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Study Properties of Alumina by Adding Different Ratio of Copper

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ABSTRACT

Powder Technology (P/T) process includes compacting of fine powders followed by a sintering process to get products of desired properties. Several factors affected sintering; however, the most significant are time, temperature, and composition. In this research, different ratio of copper being the most important single variable.

The pure alumina powder was mixed with different weight percent of (1%, 2%, and 3 %,) Cu. A mixture of alumina and copper were prepared by cold pressing at a pressure of (40) MPa, and sintered under isothermal conditions in the temperature range from 1350 to 1400 °C for up to 120 min to obtain a very low porosity after final sintering, a good results have been getting for the mechanical and physical properties of these materials.To evaluate the performance of the prepared material, several tests were conducted such as strength and hardness as a mechanical test. In addition, physical tests which include density, shrinkage, porosity, and absorption. This study shows improvement the properties of alumina by adding a different ratio of copper.

Keywords: *Alumina, Copper, Sintering, Composite material.*

1. INTRODUCTION

The subject of ceramics covers a wide range of materials. One recent attempts have been made to divide it into two parts: traditional ceramics and advanced ceramics. Traditional ceramics still represent a major part of the ceramics industry. In recent years interest has focused on advanced ceramics that, with minor exceptions, have been developed within the last 30 years or so. Advanced ceramics include ceramics for electrical, magnetic, electronic, thermal and optical applications, and ceramics for structural applications at ambient as well as elevated temperatures [1].

The development in ceramic technology led to extend this to include other binary and complex compounds of metals such as oxides, carbides, nitrides, borides and silicids [2].
One of the most important production routes for ceramic or hard metal parts is powder technology by using pressing and sintering.

After compaction, the green-state part is transferred to a sintering furnace, where it is heat treated for up a given time. Although the temperature inside the furnace is below the melting point of the metal. It causes a significant transformation in the microstructure of the compact [3].

Composite material consists of two or more distinct phases. The term phase indicates a homogeneous material, such as a metal or ceramic in which all of the grains have the same crystal structure, or a polymer with no fillers. By combining the phases, using methods yet to be described, a new material is created with aggregate performance exceeding that of its parts. The effect is synergistic. In the selection of a composite material, an optimum combination of properties is usually being sought, rather than one particular property. Several fiber-reinforced ceramics possess this combination of properties[3].

There are many research studies used a composite material of alumina and copper including:

In this project, the researchers were studying the effect of different size and the amount of Al_2O_3 particles on strengthening, thermal stability and electrical conductivity of the copper based composites during internal oxidation and mechanical alloying of the copper-based composites. The electrolytic copper powder, inert gas atomized pre-alloyed copper powder containing3.5 wt.% Al, and the mixture of copper and commercial Al2O3 powder particles (4 wt.% Al2O3) were milled separately in the high-energy planetary ball mill up to 20 h in the air. The results were discussed in terms of the effects of the grain size refinement along with micro- and nano-sized Al2O3 particles on strengthening of the copper matrix [4].

The study situ consolidation of a cu 2.5 vol% Al_2O_3 powder by high energy ball milling has been studied by examining changes of size, morphology, macrostructure and microstructure of the powder particles, lumps, and balls formed with increasing milling time under different conditions. The results show that the consolidation process is slower due to increase hardness of the powder particles .The study also shows that the Al_2O_3 fine particles are incorporated into the cu matrix forming a composite structure when the lumps are formed and the large balls exhibit a nanostructure with grain sizes smaller than 100 nm[5].

In this study thermo-chemical technique was used to synthesize cu –Al_2O_3 nonocomposite powders 20–50 nm, then sintering, with a comparative analysis of the mechanical and electrical properties of the obtained solid samples. Spray-drying, oxidation of the precursor powder, reduction by hydrogen and homogenization, analytical electron microscopy (AEM) coupled with energy dispersive spectroscopy (EDS), differential thermal and thermogravimetric (DTA–TGA) analysis and X-ray diffraction (XRD) analysis, these are the following stages of powder product . The structure, provided a sintered material with a homogeneous distribution of dispersed in a copper matrix, with exceptional effects of reinforcement and an excellent combination of mechanical and electrical properties [6].

The study thermo-chemical technique was used to synthesize Cu –Al_2O_3 nonocomposite powders. The nanocomposite powders of both copper and alumina were thoroughly mixed, cold pressed into briquettes and sintered at 850°C in hydrogen atmosphere. The x-ray diffraction and scanning electron microscope (SEM) with an energy dispersive spectrometer (EDS) were used to characterize the structure of the obtained powders. The results showed that alumina nanoparticles (20 nm) and ultra-fine copper crystallite (200 NM) were obtained. The results show alumina content up to 12.5% resulted in an increase of 47.9% in hardness and slight decrease 7.6% in relative densities, the results of compression tests showed a considerable increase in compression strength 67% as alumina content increase up to 12.5%. The compression strength showed a further increase in compression strength (24%) as strain rates were increased from [7].

Objective

The aim of this research is to study the mechanical and physical properties for mixture of pure alumina as a matrix reinforced with different ratios of copper, while other researchers study the properties of copper as a matrix reinforced with alumina.

2. EXPERIMENTAL WORK

2.1. Materials

a. Alumina

Alumina is one of the most cost effective and widely used material in the family of engineering ceramics. The raw materials from which this high performance technical grade ceramic is made are readily available and reasonably priced, resulting in good value for the cost in fabricating alumina shapes. With an excellent combination of properties and an attractive price, it is no surprise that fine grain technical grade alumina has a very wide range of applications. High purity alumina, and alumina with different ratios of copper (ready to press) has been used as a starting material. Alumina powder sieving in order to received greets particle size, and then mixing with copper powder. They were dry mixed using (the rotating mixer with milling balls) to break soft agglomerating for 5 hrs. So the figure (1) shows the microstructure of alumina powder which is used in this work.

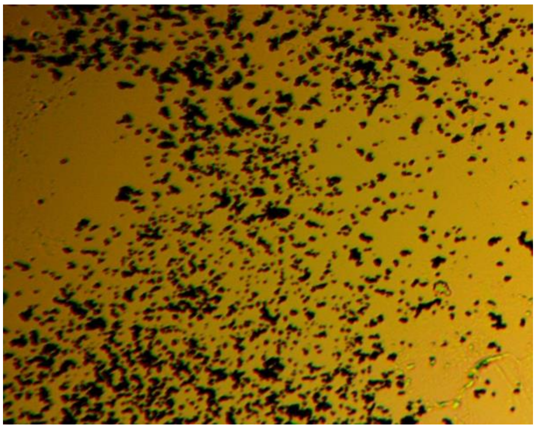


Fig (1) Microstructure of Alumina Powder

b. Copper

Copper is one of the important industrial metals. It has been found more properties, such as the advantages of thermal, electrical conductivity and good resistant to oxidation even at high temperatures. Pure copper is soft, malleable, very flexible and ductile. It can be stretched into wires easily. It has a Mohs hardness of 2.5 to 3 that means it is harder than a fingernail, but softer than a steel pocket knife. It was prepared powder of copper by using a pole purity copper of (99%) ,the figure (2) show the microstructure of the copper powder.

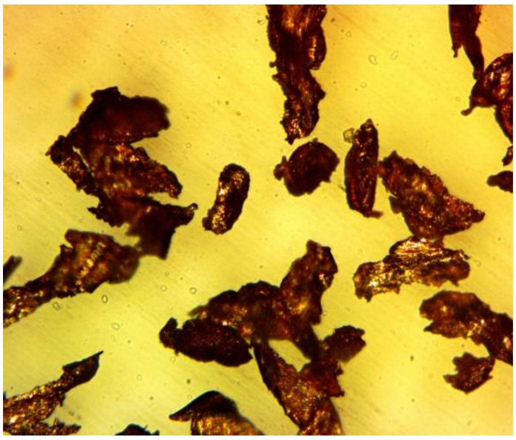


Fig (2) Microstructure of Copper Powder

c. PVA

They mixed with the addition of 3cc of the binder (PVA) with a concentration of (70%) for 6 hours, pure alumina is ready to be filled in the die to compact, as same as the alumina with different ratios of copper.

2. SAMPLES

12 samples were prepared, the first three samples without any additives, so they behave as the reference, and the other samples for each percent of Cu addition (1, 2, 3) % by weight of alumina powder. The chemical composition of samples list below in table (1)

Table (1) chemical composition of samples

Samples	No of Samples	Percentage of Al2O3	Percentage of Cu
A	3	100	0
B	3	99	1
C	3	98	2
D	3	97	3

3. PREPARATION OF SAMPLES

The composite powders were characterized by a homogenous distribution of Cu in an Al_2O_3 matrix. Mixing the two powders by electric mixer for 5 hours to get good homogenous, then (3 cc) of BVA was added to each sample. The powder was cold pressed at a pressure of 40 MPa and sintered under isothermal conditions in the temperature range from 1350 to 1400 °C for up to 120 min. Characterization of the Al2O3-Cu sintered system included determination of several tests such as strength and hardness as a mechanical test. In addition, physical tests which include density, shrinkage, porosity, and absorption.

4. GRINDING AND POLISHING

Standard grinding were done for the sintered samples before starting the required mechanical tests. The grinding process was accomplished with silicon carbide papers of different grades. Followed by cleaning in distillate water and alcohol, sample in the same dimension were used to measure different properties. Figure (3) shows the samples that were prepared.

Fig (3) Samples a) without Cu, b) with 1% Cu

5. MECHANICAL PROPERTIES

A-Hardness

Hardness is one of the important measured properties of a ceramic. Its value helps to characterize resistance to deformation, densification, and fracture.
Hardness was determined by using the Rockwell hardness test (HRC). The Rockwell hardness test is the most widely used method for determining the superficial hardness of a material. The samples were tested using loads associated with the Rockwell scales. Generally, the surface should be flat and sanded smooth to obtain an average of three of more readings.

B-Compression

One of the most common mechanical stress–strain tests are performed in compression that was determined by using (Universal Machine),for most materials used in different applications, additional information was obtained from compressive tests.The applied load in this test was (50) kg. It can be calculated by the following equation [8]:

$$\sigma = \frac{F}{A}$$

Where:

σ = compression strength (N/mm^2)
F= applied load (N)
A= sample area (mm^2)

6. PHYSICAL PROPERTIES

A-Density, Shrinkage

Experiments were performed to measure the sinter density and shrinkage. The former was accounted for by measuring the following according to ASTM (Archimedean way) [9].

W_d = Dry weight, it is the weight of the sample after drying in g.

W_s = Suspended weight, which determines the weight of the test specimen after boiling in water . This weight is usually accomplished by suspending the specimen in a loop hung from one arm of the balance,Ws in g.

W_w = Saturated weight, after determining the suspended weight. Blot each specimen lightly with moistened smooth linen or cotton cloth to remove all drops of water from the surface and determine saturated weigh, Ww in g by weighting in air.

The density is defined as:

$$\rho = \frac{W_d}{W_w - W_s}$$

On the other hand the volume shrinkage is given by the equation's diameter shrinkage given by the equation :

Diameter shrinkage = $\frac{d - d^{\circ}}{d^{\circ}}$ * 100

B-Porosity

It is very difficult to produce P / M parts without any porosity remaining after sintering. The total porosity present in the sintered part may be calculated from the following relationship [10]:

p% = $\frac{W - D}{M - S}$ * 100

Were:
p% : porous virtual
W : wet weight
D : dry weight
M : weight saturated
S : weight commentator

C-Absorption

Absorption was related to porosity. So it was determined by using this relation [10]:

W.A% = $\frac{W - D}{D}$ * 100

Were:
W.A % : absorption
W : wet weight
D : dry weight

7. RESULTS AND DISCUSSION

7.1. Mechanical Properties

a. Effect of Hardness

Figure (4) shows the relationship between hardness and different ratio of copper reinforced alumina during the sintering. In this figure the hardness increase with increase the ratio of Cu, and the best value of hardness at ratio of copper about (3 %).

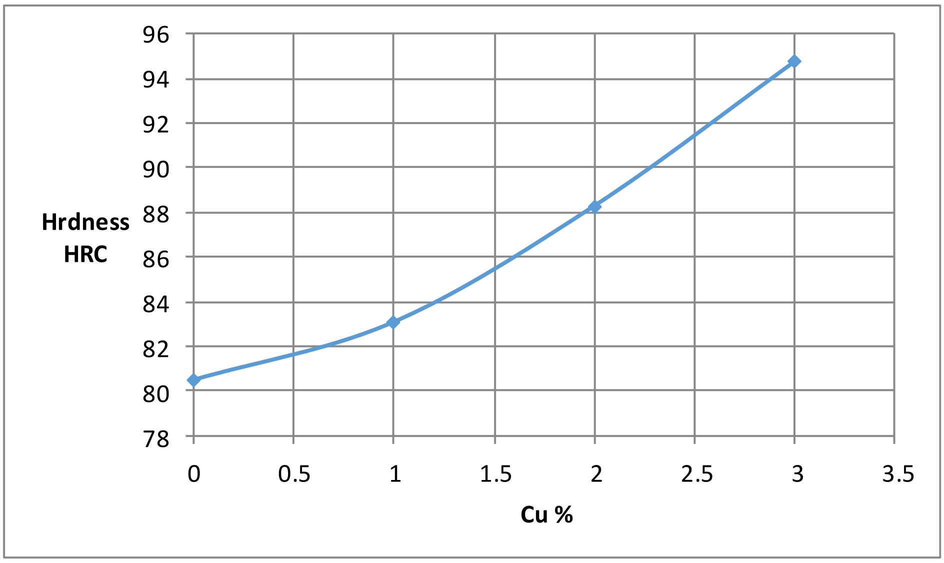


Fig (4): Variation in hardness of the samples with different ratios of copper.

b. Effect of strength

The relevance between strength and different ratio of copper is shown in Figure (5). It has been found that the strength increase with increase of copper content. So the maximum value of the strength that has been obtained in the ratio of copper about 3%.

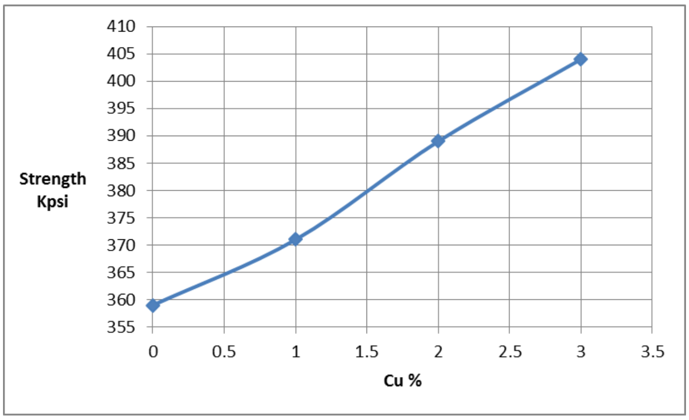


Fig (5) Variation in the strength of the samples with different ratios of copper.

7.2. Physical properties

a. Effect of Density

Figure (6) refers to the relation between density and different ratio of copper reinforced alumina during the sintering. In this figure the density increased with increase the ratio of Cu. It should be used a fine grain material to get a very homogeneous sintering temperature.

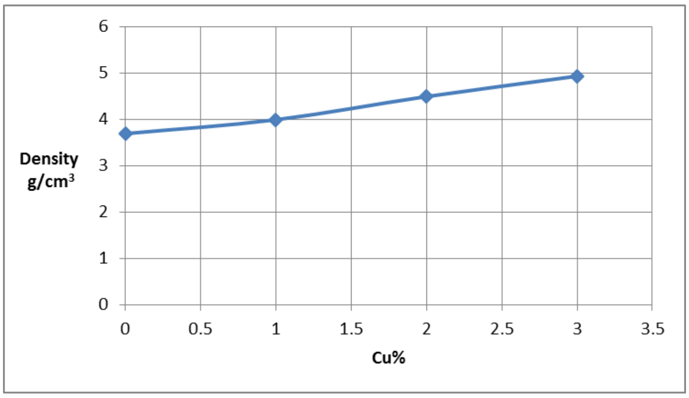
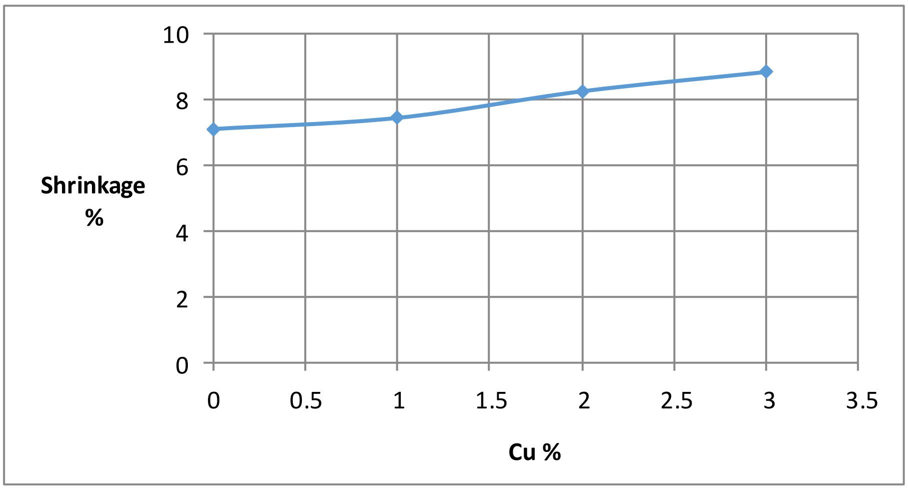


Fig (6) Variation in density of the samples with different ratio of copper.

b. Effect of Shrinkage

Figure (7) appears the shrinkage that happens when the different ratio of copper reinforced alumina during the sintering cycle. In this figure the shrinkage increased with increase the ratio of Cu. Good adhesion could be got in use homogeneous sintering temperature.



Fig(7) Variation in shrinkage of the samples with different ratio of copper.

c. Effect of Porosity

The porosity change according to the different ratio of copper reinforced alumina and figure (8) shows this range .In this figure the porosity decreased with increase the ratio of Cu. The porosity was a good factor related to the density.

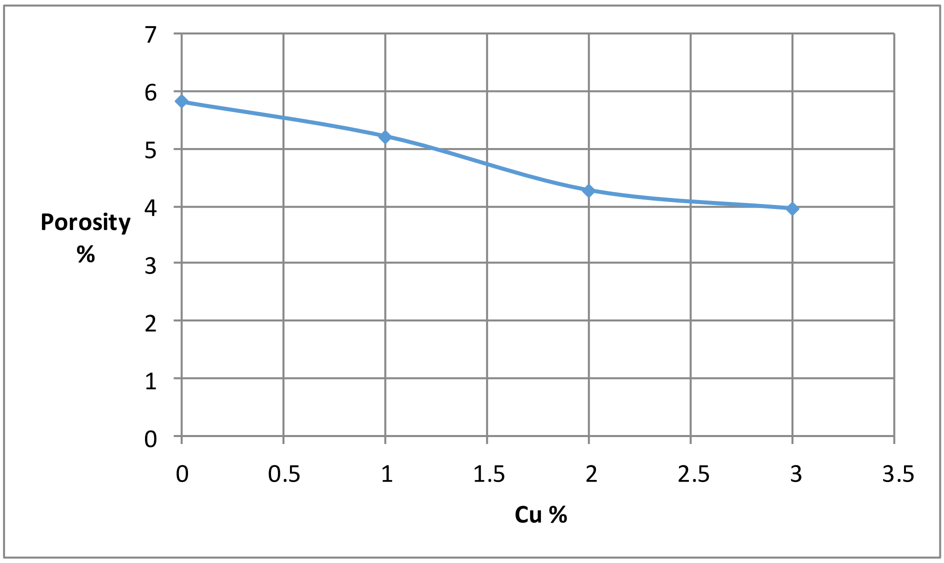


Figure (8) Variation in porosity of the samples with different ratio of copper.

d. Effect of Absorption

Figure (9) shows the relationship between absorption and different ratio of copper reinforced alumina. In this figure absorption decreased with increase of copper ratio, so it was a function of porosity.

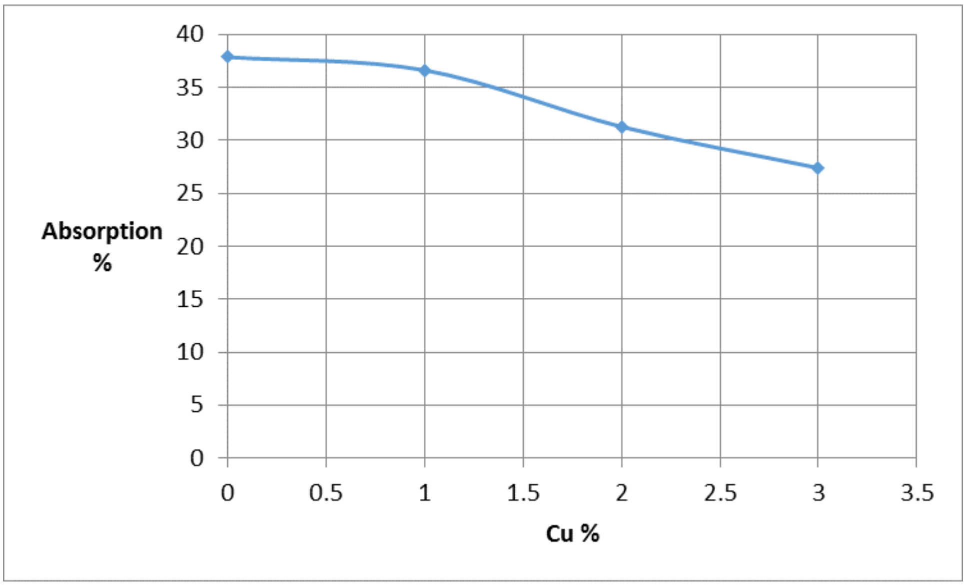


Figure (9) Variation in absorption of the samples with different ratio of copper

7.3. CONCLUSIONS

1. The increase in hardness of a composite material (83.1) for (1%) Cu, (88.3) for (2%) Cu, (94 .77) for (3%) Cu, compared to pure alumina (80.5 Rockwell 45 N).
2. High strength (371 Kpsi) for (1%) Cu, (389 Kpsi) for (2%) Cu, (404 Kpsi) for (3%) Cu, compared to pure alumina (359 Kpsi).
3. Physical properties play good role in this study, density and shrinkage were about (3.99 g/cm3) and (7.45%) respectively, for (1%) Cu. (4.49 g/cm3) and (8.26%) respectively, for (2%) Cu, , (4.93 g/cm3) and (8.85%) respectively, for(3%) Cu, and (3.69 g/cm3), (7.11%), respectively for alumina.
4. Porosity were about (5.22%), for (1%) Cu, (4.28), for (2%) Cu, (3.96%) for(3%) Cu, and (5.82%) for alumina.
5. Absorption, were about (36.61%) for (1%) Cu, (31.27%), for (2%) Cu, (27.38%) for (3%) Cu, and (37.85%) respectively for alumina.

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