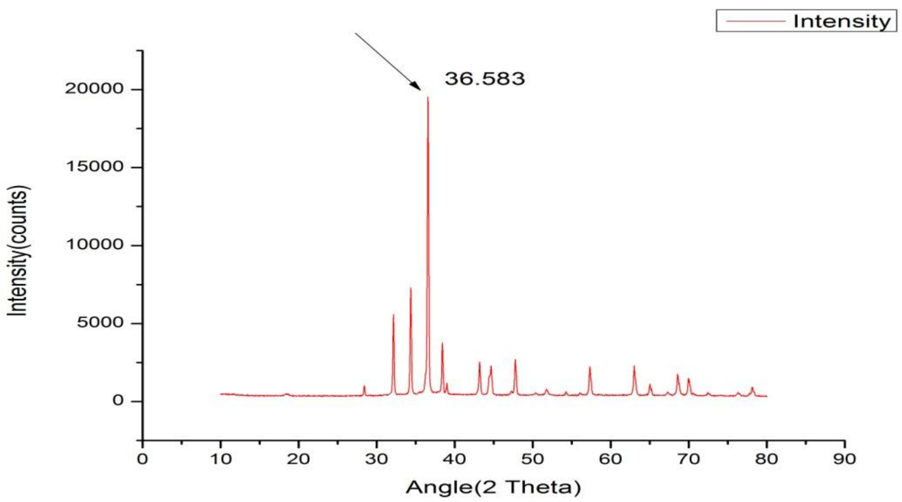
For the classification of the characteristic functional group in extract, Fourier transform infrared (Bruker, Alpha T, Germany) was used. This gives information on the composition of the molecule from its absorption spectrum. In dry potassium bromide (KBr), a small amount of specimen extract was mixed. The mixture was mixed thoroughly in mortar and pressed to form a thin KBr disk at a pressure of 6 bar within 2 min. Then the sample cup of the diffuse reflectance accessory was mounted on the disk. The IR spectrum was measured using Alpha T, Bruker, Germany, 70 infrared spectrometer. Around 4000-400 cm^{-1} the specimen was scanned. The FTIR value were recorded.

Results

X-Ray Diffraction (XRD)

XRD pattern observed shows well match with the standard cubic fluorite phase (Fm-3m225) of CeO_2. The diffraction peaks of the sample situated at 28.2°, 32.6°, 46.8° and 55.6° indexed to the (111), (200), (220) and (311) planes (JCPDS File 043-1002).

From the observation of the XRD patterns of CeO_2 particles and lanthanum nano particles dispersed in Magnesium matrix composite. We can observe that a shift in the peaks and intensity change in peak. If we comparing Cerium with Lanthanum, it having higher ionic radius. Its structure lead to lattice expansion of crystal. Due to the larger ionic radius of La versus Ce and large number of oxygen vacancy attribute the lattice expansion[21]. The lattice parameter and diffraction angle θ having inverse relation. We can see that apparent shift in all peaks in the direction of lower diffraction angle due to lattice expansion. This property confirms of peak shift [22]. Doping of Lanthanum can change mean atomic scattering. From the XRD, we can observe that atomic radius of the given sample can change the strength of the atomic scattering. Atomic radius of the dopant increases with atomic scattering and intensity also increases[23]. Higher relative intensity of the XRD peaks messured in La-doped comparing with CeO_2. Because of the higher ionic radius Lanthanum.



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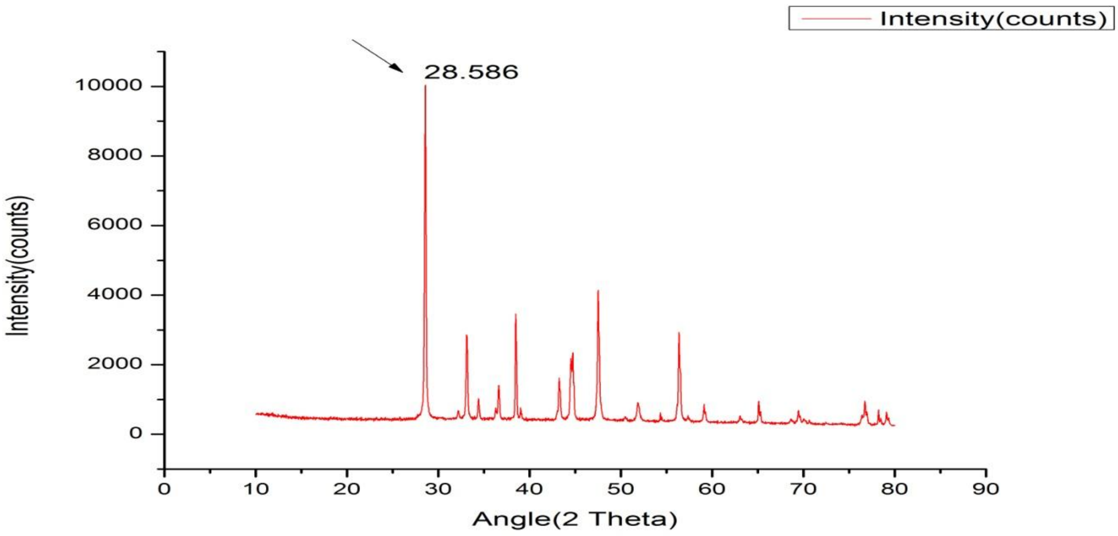
The XRD cerium pattern of Magnesium metal matrix is shown in Fig.1 The broad reflection seen at 2 theta = 36.58⁰ shows nano reinforced properties present in the metal alloy



XRD pattern of Cerium dioxide doped lanthunm is shown in Fig.2 The broad reflection seen at 2 theta = 28.58⁰ shows nano reinforced properties present in the metal matrix

Raman

Raman spectra of anodized CeO2 alloy in Magnesium metal matrix and lanthanum in Magnesium metal matrix contain the peaks range of 1000-2000 cm-1.These peaks represents the 1000-2000 peaks variation different chemical components of Aluminum, Zinc, Manganese, Iron, Copper Nickel, Magnesium are present in the anodized AZ91D alloy. The higher intensity of Raman band observed with different metal in magnesium matrix. We can observe that High-intensity broadband due to the large number of oxygen vacancies [22].

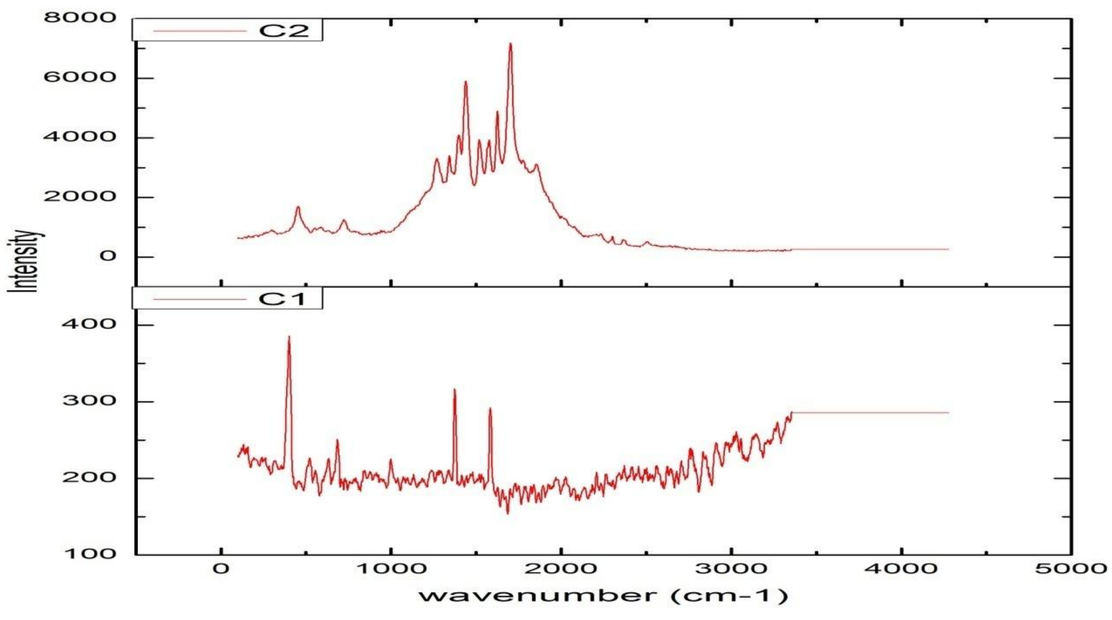


Fig 3 shows that Raman spectra of anodized CeO2 alloy in Magnesium metal matrix (C1) lanthanum in Magnesium metal matrix (C2)

FTIR

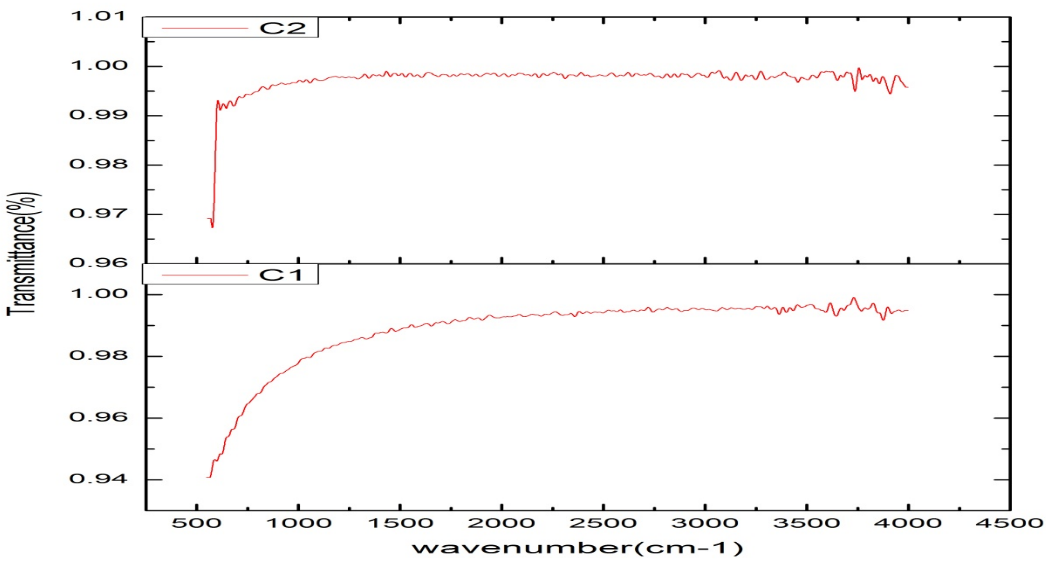


Fig 4 FTIR spectra of anodized CeO2 alloy

Peak values Frequency, cm-1	**Bond**	**Functional groups**
1737	O-C = O stretch	Carbonyl group bound to ester
2879	C = C stretch	Methyl group
2850	Sp3-CH stretch	Alkane C-H
3200	Sp2-CH stretch	Alkene C-H (Aliphatic)
3824	Sp2 C-O stretch	Carbonyl single bond stretch

Table 1 : Characteristic peaks in FTIR spectrum of CeO2 alloy

Fig 4,Table 1 shows that showed FTIR spectrum of anodized CeO2 alloy presence of 1737- O-C = O stretch(Carbonyl group bound to ester), 2879- C = C stretch (Methyl group), 2850- Sp3-CH stretch(Alkane C-H), 3200- Sp2-CH stretch(Alkene C-H (Aliphatic), 3824- Sp2 C-O stretch,(Carbonyl single bond stretch).

Conclusion

Based on studies done in the current research, Hybrid Magnesium metal matrix filled with micro CeO_2 particles arrives at the following conclusion. Nano Cerium dioxide particles are successfully prepared using the ball milling process. Raman XRD with FTIR analysis is characterizing the CeO_2 particles and lanthanum nano particles dispersed in Magnesium matrix composite. The result shows the existence of lanthanum oxide and Cerium dioxide nano particles in , Magnesium metal matrix composite. Lanthanum and Nano Cerium dioxide particle size observed in XRD image. Pattern of XRD confirms the Mg, CeO2 and , lanthanum peak using JCPDS file. The Raman and FTIR shows that various functional groups are identified in the nanocomposites. It is possible to conclude from studies that the use of CeO2 in Metal Matrix composite enhances the composite material's property and structure. It exhibit better corrosion resistance comparing to the other.

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