Investigation of Some Properties for Cu Al_2O_3

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Abstract:

The aim of this work is the development of Cu-Al_2O_3 composites of copper matrix composite materials reinforced by (0.5-5-10-20)%Wt of Al_2O_3 particles that based on a fine dispersion rout of composites materials and study of some physical properties. This article is revealing the effect of weight percentage, sintering temperature on the microstructure and physical properties. The alumina used as a reinforcement particle in cupper metal matrix composite by powder metallurgy route to produce insulating material combine with high micro hardness. Composite samples were prepared based on (> 0.063µm) Al_2O_3 reinforcement. The matrix and reinforcement materials were mixed. The sample were cold pressed at 5 ton and sintered at (400,500,600,700,800)̊ C for 2 hours. This search will discuss the thermal, electrical conductivity and Vickers micro-hardness value of the composites In this report the effect of both grain size and the amount of Al_2O_3 particles on strengthening, thermal stability and electrical conductivity for copper-based composites was studied. The results were show that the thermal conductivity will be decreasing gradually with increasing both of fine alumina amount and sintering temperature, the electrical conductivity will be decreasing with increasing in weight percentage of Alumina and in sintering temperature. The Vickers micro-hardness value of composite samples will increasing with the increasing of weight percentage.

Keywords: Alumina particle, Cupper powder, ceramic particles reinforcement, powder metallurgy.

التحقيق لبعض خصائص نحاس- الومينا

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الخلاصة :

ان الهدف من اجراء البحث هو تطوير المادة المتراكبة المتكونة من مادةالاساس المعدني وهي مادة النحاس والمدعمة بمادة الالومينا وبنسب وزنية (20–10–5–0.5) من مادة الالومينا وتعتمد الية التدعيم بألية التدعيم بالتشتيت وبعدها يتم دراسة الخصائص الفيزيائية لها.هذا البحث يوضح تاثير كل من نسب الاضافة لمادة الالومينا،درجة حرارة التلبيدعلى كلا من التركيب والخصائص الفيزيائية.تم اضافة مادة الالومينا الى مسحوق النحاس و حضرت بطريقة تكنولوجيا المساحيق وذلك لصنع مادة عازلةو ذات صلادة مايكروية عالية .حضرت هذه النماذج بالاعتماد على حجم دقائق الالومينا (<٠,٠٦٣) .خلطت النماذج معا ثم كبست بالكبس البارد وبحدود ٥ طن وتم تلبيدها بحدود (٤٠٠–٥٠٠–٦٠٠–٧٠٠– ٨٠٠) سيايزي ولمدة ساعتين .هذا البحث سيناقش كلا من التوصيلية الكهربائية والتوصيلية الحرارية و الصلادة المايكروية بطرقة فيكرز. تم دراسة تاثيرالحجم الحبيبي لمادة الالومينا ونسبة التدعيم للمادة الاساس على كل من الخصائص المتانة ،والثبات الحراري و التوصيلية الكهربائية واظهرت النتائج بان التوصيلية الحرارية قلت بصورة تدريجية مع زيادة نسب الالومينا وبزيادة درجة حرارة التلبيد.وكذلك نقصان في قيمة التوصيلية الكهربائية مع نسب الالومينا وزيادة درجة التلبيد.وزيادة قيم صلادة فيكرز المايكروية مع زيادةنسب الالومينا وزيادة درجة التلبيد.

الكلمات المفتاحية: دقائق الالومينا، مسحوق النحاس، التدعيم بالدقائق السيراميكية، تكنلوجيا المساحيق

Introduction: There are major interests to develop the metal matrix composites (MMC) for the past three decades. This because it offers some unique mechanical properties such as low density, high strength, high stiffness, high wear resistance and other attractive properties such as, physical properties such as Electrical conductivity, thermal conductivity, apparent porosity, and Real porosity.. A composites materials are form by combine two distinct materials ,one called matrix and surrounds which called a reinforcement materials ,these materials are classified in to different criteria:1) type of base material-metal matrix-polymer matrix-ceramic matrix ,2)size-shape of dispersed phase –particle reinforced, or fiber-reinforced .Now a days a lot part of composites materials used in automobile industry like pistons, connecting rods, gudgeon pins, cylinder liners, valve, train part and brake pads and discmade from MMC materials. The use of MMC materials is also being using in other application including aerospace, electronics, structural and sporting goods. Particle reinforced MMC represent many types of materials where the hardness, resistance of reinforcement are corporated with the ductility and toughness of a matrix materials [1]

In this search which based on Fine dispersed particles where it introduction to metal matrix, has significantre in forcing effects. For such reinforcement, ultra fine and nano particles of oxides are suitable, which due to their hardness. Maximum effects of reinforcing are achieved by even distribution of oxide particles. Research of dispersion reinforced materials, led to the significance of properties of starting powders, which, although suffer some changes in further processing,. [2]

Copper is metal with low hardness, so addition of alumina decreasing in hardness value to the metals as well inertness at high temperature. The systems of composites have hardness and strength higher than other materials. These composites materials have strength and ductility that offers applications in many fields of engineering and technology. Aluminum oxide (alumina) is the workhorse of advanced ceramic technique. It has good mechanical and electrical properties, wear resistance and corrosion resistance. It has relatively poor thermal shock resistance. It is used as an electrical insulator for number of electrical and electronic applications, including sparkplug insulators and electronic substrates. It is also used in chemical, medical and wears applications. [3]

The objective of this research was investigated the strengthening of copper matrix by a fine dispersion of alumina particles. Also to reveal the effect of grain refinement as well as amount of Al_2O_3 particles, and effect of sintering process during these processes.

2. Experimental Procedure:

In this work used Cu fine grey powder (220µm) purity 99.5% as matrix material to prepared composite material,500g, the source is Central Drug House (P) Ltd. Alumina powder (Al_2O_3) that added with weight ratio (0.5,5,10,20)% has particle size (> 0.063µm), type T. 99.51%, the source is RIEDEL-DE HEAN AG-Hannover-Germany. Are enforced material. Cu and Al_2O_3 compressed at (5tone) after mixing process this procedure was used for all samples .The final sample has weight (4g) with diameter (25mm), height (10mm), the die has a dimensions length to diameter (120mm*40mm) from stainless steel. The product sample sintered at (400,500,600, 700,800)̊C for soaking time (2hr) in electrical furnace. (means at 400°C for Cu pure, at 500°C for 0.5% alumina, 600° C for 5% alumina, 700° C for 10% alumina, 800° C for 20%alumina).

3. Testing:1. Electrical Measurement (Electrical Conductivity):

Studying of the (I-V) characteristics is essential in order to calculate the conductivity of the prepared samples. It was carried out on a two –point probe connected to a D.C power supply in the range of (0-30) voltage, supplied by Franell.It provides an out voltage from (0-30) volt across the sample. The resulting current was measured with digital millimeter supplied by SUNS. The conductivity is calculated according to the relation: V=IR….. Ohms law(1) Ohms law relates the current I(Ampere),to applied voltage V(volt).

G=1 / R…….(2) where G is the symbol used to denote the conductance

2-Vickers micro-hardness Test:

Vickers micro-hardness test was carried out on the cross-section of the ($Cu-Al_2O_3$) composite material (0.5-5-10-20)% Al_2O_3 by using digital Vickers micro-hardness type (HVS-1000,Laryree technology Co .Ltd). This test was done by using load (1.96 N). For dwell time (10 Sec) as seen in fig. below. One reading was taken for each sample of $Cu-Al_2O_3$ composite materials. The indenter of Vickers micro- hardness is diamond indenter which was pressed on to prepared metal surface to cause a square-based pyramid indentation.

Fig.(1) show Vickers micro-hardness device

3. Thermal Conductivity Test:

To measure the coefficient of thermal conductivity for all samples, the Lee`s disc device was used as seen in fig below. It is manufactured from (Griffen and George) Company in England. The samples of thermal conductivity were cut according to specification of instrument, the value of (e) is calculated by the equation :

$IV=\pi r^2(T_A+T_B)+2\pi re[d_AT_A+d_s \frac{1}{2}(T_A+T_B)+d_BT_B+d_CT_C]$..........2

(e) represent the amount of heat (heat energy) through unit per second. (I) is the electrical current value through the electrical circuit. (V)is the applied voltage. for calculation the cofficent of thermal conductivity (K), the following equation is used:

$K(T_B - T_A/ d_s)=e[T_A+2/r(d_A+(1/4\, d_s))\, T_A+1/2r\, d_s\, T_B]$.........3

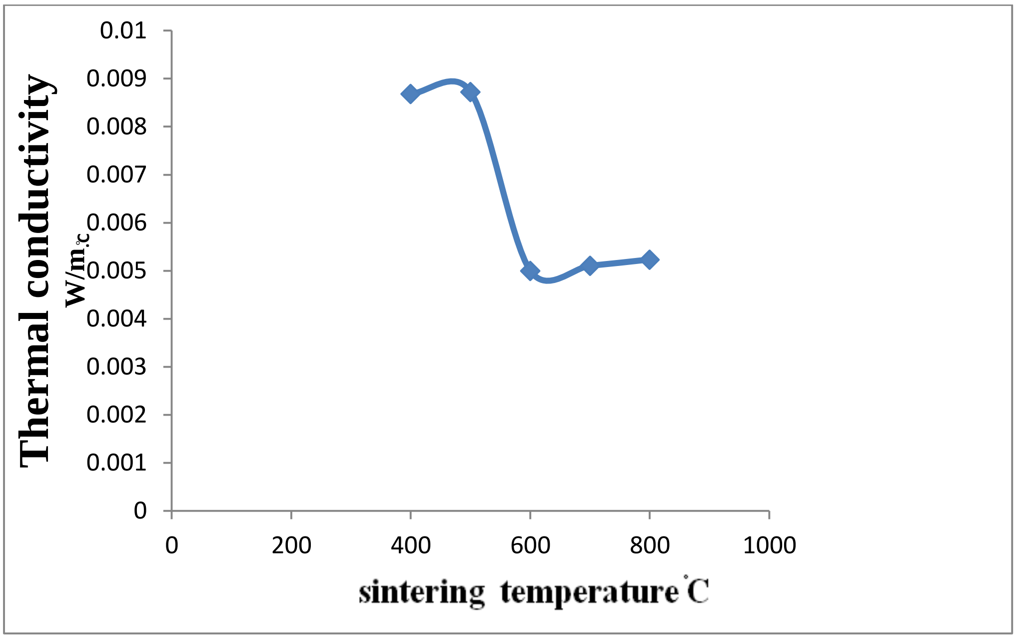
Where T: temperature of three discs A,B,C (°C)
d: thickness of five samples (mm)
r: radius of samples (mm)

Fig(2) show the Lee`s disc device

4. Result and discussion:

This section presents the results of (Cu pure, 0.5, 5, 10, 20) % Al_2O_3 samples which performed by using powder metallurgy technique, this samples was studied under the following parameters; sintering temperatures at (400, 500,600,700,800)° C, and Al_2O_3 percentage. The results show the effect of these parameters on electric conductivity ,thermal conductivity ,Vickers micro-hardness tests as shown in figures (3,4,5) below, from fig.(3) shows at (400, 500)℃ high values for (pureCu,0.5) of alumina additives while at (600,700,800)℃ for (1,10,20) of alumina additives which indicates that the influence of sintering process and the amounts of fine alumina (> 0.063µm).

Also this figure show that the thermal conductivity was affect by imperfection in the structure, the insulating properties of ceramics essentially depend on the microstructure imperfections. The travelling of wave like phonon or photon is discontinuous by grain boundaries, from fig.(3) The use of ceramic insulator materials like Alumina with base materials Cupper show a stability in thermal conductivity especially at (600-700-800)°C for (5-10-20)% of Al_2O_3. (means at 400°C for Cu pure, at 500°C for 0.5% alumina, 600°C for 5% alumina, 700°C for 10% alumina, 800°C for 20% alumina).



Fig(3) show the result of thermal conductivity for composites samples for(Cu pure, 0.5, 5, 10, 20) at (400, 500,600,700,800)℃

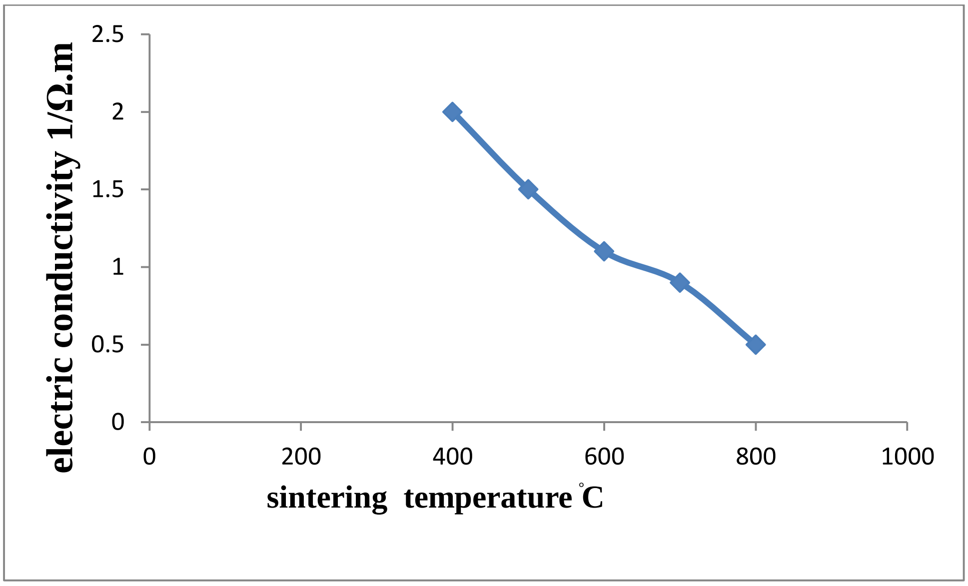


Fig.(4) show the result of electrical conductivity for composites samples for (Cu pure, 0.5, 5, 10, 20) at (400, 500,600,700,800)℃

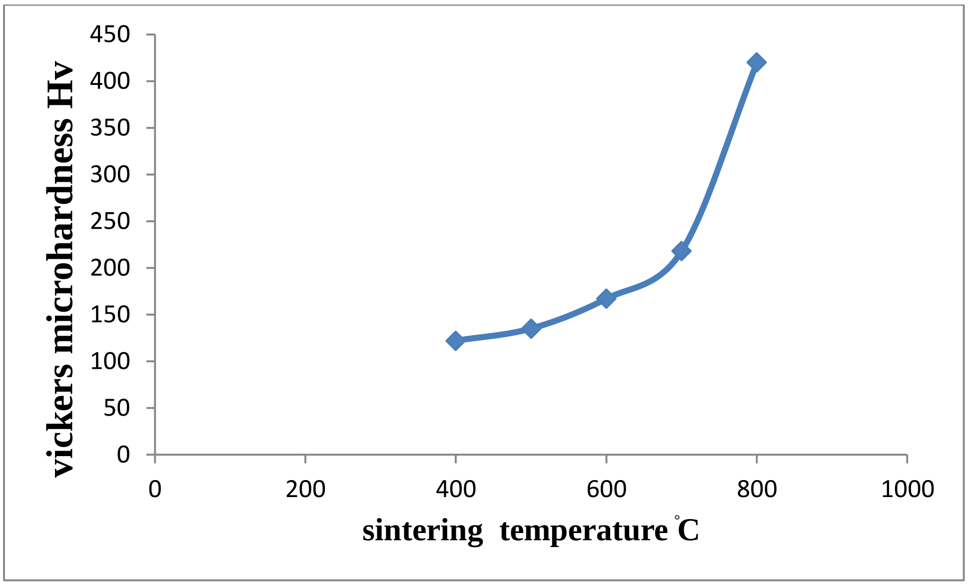


Fig.(5)show the results of Vickers microhardness for composites material for(Cu pure, 0.5, 5, 10, 20) at (400, 500,600,700,800)℃

Form the figures (4,5) as seen have a good properties for Vickers micro-hardness that gradually increase with sintering temperature and fine Alumina additives increasing, and good electrical insulators that gradually decreasing at (500,600,700,800)℃ with increase of Alumina additives that related to the characteristics of the crystalline ceramics (powders) like their particle size of (>0.063µm) of Alumina and purity are important that affect on the structure like the grain size and properties as like strength of the final samples[4].

On other hands the strength increases as the decreasing in grain size, most powders are milled or grounded to form a fine powder that's effect on properties. Sintering operation is the last step in this search. Sintering operation at high temperatures (800°C) causes enforcement in structure so that reinforcement the ceramic samples its strength and properties. During this operation, the specific ceramic particles are coalescing to form a continuous net from particles and pore. Generally the microstructure of the sintered samples having the component parts closely compacted together compacted, where an separated grain is formed from several particles like fig.(6)(7) below[5]:

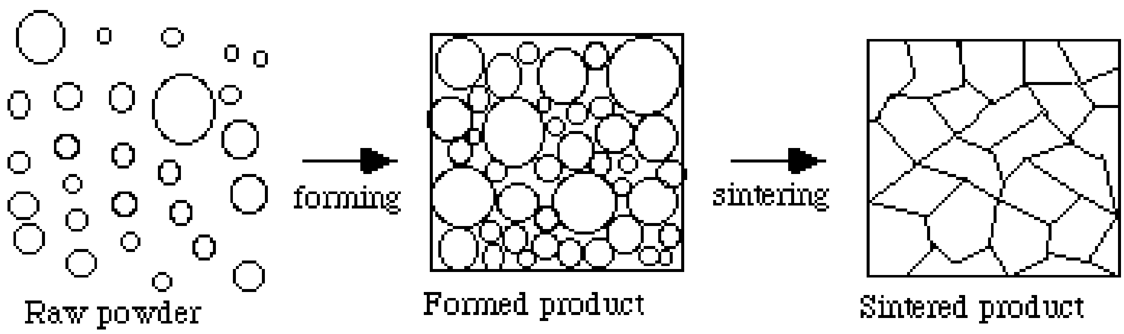


Fig.(6): Microstructure of sintered ceramic products

Also The type of bond like (ionic or covalent) and the interior structure (crystalline or amorphous) effects on the properties of ceramic material such as, The mechanical, electrical, thermal, and optical properties of ceramics .on the other hands alumina has ionic bond that effect on thermal and electrical properties[6]. in this search Al_2O_3 has ionic bond so this bonding effect on properties like thermal, electrical properties, for figure (1) show that a thermal stability at high temperature (600,700,800)°C for(5-10-20)%$Al_2O_3$and they decreasing for both pure copper at 400°C, and at 500°C for 0.5% Al_2O_3.

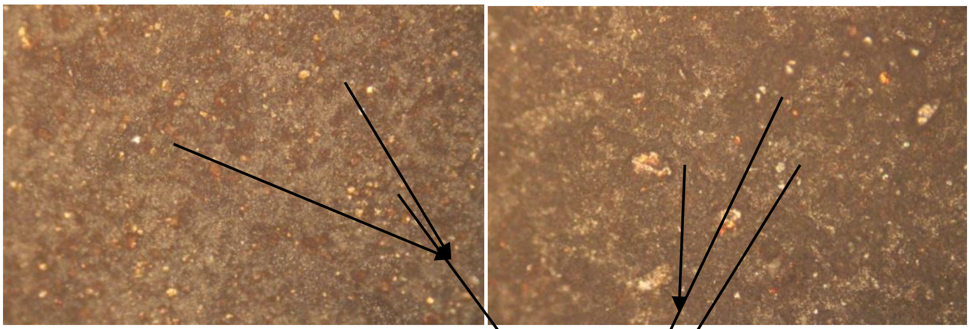
In general the mechanism of heat transfer at high temperature the atoms will be vibrate and each atom effects on the movement of neighbors atoms, so the result is elastic waves that will be propagating at the whole material. While at low temperatures like in our work (from 400°C and above), heat energy will be travel through the material by phones, these Phonons are result of particle vibrations which that increase as temperature increases. Phonons traveling through the material till they were scattered and that what happen in tests of thermal, electrical conductivities. Although that $Al_2O_3$and all ceramic materials have poor electrons that known as the charge carrier therefore the ceramic are poor conductors. [6][7]
Furthermore from fig.(3) Those materials $CuAl_2O_3$ composites have a lower value of electric conductivity especially at (600,700,800°C at (5,10, 20% Al_2O_3) more than at (0.5% at 500°C - and at 400°C for pure Cu). Those poor properties in electrical, thermal property cause also for thermal boundary resistance that is a refer to an interface's resistance to thermal flow.[8][9]

When an energy carrier (phonon or electron, depending on the material) try to transfer the interface it will be scattering at the interface surface between Alumina and Copper composites material. The probability of transmission after scattering will be depending on the energy states. When the thermal flux is applied through an interface, this interfacial thermal resistance will be lead to a finite temperature discontinuous between two materials. The thermal resistance at the interface between two materials was the primary significance in the study of its thermal properties. The interfaces often lead to the most important properties of the materials as stated above.[10]

From fig(5) show the results of Vickers microhardness that represent gradual increasing from 0.5%to 20 % of fine particle size of Alumina at(400-800)°C because of Alumina properties like high hardness, strength and other properties (where these the basic properties of Alumina) also the effect of sintering temperature, and fine grain size of Alumina which effect on materials properties fine dispersed particles which use it in our search means that play important role to act as a reinforcing effects, which can be still at elevated temperatures. this reinforcement like ultrafine particles of oxides are suitable, that led to hardness for the base metal that represent obstacles to move the dislocations at the elevated temperatures.

The research of dispersion reinforced materials mechanisms indicate the good value of properties for these powders, Also very important information about of dispersion strengthening is reveal that as less as possible percentage of dispersed particles into the base material.[10][11]

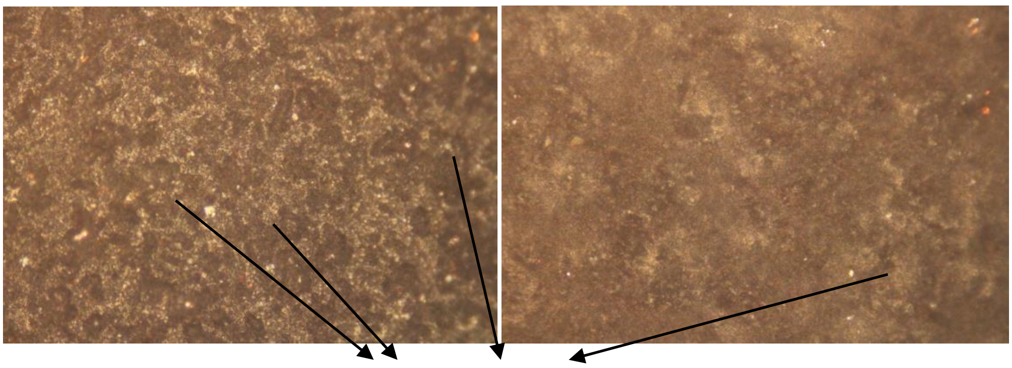
At last the composites samples have lower values (thermal,electrical)properties at high sintering temperature with high additives of alumina particles and hardness value has a high values also at high sintering temperatures with high alumina particles .on other hand the samples for lower sintering temperature with low alumina values have a lower properties in Vickers micro-hardness , high valuein thermal and electrical properties ,as can see the structure in the following figure:



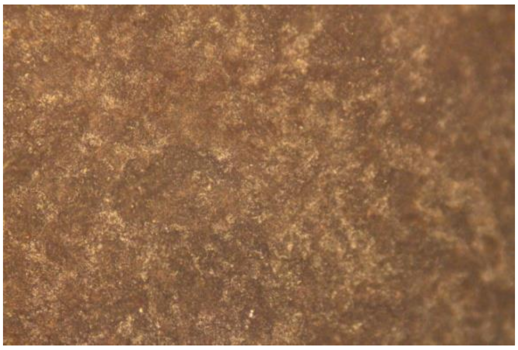
a)800 °C -20% Al_2O_3 b)700 °C-10% Al_2O_3

Al_2O_3

Fig(7) show the structures for(800 °C -20%,700 °C-10%) Al_2O_3



c) 600° C -5%- Al_2O_3 Al_2O_3particles d) 500° C -0.5%- Al_2O_3



e) pure Cu at 400℃

fig(8) show the structures of (600°C -5%)(500°C -0.5%) Al_2O_3

Conclusion:

1)A composites material composed of Cu powder (99.5%)purity matrix material with fine powder of Alumina (> 0.063µm) at five sintering temperatures (400, 500,600,700,800)℃ and four weight percentage of Alumina (0.5-5-10-20)% by metallurgy technique and characterized by high Vickers micro-hardness, low electrical and thermal properties.

2)Reinforcing by Al_2O_3 particles of Cu matrix applying by powder metallurgy using cold pressing method makes possible manufacturing ofcomposite Cu-based materials characterized by increase value of Vickers microhardness with increase in both amount of Alumina and increase in sintering temperatures because of Alumina properties .

3)Thermal and electrical conductivity for Cu- Al_2O_3 composites materials are present in lower value and have thermal stability in (600-700-800) °C,while in electrical conductivity has a gradual decreasing reach to 20%of Alumina at 800°C.

4)Cu Al_2O_3 composite are good insulator in thermal, electrical conductivity for (5-10-20)% for Al_2O_3 at(600-700-800) °C .

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