POLİTEKNİK DERGİSİ

JOURNAL of POLYTECHNIC

ISSN: 1302-0900 (PRINT), ISSN: 2147-9429 (ONLINE)

URL: http://dergipark.gov.tr/politeknik

Synthesis and characterization of Copper metal matrix composite reinforced with ceramic oxide extracted by the green route

Yeşil yolla elde edilen seramik oksit ile güçlendirilmiş bakır metal matris kompozitin sentezi ve karakterizasyonu

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Bu makaleye şu şekilde atıfta bulunabilirsiniz(To cite to this article): Laad M.,Datkhile R., " "Synthesis and characterization of Copper metal matrix composite reinforced with ceramic oxide extracted by the green route", ", ***Politeknik Dergisi***, 25(3): 1185-1189, (2022).

Erişim linki (To link to this article): http://dergipark.gov.tr/politeknik/archive

DOI: 10.2339/politeknik.824853

Synthesis and characterization of Copper metal matrix composite reinforced with ceramic oxide extracted by the green route

Highlights

- *Agro waste*
- *Metal Matrix Composites*
- *XRD, SEM, EDS, TEM*
- *Mechanical Properties of the composite*
- *Silica extracted from rice husk ash*

Graphical Abstract

Copper metal matrix composite reinforced with silica extracted from an agrowaste were synthesized, Advanced characterization techniques were employed to study microstructural, compositional, morphological and mechanical properties. The work done in the article should be summarized in one or two sentences.

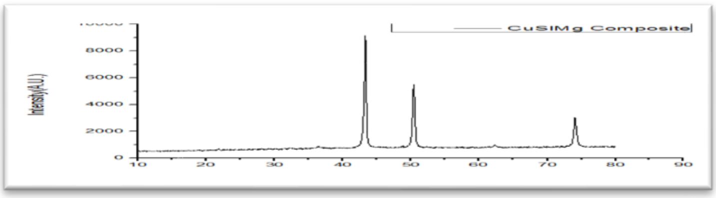

Figure. 4 XRD of Copper Silica composite

Aim

Synthesis and characterization of Copper metal matrix composite reinforced with ceramic oxide extracted by the green route

Design & Methodology

Reinforcement material silica was extracted from agro waste rice husk ash under controlled conditions of sintering temperature and duration of heating from rice husk ash using alkali extraction method. Using Copper as metal matrix and silica as reinforcement material Copper metal matrix composite was synthesized using powder metallurgy route. Silica and the composite were characterized for microstructural studies, elemental composition and surface morphologies using X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray (EDX) and Transmission Electron Microscopy (TEM). The synthesized copper silica composite was studied for structural, compositional and mechanical properties.

Originality

This work reports a non-toxic, cost effective, light weight and improved mechanical strength substitute for copper metal applications.

Findings

The XRD and EDX of silica and Copper confirm the characteristic peaks of silica and presence of SiO2 α-cristobalite.. A X-ray diffraction peak was observed at 20.69° characteristic of quartz silica. SEM of composite revealed uniform distribution of reinforcement silica particles in base copper metal. TEM image of silica indicates the spherical morphology of silica particles. The composite shows increased tensile strength and low density as compared to pure Copper.

Con*lusion*

The reinforced material extracted silica from rice husk was of high purity and non toxic. The synthesized composite was found to have improved mechanical strength and lesser density to make it lighter in weight.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Synthesis and Characterization of Copper Metal Matrix Composite Reinforced with Ceramic Oxide Extracted By The Green Route

Research Article

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(Geliş/Received : 12.11.2020 ; Kabul/Accepted : 15.04.2021 ; Erken Görünüm/Early View : 25.05.2021)

ABSTRACT

The paper presents the synthesis and characterization of Copper metal matrix composite reinforced with silica using powder metallurgy route. The 5%wt of silica is reinforced with copper metal as matrix material. 5% wt Magnesium was added as wetting agent as copper shows poor wettability towards silica. The reinforced silica was extracted from agro waste rice husk ash under controlled conditions of sintering temperature and duration of heating from rice husk ash using alkali extraction method. Reflux method was used to extract nanosilica from silica. Silica and the composite were characterized for microstructural studies, elemental composition and surface morphologies using X-Ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray (EDX) and Transmission Electron Microscopy (TEM). The synthesized copper silica composite was studied for structural, compositional and mechanical properties. The results showed that the copper metal matrix composite reinforced with silica showed improved mechanical behavior and can be used in all such applications where light weight and better mechanical strength from copper metal are expected. As the filler material silica is extracted from green route which partially replaces the expensive metal, this work reports a non-toxic, cost effective, light weight and improved mechanical strength substitute for copper metal applications.

Keywords: Agro-waste, Rice husk ash, silica, metal matrix composite, XRD.

1. INTRODUCTION

With the advancement in technology, there is a growing demand for new, light weight and multi-functional materials. The existing traditional polymeric, ceramic and metallic materials are not able to offer a combination of variety desired properties [1]. Metal matrix composites (MMCs) with copper as the base metal find wide applications in different industries such as electronic and automotive industries. These Copper MMCs exhibit excellent wear resistance, corrosion resistance, mechanical and electrical properties [2-5]. Ceramics are popularly used as reinforcement material with copper as the base metal to fabricate low cost and high performance materials with improved corrosion and wear resistance, hardness and cost effectiveness [6-7]. In electronic industry copper based Metal Matrix Composites are used in electronic packaging and contacts, resistance welding electrodes, heat exchangers etc.,[8].

The copper MMCs have been synthesized with ceramics as the filler materials such as alumina and silicon carbide [9-14] which are the most preferred filler materials. Silicon oxide exhibit elevated hardness and wear resistances. These ceramics are refractory in nature, easily available and cost effective [15-18]. Copper MMCs have been attracting the attention of researchers in recent years due to their excellent properties. Other ceramic particles which improve the mechanical strength of copper with no noticeable decrease in electrical conductivity are Al_2O_3, SiO_2, ZrO_2, Cr_2O_3, BeO, MgO etc. Carbides, borides and nitrides of silicon, titanium, chromium etc. are also used. One advantage of using ceramics is that diffusion phenomenon does not occur between the metal matrix and reinforced ceramic particles due to which composites with electrical conductivity as good as pure copper are acquired. Such ceramic reinforced MMCs show the combined properties of ceramics and metal and can be used for a large number of applications such as high value of hardness and ability to operate at elevated temperatures. These properties are characteristic of ceramics. Metal matrix composites reinforced with ceramic particles are usually synthesized by powder metallurgy. Researchers are attempting to fabricate Copper MMCs by hot pressing or Spark plasma sintering techniques too

2. MATERIALS AND METHOD

In the present work, Copper metal matrix composite reinforced with silica particles is synthesized by powder metallurgy. The filler silica particles are extracted by green route from agro waste rice husk ash. The extracted silica is characterized for microstructural studies using Scanning Electron Microscopy, Transmission Electron Microscopy, X-Ray Diffraction, Energy Dispersive X-Ray techniques. The synthesized Copper silica composite was subjected to microstructural investigations using Scanning Electron Microscopy and X-Ray Diffraction and also its mechanical properties are studied.

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3. RESULTS AND DISCUSSION

The extracted silica and nanosilica from green route were characterized for its chemical composition, surface morphology and micro-structural properties Using X-Ray Diffraction, Scanning Electron Microscopy, Tunneling Electron Microscopy and Energy Dispersive X-ray characterization techniques. The composite was characterized by X-Ray Diffraction and Scanning Electron Microscopy and its mechanical properties were studied.

3.1 Energy Dispersive X-Ray Analysis

The Energy Dispersive X-ray pattern of nano silica powder is shown in Figure 1. Nano silica predominantly contained Si and O. The Si and O peaks in the Energy Dispersive X-ray image confirmed the presence of silica along with some impurities such as sodium and carbon.

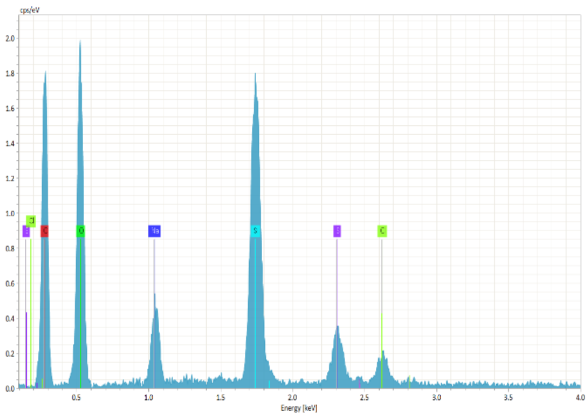

Figure 1. Energy Dispersive X-Ray Spectroscopy of Nanosilica at 600^0C

3.2 X-Ray Diffraction Spectroscopy

Bruker D8 Advance X-ray diffractometer was used to carry out X-Ray Diffraction measurements of silica and the copper silica composite. Rice Husk Ash is a rich source of SiO_2.The sharp peaks in XRD pattern of silica (Figure 2) indicate the crystalline behaviour of extracted silica.

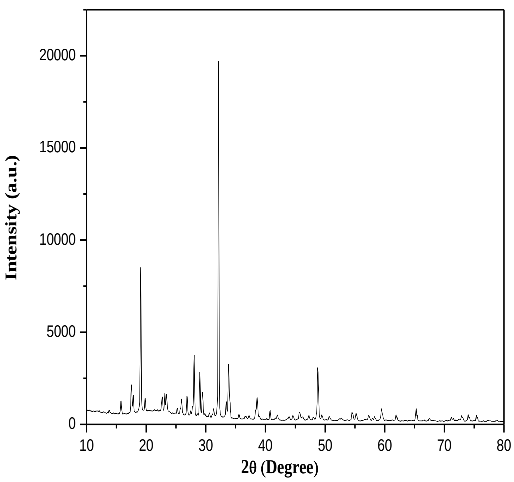

Figure 2. X-Ray Diffraction pattern of Powder Silica extracted from natural resource Rice Husk Ash

Figure 2 shows X-ray Diffraction graph of silica. Silica was extracted by acid leaching treatment from agro waste Rice Husk Ash. The X-ray diffraction pattern of powder silica showed characteristic peaks at 20 ^0C, 28.46^0C , 31.46^0C , and 36.09^0C of silica . These peaks correspond to the spacing of the 101, 111, 102, and 200 crystal planes of SiO2 α-cristobalite (JCPDS PDF No. 39-1425) [19]. A X-ray diffraction peak was observed at 20.69° characteristic of quartz silica (JCPDS PDF No. 46-1045).

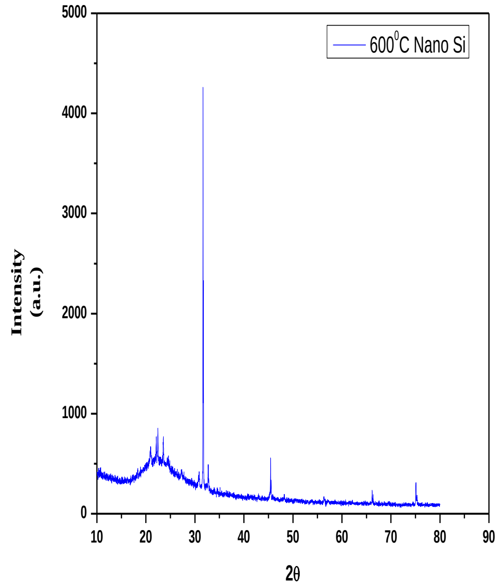

Figure 3. X-Ray Diffraction of Nano Silica at 600^0C

Figure 3 represents X-Ray Diffraction pattern of nanosilica obtained after sintering rice husk ash sintered at temperature 600^0C. XRD pattern of SiO_2 nanoparticles shows one broad peak located at 2θ around 22°confirms the formation of amorphous nano silica.

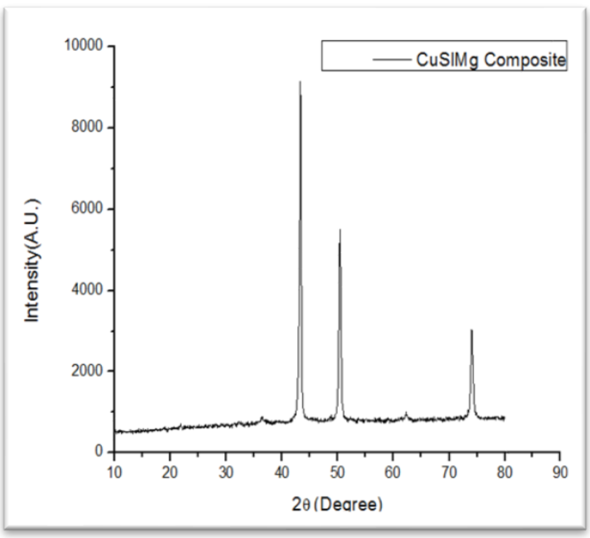

Figure 4. X-Ray Diffraction of Copper silica composite

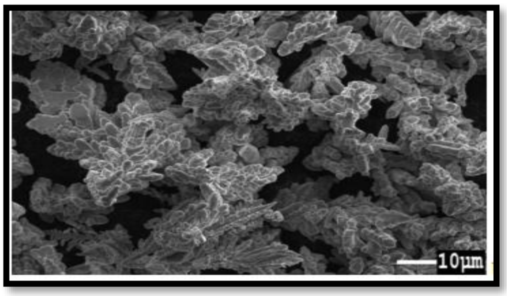

Figure 5. SEM image of Copper powder

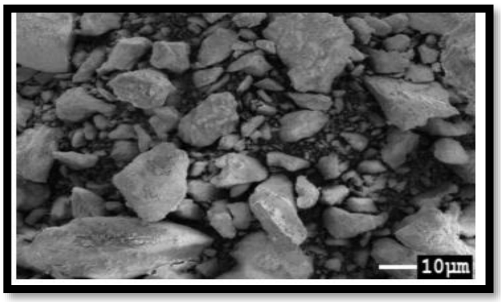

Figure 6. SEM image of Silica extracted from RHA

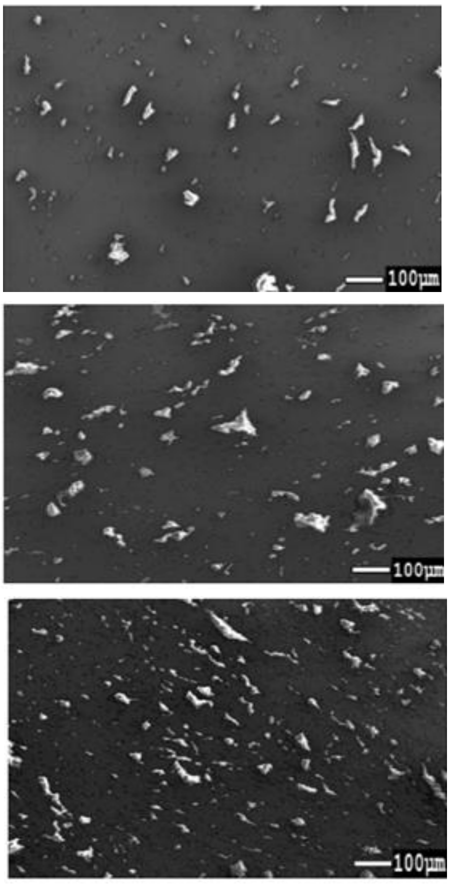

Figure7. SEM image of Copper Silica composite

Figure 4 shows the X-Ray Diffraction pattern of Copper metal matrix composite reinforced with silica. Magnesium was used as wetting agent. The characteristic peaks around 2θ = 43.3° indicates Cu_2O,

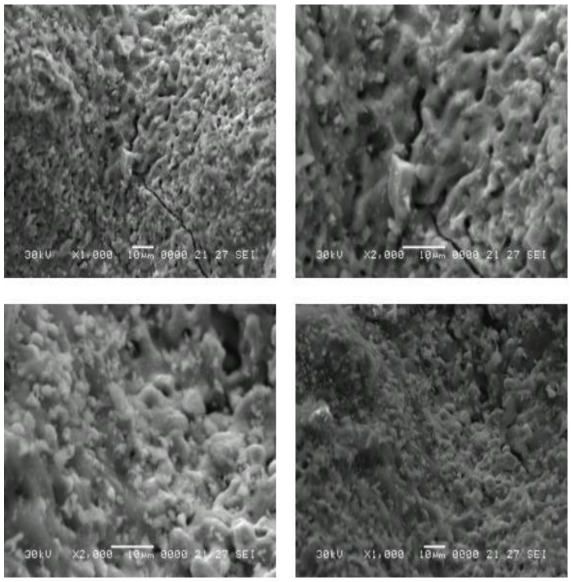

Figure 8. SEM images of copper silica composites at different magnifications

at 2θ = 50.4° and 74.1° indicate copper metal corresponding to planes (200), and (220) planes respectively.

3.3 Scanning Electron Microscopy

Scanning Electron Microscope images of Copper metal, rice husk ash , extracted silica and copper silica composites were taken using FEI NoVa Nano SEM 450 FE-SEM instrument operated at 18KV. The main purpose of taking Scanning Electron Microscope images were to observe the adhesion in the samples. Figure 5 shows the Scanning Electron Microscope image of copper powder (99.5% purity). Figure 6 shows Scanning Electron Microscope image of extracted silica particles. Thermal treatment of rice husk decompose the organic matter causing highly porous structure of material. The loss of volatile organic matter increased with the duration of heating. It resulted in more porous silica which is chemically more reactive. The silicasizes are obtained in the range of 18µm to 0.2µm. There is also a clustering of silica-particles. The developed microstructure can be observed in the Scanning Electron Microscope images of silica.Scanning Electron Microscope images of copper silica composite is shown in figure 7. It indicates the uniform distribution of reinforcement silica particles in base copper metal which is responsible for the change in its mechanical properties. No agglomeration of silica particles was observed in the composite. Figure 7 shows fine pores and grains of filler particles in metal matrix.

Figure 8 shows Scanning Electron Microscopy images of Copper Silica Magnesium Composites. The SEM images are taken at different magnifications and show agglomeration on the surface of the sample. It also shows porous structure of sample.

3.4 Transmission Electron Microscopy

The size and shape of silica with 120 kV acceleration voltage were analyzed using TEM (JEM-1400 Plus, JEOL Ltd.). Figure 9 shows TEM images of silica. The

TEM image shows the spherical morphology at temperature 600 ^{0}C. The extracted nanosilica was found to have particles of size ranging between 24 nm to 86 nm.

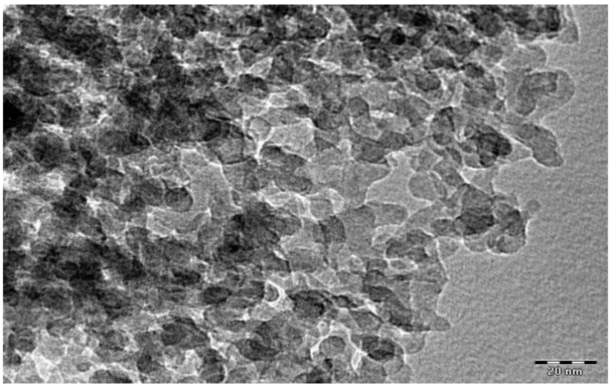

Figure 9. TEM Micrograph of extracted Silica

3.5 Measurement Of Mechanical Properties Of Copper Silica Composite

The tensile strength of copper was found to be increased from 0.01KN/mm^2 to 0.02KN/mm^{2}when reinforced with 5 wt%SiO_2. The density of the composite was observed to be drastically low; 1.09 g/cm^{3}in comparison with the density of copper which is 8.19 g/cm^3. It indicates that the addition of silica resulted in a light weight yet stronger composite material. The percent elongation of copper silica composite was also observed to be increased.

6. CONCLUSION

The metal matrix composite of copper reinforced with silica was successfully synthesized. The reinforcement material silica was extracted from the green route from an agro waste rice husk ash. The microstructural, compositional properties and surface morphologies of extracted silica and MMC were studied using advanced characterization techniques. The density, tensile strength and percent elongation of the composite were also studied. The reinforced material extracted silica from rice husk was of high purity and non toxic. The synthesized composite was found to have improved mechanical strength and lesser density to make it lighter in weight. This natural silica can also be used to synthesize hybrid epoxy composites with glass fibre cross-ply fabric and short sisal fibre layers for improved density, tensile and flexural strength and enhanced mechanical performance [20]. Natural rubber and silica composites [21], dental resin composites and many other composites reinforced with silica can be synthesized with improved properties with silica reinforcement that is extracted from green route [22].

ACKNOWLEDGEMENT

This work is funded by UDC-DAE Consortium for Scientific Research, Indore (M.P.). All the experimental work related to material characterization using XRD, EDS-SEM, TEM, Raman Spectroscopy, and UV-FTIR spectroscopy was carried out at UGC DAE- CSR, Indore. The authors are also thankful to all the scientists and specially Dr. Mukul Gupta, Scientist F, UGC-DAE-CSIR, Indore, the collaborator for this project. Authors thank all the scientists in charge of above facilities at UGCDAE-CSR, Indore for their support and valuable suggestions

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Laad Meena: Result analysis, Data validation, Writing manuscript

Datkhile Rinku: Perofrmed the experiments for extraction of silica and synthesis of Copper Metal matrix composite

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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