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Electrical, Mechanical and Microstructural Properties of Copper-Chromium-Silver-Alumina Composites Obtained by Powder Metallurgy.

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Abstract. It has been studied the correlation of the obtained microstructures in cermets of Cu-Cr-Ag-Al_2O_3 with the physical properties and the fabrication method varying the components proportions to obtain by powder metallurgy a material with good electrical conductivity and also good mechanical strength compared with pure copper allied to efficient fabrication and economical energetically process. The electrical conductivity data correspond to 40% IACS indicating that the utilized thermal treatments were relatively good for electrical contact applications and also mechanically.

Introduction

In this work were synthesized composites of Cu-Cr-Ag-Al_2O_3 with the aim of obtaining a steadily composites production by sintering (powder metallurgy) in laboratory scale and optimizing the electrical and mechanical properties. The alloy elements are added to copper to improve its mechanical resistance, ductility and thermal stability, without causing considerable costs on its form, electric and thermal conductivity and its resistance to the corrosion, typical characteristic aspects of pure copper. The process offers the potential to produce a wide variety of alloys with different material properties such as high temperature toughness and hardness. Metal-ceramic composites are recently being used as electrode materials in solid oxide fuel cell (SOFC), which have received much attention as alternative energy sources. It is mentioned in literature that in some cermets the dependence of the electrical resistance with the temperature can be similar to that of the metals. Some conductor composites are also employed in high speed railways electrical systems [1 – 10].

Experimental Procedures

Samples of Cu-Cr-Ag-Al_2O_3 composites (precursors of high purity; powder form; weight%; alloy element: Cu; Cr; Ag; Al_2O_3), initially compressed, sintered and sometimes homogenized were characterized by optical and electronic metallography (microstructure), mechanical strength (Vickers hardness), electrical properties (electrical conductivity) for the study of the influence of sintering processing (powder metallurgy) (Table 1).

Table 1 - Sintering parameters of Cu-Cr-Ag-Al_2O_3 composites

Condition	Premixed well done milled powders		
Compaction pressure	50MPa		
Chemical composite composition (wt %)	Cu-5%Al_2O_3; Cu-10%Al_2O_3; Cu-15%Al_2O_3; Cu-3%Cr-7%Al_2O_3; Cu-5%Cr-5%Al_2O_3; Cu-7%Cr-3%Al_2O_3; Cu-5%Cr–5%Ag-5%Al_2O_3; Cu-5%Cr–3%Ag-2%Al_2O_3; Cu-5%Cr–2%Ag-3%Al_2O_3.		
Sample dimensions	Cylinder: $\phi = 25.0x10^{-3}$ m; h = $4.00x10^{-3}$ m		
Sample weight	0.010 kg		
Sintering temperature and conditions	Temperature	Premixed condition	Vacuum pressure
	923 K	Solid State Sintering	10^{-3} mBar
Sintering time	$2.16x10^4$ s		

Results and Discussion

The mechanical behavior of Cu-Cr-Ag-Al_2O_3 composites shows an increase in microhardness principally due to the distributed alumina particles and relatively small grain size of the copper matrix. Fine dispersed ceramic particles introduction into the metal matrix have significant reinforcing effects which can be kept at elevated sintering temperatures. For such reinforcement ultra-fine oxide particles are appropriate, which, due to their hardness, stability and insolubility in the base metal also represent obstacles to moving of dislocations at the elevated sintering temperatures. Important facet of dispersion strengthening is the introduction of possible amount of dispersed particles into volume of base material.

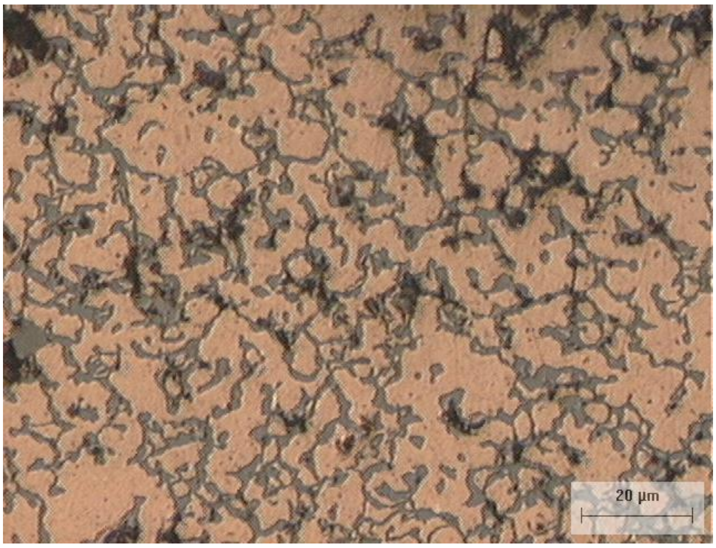

Fig. 1 Optical micrograph of the composite Cu-5%Cr-2%Ag-3% Al_2O_3 cold compact (50MPa) and sintered at 923 K for $2.16x10^4$ s. Good coalescence of copper grains. Some porosity and presence of second phases inside copper grains (Cr, Al_2O_3).

Sintering of fine dispersed powders occurs due to sliding of the particles along their boundaries; in that case a sliding mechanism is responsible for creation of additional vacancies. Number of supplementary vacancies can arrive at a value which corresponds to the density of vacancies in temperatures near the materials melting temperature. Then, it could be fulfilled that diffusion activity during sintering of dispersed particles in low temperatures (until 0.3 of melting temperature) is related by extras vacancies presence. Such obtained nanocomposite powders, with the preserved structure in final product, have provided production of the sintered system with special effects of reinforcement and a good combination of mechanical and electrical properties. The results of the hardness examination of the sintered samples show that the growth of the hardness value is due to the lessening specific electric resistance, which is a system structural stabilization, confirmed by the microstructural investigation.

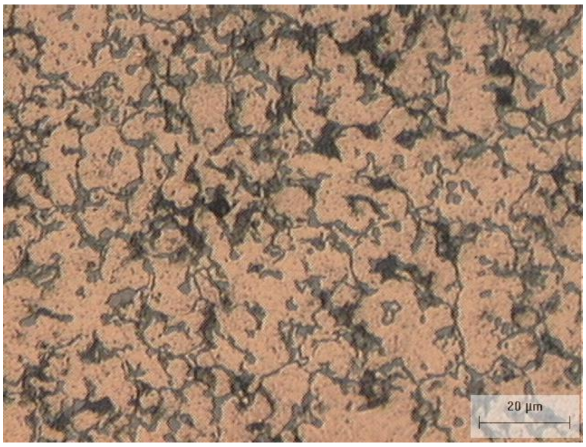

Fig. 2 Optical micrograph of the composite Cu-5%Cr-5%Al_2O_3 cold compact (50MPa) and sintered at 923 K for $2.16x10^4$ s. Intense copper grains coalescence. Relative porosity; presence of second phases (Cr; Al_2O_3 particles) inside copper grains.

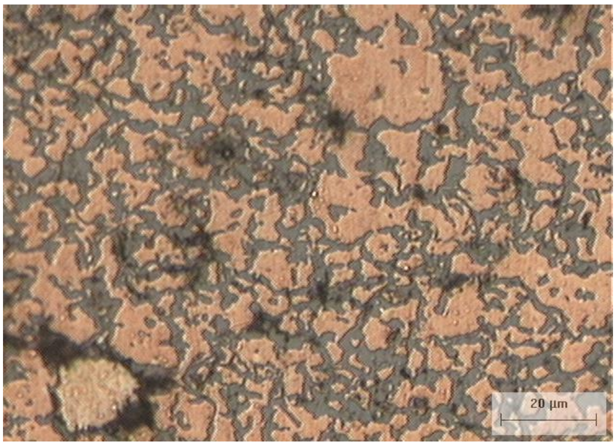

Fig. 3 Optical micrograph of the composite Cu-7%Cr-3%Al_2O_3 cold compact (50MPa) and sintered at 923 K for $2.16x10^4$ s. Good coalescence of copper grains. Some porosity; presence of second phases inside copper grains (Cr and Al_2O_3 particles).

The microstructural aspects utilizing optical microscopy (figures 1 - 6) are observed in samples of various Cu-Cr-Ag-Al_2O_3 composites. It is observed a good coalescence of copper grains, some porosity, presence of second phases (chromium, silver together with copper) inside copper grains that need correct identification and small alumina particles. There is also missing of some particles (visible dark areas) due to the metallographic polish processing.

The presence of porosity and second phases show that homogenization treatments will be necessary to overcome this situation and also investigations with scanning and transmission electron microscopy to identify the presence of second phase. The mechanical resistance in MMC composites depends on the second phase distribution to obtain comparable electrical conductivity of pure copper (matrix).

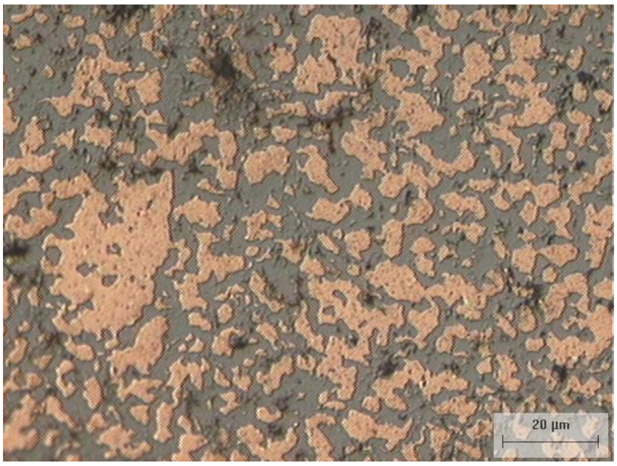

Fig. 4 Optical micrograph of the composite Cu-5%Cr-5%Ag-3%Al_2O_3 cold compact (50MPa) and sintered at 923 K for $2.16x10^4$ s. Very good coalescence of copper grains, small presence of porosity, second phases (Cr, Ag and Al_2O_3).

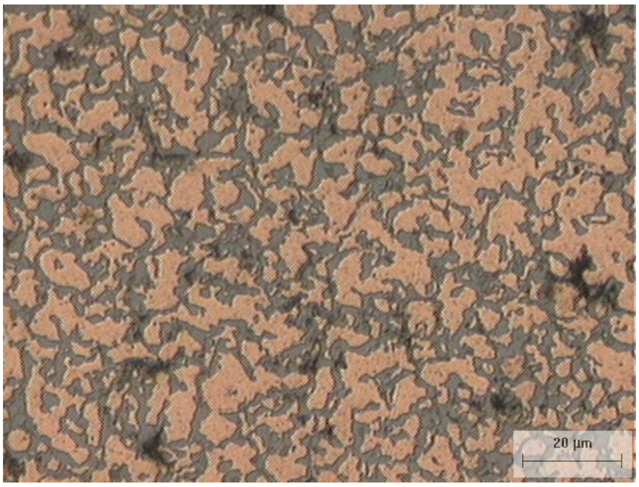

Fig. 5 Optical micrograph of the composite Cu-5%Cr-3%Ag-2%Al_2O_3 cold compact (50MPa) and sintered at 1073 K for $2.16x10^4$ s. It is observed a coalescence of copper grains, some porosity and presence of second phases (chromium and silver).

Nowadays the obtained mechanical strength (650 MPa) with electrical conductivity measurements until 50%IACS indicate a fine appliance for these composites utilizing powder metallurgy as a substitute of conventional metallurgy processing. The presence of chromium increases the hardness and seems contributes to the higher conductivity possibly through a precipitation mechanism [1]. The results of electrical conductivity measurements in Cu-Cr-Ag-Al_2O_3 composites of the samples are carry on Table 2.

Table 2: Electrical conductivity measurements of Cu-Cr-Ag-Al_2O_3 composites samples

Chemical Composition (wt %)	Electrical Conductivity (% IACS)
100%Cu	(96 ± 3)
Cu - 5%Al_2O_3	(43 ± 3)
Cu - 10%Al_2O_3	(39 ± 3)
Cu - 15%Al_2O_3	(37 ± 3)
Cu - 3%Cr - 7%Al_2O_3	(37 ± 3)
Cu - 5%Cr - 5%Al_2O_3	(40 ± 4)
Cu - 7%Cr - 3%Al_2O_3	(38 ± 3)
Cu - 5%Cr - 5%Ag - 5%Al_2O_3	(42 ± 4)
Cu - 5%Cr - 2%Ag - 3%Al_2O_3	(43 ± 4)
Cu - 5%Cr - 3%Ag - 2%Al_2O_3	(45 ± 4)

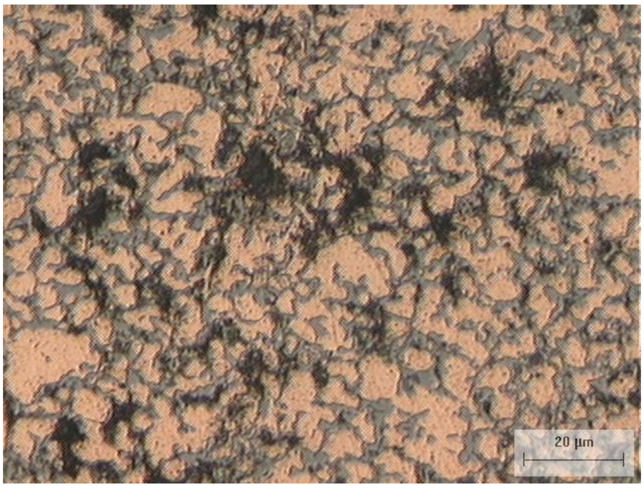

Fig. 6 Optical micrograph of the composite Cu-3%Cr-7%Al_2O_3 cold compact (50MPa) and sintered at 923 K for $2.16x10^4$ s. Good coalescence of copper grains. It is observed porosity, presence of second phases inside Cu grains and Al_2O_3 particles.

Conclusions

The applied powder metallurgy processing steps on the Cu-Cr-Ag-Al_2O_3 composites support a first-rate mechanical strength and electrical conductivity values that indicate a good quality application for these composites utilizing powder metallurgy instead conventional metallurgy processing.

Relating to mechanical measurements in these composites indicate adequate values, almost 600MPa, and the electrical conductivity stay in the range 35 to 45% IACS corresponding to 0,216 ≤ σ ≤ 0,309 ($\mu\Omega$cm)$^{-1}$. The good conductivity and hardness were obtained for the composition with copper and chromium. It can be confirmed that chromium increases the hardness and could contribute to the upper conductivity through a precipitation mechanism.

The study of dispersion reinforced materials emphasizes the importance of properties of the starting powders, magnitude of the starting structure, respectively, which, although suffer certain changes in further processing, basically remains preserved in the structure of the final product. Important facet of dispersion strengthening is the introduction of possible amount of dispersed particles into volume of base material.

The presence of Al_2O_3 could increase the corrosion resistance of the obtained cermets and could be related to the copper crystalline structure presents internal strengths and possibly crystallites with different cell parameters due to the effect of thermal and mechanical treatments in presence of some percentage of Al_2O_3.

Acknowledgements

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