This paper presents the research results of copper Covetic metallurgical synthesis along with the characterization of cast material and the processing of casts into wires. The Cu-C composite production method was based on patent applications of Third Millennium Metals. Obtained materials were tested for their chemical composition (including Secondary Ion Mass Spectrometry (SIMS) analysis for carbon presence), mechanical properties and electrical conductivity. Measurements were also performed for wires which were first cut from obtained casts and next cold drawn into final wire form. Produced wires were tested for their mechanical and electrical properties. Electrical conductivity of wires was measured with the use of high precision Thompson’s–Kelvin’s bridge type device. A key objective of the research was to determine if Covetic copper has higher electrical conductivity than pure oxygen free copper.

Keywords: Covetic, copper, carbon, graphene, Cu-C
temper and cold drawn wire form. Research was carried out for electrical and mechanical properties to investigate if the properties of this new kind of material are there are better than the standard properties of copper.

Fig. 1. Idea of copper Covetic material nanoscale structure

2. Copper carbon synthesis and processing method

Copper carbon synthesis was conducted with the use of special laboratory induction furnace equipped with the graphite crucible, mixing device and current electrodes. Addition of carbon was realized with the use of a feeding device that allowed carbon to be added slowly and directly into the molten metal surface, close to the electrical current flow zone. The process was carried out under argon gas protection to prevent copper from oxidizing and to ensure that the carbon would not be combusted in the air.

Cu-C metallurgical synthesis was carried out with the use of Cu-OFC base material and three different types of carbon powder as shown in the Table 1. Table 2 shows basic process conditions for produced casts W10, W15 and W16.

![Graphene structure](image)

After solidification copper-carbon composites were extracted from crucibles and tested for chemical composition and basic mechanical and electrical properties. In the next stage, 20 mm diameter rods were machined out of the casts and drawn into wires. While drawing, all samples were tested for their general formability and surface quality. Obtained wires were next tested for their electrical and basic mechanical properties in two different tempers – hard temper and annealed temper.

3. Chemical composition of casts

Chemical composition, tested for all obtained casts, is shown in the Table 3. Measurements were carried out using Solid-State Infrared (IR) Leco TC500 analyzer for oxygen content and Optical Emission Spectroscopy (OES) for remaining elements content.

The analysis shown that all casts have iron and sulfur impurities at the level of 10 – 40 ppm of Fe and 1 – 15 ppm of S. These impurities come directly from the carbon powders. Oxygen content is in all cases lower than 3 ppm. Most popular analytical methods do not allow the measurement of carbon presence or content. For carbon presence Secondary Ion Mass Spectrometry (SIMS) method was used – Fig. 2. This method reveals the presence and distribution of carbon in analyzed cube samples. The lighter color in the cube, the higher level
of carbon presence in the sample. Analysis shown that a sample cut from cast W10 has a large amount of carbon which is evenly distributed in the sample volume. In the samples W15 and W16, the presence of carbon is much lower and localized close to the surface area.

4. Basic mechanical and electrical properties of casts

Table 4 shows density, hardness and basic electrical properties of produced casts. All samples have density at the level of 8.91 – 8.92 g/cm³ which is slightly lower than pure copper density. Hardness for the sample W10 which is 58HV5 is about 20% lower than for casts W15 and W16. Electrical conductivity is between 98,28 – 100,17% IACS which is surprisingly high taking into account that those samples have significant amount of impurities like iron and sulfur. Electrical conductivity of standard copper cast with the same level of impurities is usually from 1 to 2 MS/m lower.

5. Basic mechanical and electrical properties of wires

Cold drawing of Covetic wires shown that produced composites have good formability and do not delaminate during drawing process. Obtained wires were tested in hard temper ($\lambda = 15.2$ and $\lambda = 60.7$) and in annealed ($550^\circ$C/1h) temper. Tensile strength, yield strength and elongation of samples were measured along with electrical conductivity and shown in the Table 5. Electrical conductivity measurements were performed using Buster High-Precision Automatic Inspection and Test Unit for Electrical Resistance Testing RESISTOMAT®. All samples have electrical conductivity within the range of 96.07 to 98.66%IACS in hard temper and 98.02 to 100.68%IACS in annealed temper.

6. Conclusions

In this paper research results concerning production, characterization and processing of copper Covetic materials are presented. Measurements of mechanical properties shows that the obtained wires have tensile strength, yield strength and elongation in tested tempers that is not higher than pure copper material. Formability of synthesized composites is very good. Excellent material draw ability with level about four true total strain without breaks during laboratory rod cold rolling and cold drawing tests were reported.

The research conducted shows that the produced materials in as-cast and wire form do not have electrical conductivity at more than standard level. However, the obtained electrical conductivity parameters are relatively high and are therefore unusual and interesting taking into account that samples have significant amounts of impurities (mainly sulfur and iron) which came directly from used activated carbon. This suggests that it may be possible to obtain copper carbon composites with higher than pure copper electrical conductivity if Fe and S impurities are eliminated during the synthesis process. To test this hypothesis, authors are planning a next set of experiments with the higher purity activated carbon materials and possibly in a vacuum furnace.
Acknowledgements

The authors would like to express their gratitude for the financial support provided by International Copper Association, Ltd. for this study, and to Third Millennium Metals, LLC for their advisory role in this project.

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Received: 20 December 2013.