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Microstructural and Electrical Investigation of Cu-Ni-Cr Alloys Obtained by Powder Metallurgy Method

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Abstract: The aim of this work, using the powder metallurgy process, is to synthesize metallic alloys with high mechanical strength and high electric conductivity, after melting optimizing and thermal treatments. The Cu-Ni-Cr (wt%) alloys are characterized in their mechanical and electrical properties as well as the obtained microstructure. Through the process of powder metallurgy, contacts and structural parts can be obtained. The alloys elements are added to copper with the intention to improve their strength, ductility and thermal stability, without causing considerable damages in their form, electrical and thermal conductivity, and corrosion resistance. The metallic powders were mixed for a suitable time and then they were pressed in a cold uniaxial pressing (1000 kPa). Afterwards, the specimens were sintered in temperatures varying from 700 up to 800^oC under vacuum. At last, the samples were homogenized at 550^oC under vacuum, for special times. The comparative analysis is based on the sintered density, densification parameter, hardness, macrostructures and microstructures of the samples. The alloys were characterized by optical microscopy, x rays powder diffraction, electrical conductivity and Vickers hardness.

Introduction

Products based on copper alloys such as porous material filters, electric friction equipments, contacts and structural parts can be manufactured through the process of powder metallurgy, which have the advantages of making fine grained homogenous structures, forming complicated shapes with close dimensional tolerances and the ability to produce parts with a superior surface finishing [1-13]. These advantages reduce or eliminate costly machining processes and allow less scrap loss, compared to other forming methods. The alloy elements are added to copper with purpose to improve its 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 [14-18]. It is well known that the mechanical resistance in metallic alloys depends on the size, type, form and regular distribution of precipitations, which is also fundamental to obtain an electrical conductivity similar to that of the copper matrix. To increase the strength, ductility and formability keeping good electric conductivity of these alloys, there have been used special thermal treatments, as well as variations in the chemical composition. In this work were synthesized Cu-Ni-Cr alloys with the aim of obtaining a steadily alloys production by powder metallurgy in laboratory scale and optimizing the electrical and mechanical properties.

Experimental

High purity powders of copper, nickel and chromium were mixed for a suitable time and then compacted under 1000 kPa in a cold uniaxial pressing. Afterwards, the specimens were sintered in temperatures varying from 700 up to 800°C in a high vacuum Carbolite furnace that had a hot zone of about 150mm under vacuum. At last, the samples were homogenized at 550°C under vacuum, for special times. For process control, metallography was used to check porosity, non-metallic inclusions and cross-contamination. The most important preparation conditions of the samples are presented in Table 1.

Table 1 – Sintering Parameters of Cu-Ni-Cr

Condition	Premixed		
Compaction pressure [kPa]	1000		
Chemical alloy composition [wt %]	Cu-0.5%Ni-0.5%Cr; Cu-1.0%Ni-0.5%Cr; Cu-1.0%Ni-1.0%Cr; Cu-1.5%Ni-0.5%Cr		
Sample dimensions [mm]	Cylinder diameter ϕ=10.2 e h=12.4		
Sample weight [g]	6.4		
Sintering temperature and conditions	Sintering temperature [°C]	Condition for premixed	Vacuum pressure [torr]
	650 - 800	Solid state sintering	10^{-4}
Sintering time [s]	$1.2x10^3$ to $5.4x10^3$		
Homogenization time [s]	21,600 to 172,800		

The sintered and homogenized samples were cold mounted for optical and hardness characterization. The compacts were grinding with 400, 600, 800, 1000 and 1200 SiC papers followed by fine wet wheel polishing with diamond paste. Vickers hardness of the polished specimens was measured on a HXD 1000TM (Pantec) hardness tester with a load of 100g. Acidic $FeCl_3$ was used as the etchant. The microstructures of selected etched samples were observed in an optical microscope. Special samples for electrical conductivity studies were measured using an Agilent

4338B milliohmmeter. X rays powder diffraction data were collected with a conventional Rigaku MultiFlex diffractometer with a fixed monocromator. The experimental conditions were: 40 kV, 20 mA, $10^o \leq 2\theta \leq 120^o$, $\Delta 2\theta = 0.02^o$, $\lambda_{CuK\alpha}$, divergence slit = 0.5^o, reception slit = 0.3 mm and step time 5 s.

Results and discussion

The results of mechanical and electrical characterization in dependence of treatment of the samples are resumed in Table 2.

Table 2 – Some mechanical and electrical properties of the copper-nickel-chromium alloys obtained by powder metallurgy

Alloys	Sintering		Homogenizing		Mechanical Resistance	Electrical Conductivity
Cu-Ni-Cr	T [°C]	t [s]	T [°C]	t [s]	[MPa]	[% IACS]
Cu-0.5%Ni-0.5%Cr	780	5,400	500	32,400	330	32
Cu-0.5%Ni-0.5%Cr	800	5,400	--	--	420	37
Cu-1.0%Ni-0.5%Cr	780	5,400	500	21,600	290	36
Cu-1.0%Ni-0.5%Cr	780	5,400	--	--	460	33
Cu-1.0%Ni-0.5%Cr	800	5,400	--	--	430	27
Cu-1.0%Ni-1.0%Cr	800	5,400	--	--	370	37
Cu-1.0%Ni-1.0%Cr	800	5,400	500	172,800	400	37
Cu-1.5%Ni-0.5%Cr	780	5,400	500	32,400	370	35

The powder diffraction pattern indicate that the used amount of dopants do not affect noteworthy the copper crystalline structure. The Bragg peaks present no special broadening, which indicates normal crystallite sizes approximately between 5 and 10 μm.

The resulted average mechanical strength of 400MPa and the electrical conductivity of 35%IACS for the Cu-1.0%Ni-1.0%Cr homogenized sample indicate a good application for this alloy using powder instead conventional metallurgy. Further thermal treatments shall be applied to continue the study of these alloys and to obtain the best conditions for electrical and mechanical applications using powder metallurgy processing.

Optical micrographs of some of the samples are presented in Figures 1 to 3 to show their microstructural aspects. Fine grained presences but with inadequate porosity and second phases indicate that further treatments will be necessary to overcome this situation and also investigations with scanning and transmission electron microscopy to identify the presence of second phase on these alloys.

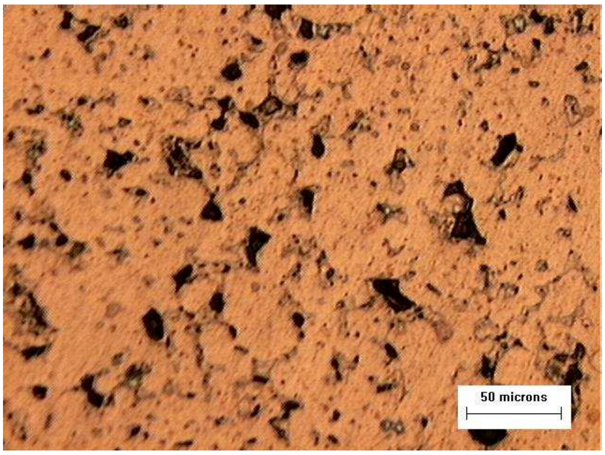

Figure 1 - Optical micrograph of the alloy Cu-0.5%Ni-0.5%Cr, cold compact (1000kPa) and sintered at 780^{o}C for 5,400 s and also homogenized at 500^{o}C for 32,400s.

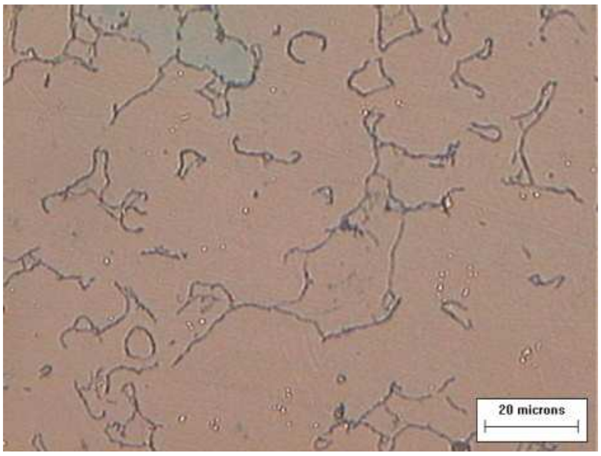

Fig.2 - Optical micrograph of the alloy Cu-1.0%Ni-0.5%Cr, cold compact (1000kPa) and sintered at 780^{o}C for 5,400 s and also homogenized at 500^{o}C for 21,600s.

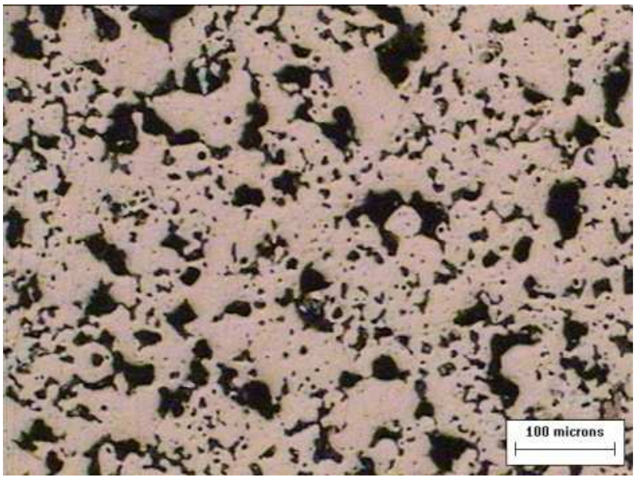

Fig.3 - Optical micrograph of the alloy Cu-1.0%Ni-0.5%Cr, cold compact (1000kPa) and sintered at 780^{o}C for 5,400s and also homogenized at 500^{o}C for 21,600s.

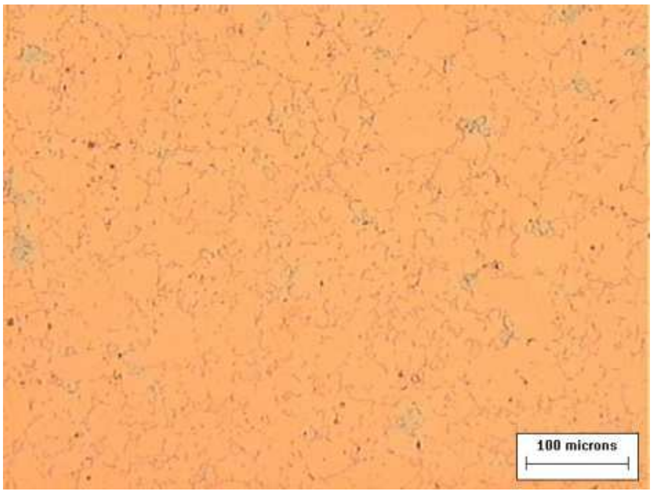

Fig.4 - Optical micrograph of the alloy Cu-1.0%Ni-0.5%Cr, cold compact (1000kPa) and sintered at 800°C for 5,400s and also homogenized at 500^{o}C for 172,800s.

Conclusions

The conventional powder metallurgy processing steps on the copper-nickel-chromium alloys resulted in first-rate mechanical strength (400MPa) and electrical conductivity (35%IACS) values that indicate a good quality employment for these alloys using powder metallurgy instead conventional metallurgy processing. The possibility to look for and construct fine grained homogenous structures, the ability to produce parts with a superior surface finish and the ability to form complex shapes with close dimensional tolerances induces this metallurgical application.

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References

[1] J. Crane and J. Winter: *Copper: Properties and alloying* (Encyclopedia of Materials Science and Engineering, vol 2, Ed. MB Bewer, Pergamon Press and the MIT Press 1986), p. 848.

[2] P. W. Taubenblat: *Copper Selection of high conductivity alloys* (Encyclopedia of Materials Science and Engineering, vol 2, Ed. MB Bewer, Pergamon Press and the MIT Press 1986), p. 863.

[3] ASM Specialty Handbook: Copper and Copper Alloys, Metal, chapter 1, section 1, ASM International, 2001.

[4] C. R. Brooks: Heat Treatment, Structure and Properties of Nonferrous Alloys. ASM, Metals Park, 1988, chapter 8.

[5] A. Butts: *Copper, the Science and Technology of the Metal, its Alloys and Compounds* (ed. Reinhold Publishing Corporation, New York, 1954, 3th printing 1960).

[6] G. Gosh, J. Kiyake and M. E. Fine: JOM, March (1997), p. 56.

[7] A. Rotem, D. Shechtman, and A. Rosen: Metall. Trans. A . Vol. 19A (1988), p. 2279.

[8] D. Steiner, R. Beddoe, V. Gerold, G. Kostorz and R. Schmelczer: Scripta Metall. vol. 17 (1983), p. 733.

[9] A. Guha, ,” Development of a high-strength, high-conductivity Cu-Ni-Be Alloy, high conductivity Copper and Aluminum Alloys, eds. E. Ling and P. Taubenblat W., TMS – AIME Publ. 1984, p. 133-145.

[10] Y. Sakai, K. Inoue, and H. Maeda, Acta Metall. Mater. 43 (1995), p. 1517.

[11] W. A. Monteiro, Proceedings of IX CBECIMAT, Águas de São Pedro /SP, dez.90, p. 546-549.

[12] W. A. Monteiro, M. A. G. Silveira e O. Júlio Jr, Metalurgia & Materiais, v. 51, may 95, p. 440-444.

[13] W. A. Monteiro, F. Cosandey and P. Bandaru, The Effect Of Thermomechanical Treatment On The Microstructure Of A Cu-Ni-Be Alloy, Proceedings of THERMEC’97, Wollongong, Australia, July 1997.

[14] Stadtler W. A., Production of Metallurgy Parts ASTM, Powder Metallurgy, Ohio, p.449-463, 1989.

[15] Ghadiri M., Farhadpour, F.A., Clift R., Seville, J. P. K. Particle characterization size and morphology, The Institute of Metals Series on Powder Metallurgy - An Overview. London, p.56-75, 1991.

[16] Powder metallurgy - An overview. 1. Ed. The Institute of Metals Series on Powder Metallurgy, London, Great Britain, 1991.

[17] Kaysser W. A. Solid State Sintering. The Institute of Metals Series on Powder Metallurgy - an overview. London, p45-53, 1991.

[18] Thümmler F. & R. Oberacker, Introduction to Powder Metallurgy, The Institute of Materials, 1993, ISBN 0-901716-26-X)

[19] J. A. G. Carrió, W. A. Monteiro, V. A. Rodrigues, M. C. Terence, T. J. Masson, L. F. de Miranda, Structural analysis of influence of dopants in the electrical conductivity of CuNi alloys, European Powder Diffraction Conference – EPDIC 11, 19-22 September 2008, Warsaw, Poland.