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# Influence of CuO Nanoparticles on the Structure, Thermal, Physical, and Mechanical Properties of MgO–NiO Nanoparticles

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In this paper, the structure, thermal, physical, and mechanical properties of magnesium oxide (MgO)–nickel oxide (NiO)/copper oxide (CuO) nanostructure are studied for renewable energy applications. The MgO–NiO compound is synthesized with concentration of 80 wt.% MgO nanoparticles and 20 wt.% NiO nanoparticles; then, CuO nanoparticles are added to MgO–NiO with different weight percentage (1, 2 and 3). The samples are mixed, and then pressed at 225 MPa, and sintered at 1250°C for 1 hour. The effect of CuO promoter on the thermal, structure, physical, and mechanical properties of MgO–NiO nanoparticles is investigated by means of x-ray diffraction, optical microscope, DTA, apparent density, apparent porosity, water absorption, and *HV* microhardness. The experimental results of XRD show formation the $MgNiO_2$ compound. It is found the increase in apparent density and *HV* microhardness, while the apparent porosity and water absorption decrease with raise in concentration of CuO nanoparticles. The results indicate that the MgO–NiO/CuO nanostructure may be used for different applications such as solar cell, integrated circuits, transistors and other modern applications.

У даній роботі розглядаються структури, теплові, фізичні та механічні властивості наноструктури «оксид Маґнію (MgO)–оксид Ніклю (NiO)/оксид Купруму (CuO)» для застосувань у відновлюваних джерелах енергії. Сполука MgO–NiO синтезується з концентрацією 80 ваг.% наночастинок MgO та 20 ваг.% наночастинок NiO; наночастинки CuO потім додаються в MgO–NiO з різними ваговими відсотками (1, 2 і 3). Зразки змішуються, а потім стискуються за 225 МПа та спікаються за 1250°C протягом 1 години. Вплив промотера CuO на теплові, структурні, фізичні та механічні властивості наночастинок MgO–NiO досліджено за допомогою рентґенівської дифракції, оптичного мікроскопа, ДТА, міряння видимої густини, видимої пористости, водопоглинення та мікротвердости за Віккерсом *HV*. Експериментальні результати рентґенівської дифракції показують формування сполуки $MgNiO_2$. Виявлено збільшення видимої густини та мікротвердости *HV*, в той час як видима пористість та поглинання води зменшуються з підвищенням концентрації наночастинок CuO. Результати показують, що наноструктуру MgO–NiO/CuO можна використовувати для різних застосувань, таких як сонячні елементи, інтеґральні схеми, транзистори та інші сучасні застосування.

**Key words:** magnesium oxide, magnesium–nickel oxide, copper oxide, apparent density, differential thermal analysis, apparent porosity.

**Ключові слова:** оксид Маґнію, оксид Маґнію–Ніклю, оксид Купруму, видима густина, диференційна термічна аналіза, видима пористість.

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## 1. INTRODUCTION

Nanoparticles are dissimilar from bulk materials because of their exclusive chemical, electronic, and optical properties. They have very attractive and practical properties, which can be used for a diversity of non- structural and structural applications. Throughout the past decade, the nanooxides have acquired greatly concentration due to their broad potential technical applications in numerous fields like conversions of solar energy, as a heterogeneous catalysts and gas sensors [1]. One of the greatest normally using metal oxides transition for a broad range of field is NiO. NiO is a NaCl-type antiferromagnetic oxide semiconductor. Uniform sized and well-dispersed nickel oxide nanoparticles like a type of useful material has concerned wide interests owing to its novel mechanical [2], optical, magnetic, electronic [3], and thermal properties and potential application in battery electrodes, catalyst, electrochemical films, gas sensors, and photoelectronic devices. In these fields, it is yet wanted to manufacture ultrafine powders with high quality to obtain properties in their morphology, dimension, magnetic properties, optical characterizations, *etc.*, which are the majority basic factors, which determine the features of the final products [2]. Magnesium oxide (MgO) has exceptional properties like chemical inertness and electric insulation. MgO has numerous advantages in applications such as microwave communication, protective layers, optoelectronic devices [4] and materials of refractory [5, 6]. Copper oxide is a transition metal oxide and has a monoclinic structure. Copper oxide compounds are industrially famous materials used in applications like electronic materials, solar energy materials, magnetic media, gas sensor, catalyst, and batteries [7]. In this paper, the preparation of MgO–NiO/CuO nanostructure and studying their structure, thermal, physical and mechanical properties to use it for modern industries and electronics applications.

## 2. MATERIALS AND METHODS

In this paper, samples of MgO, NiO and CuO nanoparticles were fabricated by using powder metallurgy, MgO (NanoShel USA company, particle size 50 nm and high purity 99.9%), NiO (NanoShel USA company, particle size range (15–35 nm) with purity 99.5%) and CuO (US Research Nanomaterials, Inc., USA, particle size 25–55 nm purity with

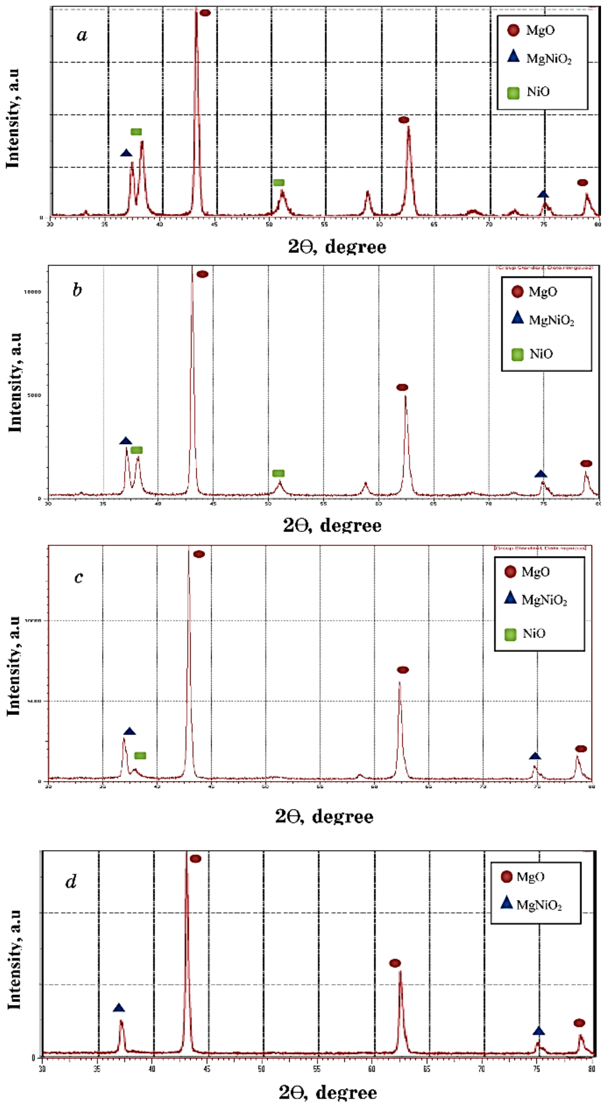


**Fig. 1.** XRD of MgO–NiO nanocompounds at: (*a*) 0 wt.% CuO; (*b*) 1 wt.% CuO; (*c*) 2 wt.% CuO; (*d*) 3 wt.% CuO.

99.5%). The MgO–NiO nanoparticles were prepared with concentration 80 wt.% MgO and 20 wt.% NiO, CuO nanoparticles added to MgO, NiO at (0, 1, 2, 3) wt.%. The mixtures mixed in electric mixer for (6 hrs) then the samples pressed at 225 MPa with 12 mm diameter. They sintered at 1250°C with heating rate 5°C/min.

The structural, thermal, physical and mechanical properties were

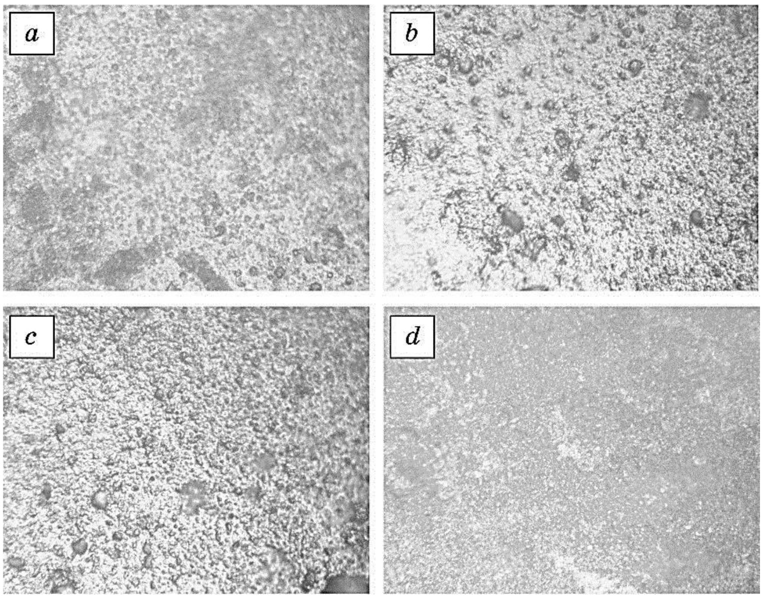


**Fig. 2.** Microscopy images of MgO–NiO–CuO at: (*a*) 0 wt.% CuO; (*b*) 1 wt.% CuO; (*c*) 2 wt.% CuO; (*d*) 3 wt.% CuO.

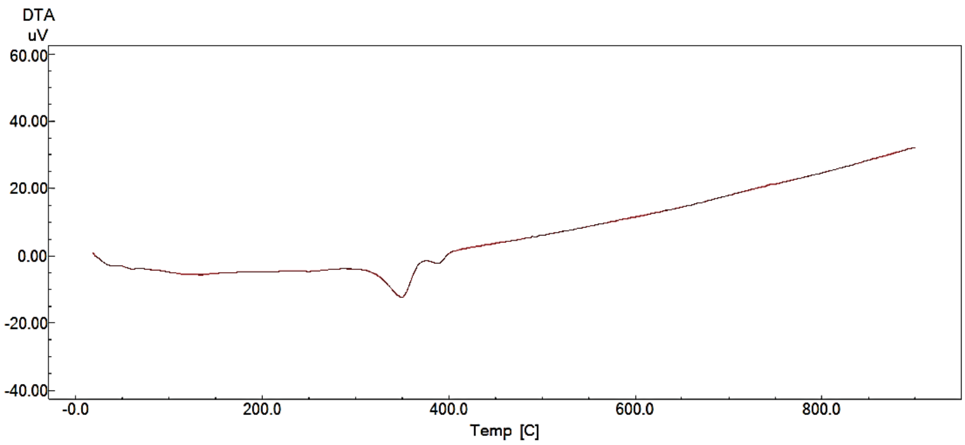


**Fig. 3.** DTA of MgO nanoparticles.

studied. X-ray diffraction and optical microscope, differential thermal analysis, apparent density, apparent porosity, water absorption, *HV* microhardness were studied. The characterizations (apparent density, apparent porosity, water absorption) were calculated by using ASTM C373-88 [8].

## 3. RESULTS AND DISCUSSION

Figure 1 shows x-ray diffraction of MgO, NiO nanocompounds with different concentrations of CuO nanoparticles. From Figure 1, *a*, *b*, and *c* explaining formation compound $MgNiO_2$ from the reaction be-

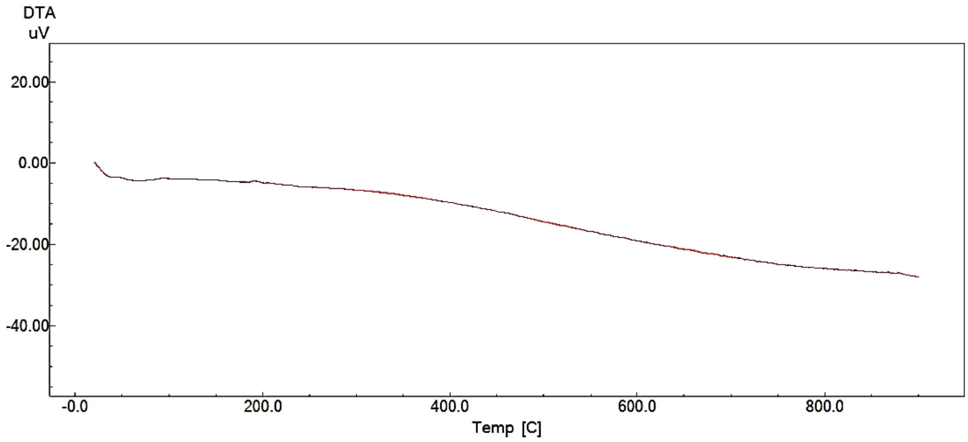


**Fig. 4.** DTA of NiO nanoparticles.

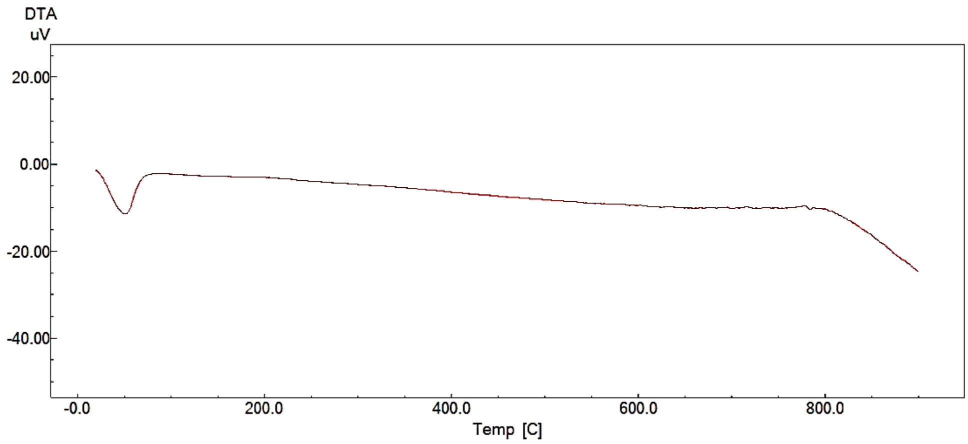


**Fig. 5.** DTA of CuO nanoparticles.

tween MgO and NiO, magnesium nickel oxide ($MgNiO_2$) compound was specified due to JCPDS card number 00-024-0712. In addition to find MgO and NiO, magnesium oxide (MgO) and nickel oxide (NiO) were matched with JCPDS card numbers 00-004-0829 and 04-0835 respectively. This behaviour returned to the oxide amounts, which dissolved in magnesium oxide lattice based largely on the oxides character, addition foreign cations and the conditions of calcinations [9].

Figure 1, *d* shows formation $MgNiO_2$ compound with availability of

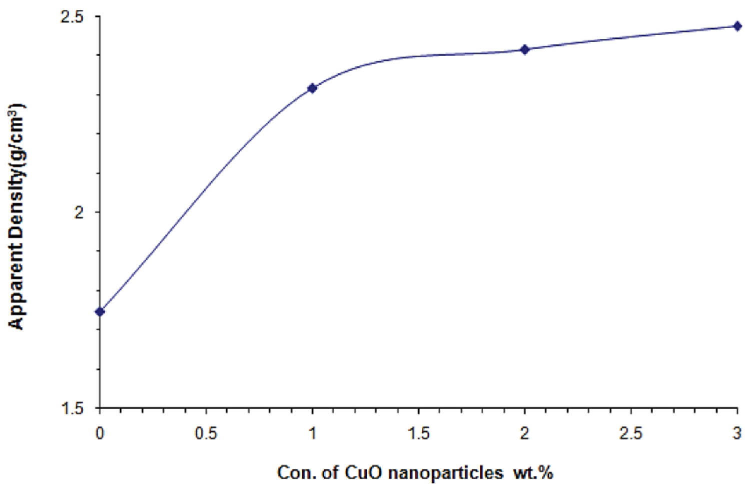


**Fig. 6.** Relationship between apparent density and CuO nanoparticles content.

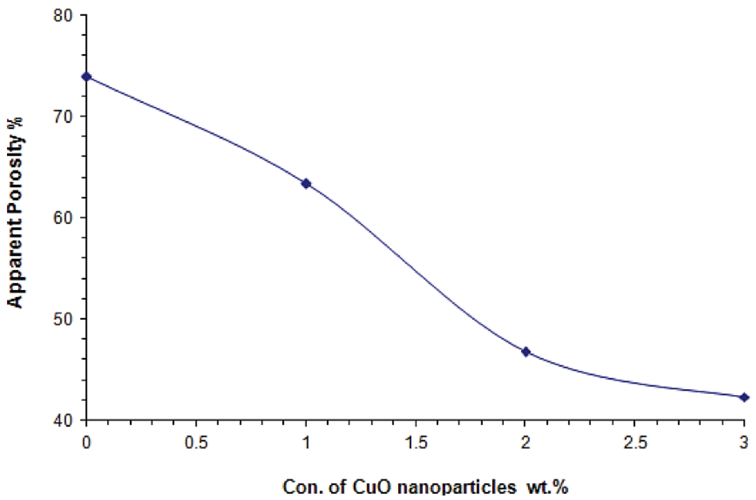


**Fig. 7.** The variation of apparent porosity and CuO nanoparticles content.

MgO. These results agree with the results of researchers [10]. Copper oxide does not appear in XRD due to little addition from it and the XRD apparatus does not fumble the copper oxide.

Figure 2 represents the microscopy images of MgO–NiO–CuO at different weight percentages of CuO nanoparticles. This figure shows uniform distribution of (MgO–NiO–CuO) nanoparticles.

Figure 3 shows DTA of MgO; the first peak shows inorganic evapo-

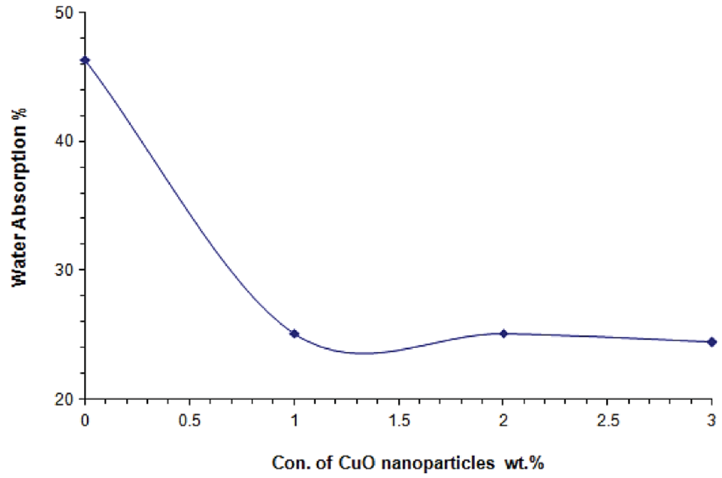


**Fig. 8.** The relationship between water absorption and CuO nanoparticles content.

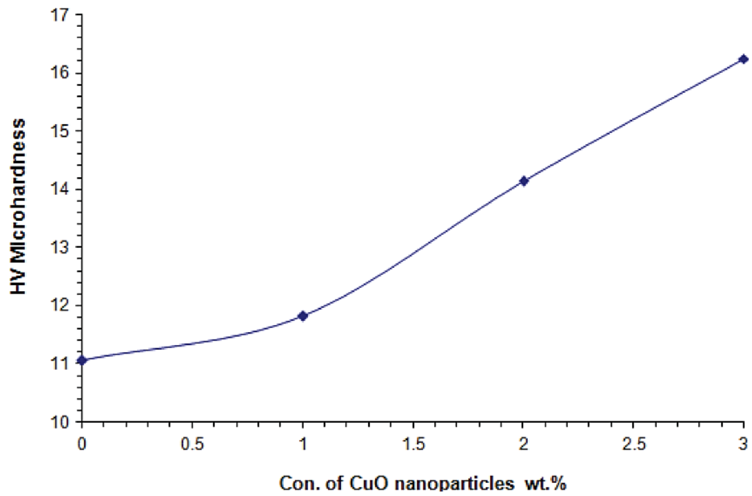


**Fig. 9.** The variation between Vickers microhardness and different concentrations of CuO nanoparticles.

ration at 350°C and the second peak explains phase transformation at 380°C [11] while Fig. 4 shows no change during heating to NiO nanoparticles, Fig. 5 explains DTA of CuO with appearing peak at 50°C which meaning moisture evaporation.

Figure 6 shows the relationship between apparent density and different weight percentages of CuO nanoparticles, this figure explains the increase in apparent density with increase concentrations of CuO nanoparticles, which may be return to full the spaces among particles by CuO nanoparticles because elevated catalyst activity [12] and formation $MgNiO_2$ compound.

Figure 7 shows the variations between apparent porosity and concentrations of weight percentages of CuO nanoparticles. The effect of CuO nanoparticles weight percentages on water absorption is shown in Fig. 8. From Figures 7 and 8, apparent porosity and water absorption decrease with raise the weight percentages of CuO nanoparticles. The reducing in apparent porosity/water absorption may be explained by increasing in the apparent density.

Figure 9 explains the variation between Vickers microhardness with CuO nanoparticles concentrations. Vickers microhardness arises with increase weight percentages of CuO nanoparticles. This increasing related to increase the compaction and decrease in porosity in addition to formation $MgNiO_2$ compound. In addition, CuO nanoparticles have different mechanical strengths from their bulk materials [13].

## 4. CONCLUSION

The XRD results of MgO–NiO samples with addition various ratios of CuO nanoparticles shows formation $MgNiO_2$ compound with appears MgO and NiO compounds. The thermal properties of MgO–NiO/CuO samples included DTA of MgO, the two peaks of MgO show at 350°C and 380°C while shows no change during heating of NiO, DTA of CuO explains peak at 50°C. The physical properties of MgO–NiO samples, the apparent density increase while apparent porosity and water absorption decrease with raise concentrations of CuO nanoparticles. The mechanical properties showed that the *HV* microhardness of MgO–NiO increases with the increase in CuO nanoparticles concentrations.

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