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COPPER MATRIX COMPOSITES REINFORCED WITH VOLCANIC TUFF

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This paper presents a manufacturing method, properties and possible use of copper matrix composites reinforced with particles of volcanic tuff. The composites were obtained by powder metallurgy and reinforced with Filipowice tuff mined near Cracow, Poland. The influence of tuff particles content on the properties of the copper matrix composites such as conductivity, durability and microstructure was assessed. Tuff was introduced into a copper matrix in an amount of 5, 15 and 30 % by volume. The composites were used to prepare the nozzle tips of resistance welding electrodes, and initial tests were performed of the behavior and stability of the materials during the welding process of steel sheet.

Key words: copper composite, powder metallurgy, tuff

INTRODUCTION

The past few years have witnessed a rapid development of composite materials that offer quite unexpected possibilities to shape the product properties. By combining two engineering materials into one monolithic whole, properties different from the specific properties of each of the constituents are obtained [1].

Metal matrix composites reinforced with particles, fibres, or flakes form a wide group of composite materials. In this field, particular interest enjoy copper alloys reinforced with ceramic particulate materials, mainly due to their ability to maintain high electrical and thermal conductivity and mechanical strength, superior to that of pure metal.

Owing to these specific properties, quite promising opportunities and perspectives open for their potential use in various sectors of industry such as aerospace, automotive, military equipment, electronics and nuclear. Copper-based particulate-reinforced composites are particularly suitable for switches operating in low-voltage installations, for tips of the resistance welding electrodes, for parts of electrical machinery operating at elevated temperatures, and for structural components of nuclear reactors [2-4].

Tuff particles are characterised by high porosity and irregular shape which has a major impact on the way in which these particles get combined with the metallic matrix of the composite. Copper-based composites containing volcanic tuff can be an alternative to the traditional materials used in the manufacture of electrodes for resistance welding – an alternative and much more.

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TEST MATERIALS

The tuff from Filipowice includes porphyry tuff and tuffite occurring between Karniowice and Filipowice and in Myślachowice in Poland. It has a structure of porphyry with phenocrysts of feldspar. The colour of Filipowice tuff is red-pinkish sometimes with white patches of secondary calcite or green streaks of chlorite. Tuff and tuffite are products of the Rotliegend (about 290 million years old) [5].

The tuff from Filipowice is based on sanidine as a main component, but also contains minerals such as kaolinite, biotite, illite and quartz. The grains of biotite are present in a size of up to 8 mm; other components have different sizes, ranging from a few millimetres up to 5 cm [6].

The tuff used in the present investigations was first subjected to mechanical and thermal treatment, which consisted in grinding the rock to powder with an average grain size of about 40 μm and annealing it at 850 °C for 4 hours.

Studies were conducted on electrolytic copper powder produced by EUROMET Production and Trading Enterprise in Trzebinia.

RESEARCH METHODOLOGY

All samples were made by uniaxial hydraulic pressing under a pressure of 200 MPa. To reduce the coefficient of friction between the powder particles and the die walls, the die walls were lubricated with zinc stearate. Samples had a cylindrical shape with Ø 20 x 5 mm dimensions, and were used for the determination of hardness, for structure examinations and measurements of the softening point and electrical conductivity.

From the copper composites with 5 % tuff nozzle tips of resistance welding electrodes were prepared (Figure 1). Trial welds were made followed by a series of several hundred welds deposited with a typical spot welder of 12 kVA capacity.

The sintering process was carried out in a laboratory tube furnace at 900 °C under a nitrogen atmosphere. The time of isothermal sintering of samples was 60 minutes. After sintering, the samples were cooled together with furnace. Slow heating at a rate of 10 °C/min to the temperature of isothermal sintering was applied.

From the tuff and copper powder, by mixing in a Turbula rotary mixer, blends were prepared containing 5, 15 and 30 vol % of tuff. Similar mixes were also prepared without the use of Turbula mixer. In the latter case, the powders were intensively stirred manually in containers with balls, checking under a stereoscopic microscope the homogeneity of the mixes. Structure of the sintered products was examined under a JSM - 5510LV scanning electron microscope made by Jeol Company.

Figure 1 The nozzle tips of resistance welding electrodes.

RESULTS

In the first stage of the study, mixing of copper powder with tuff particles was carried out in a Turbula type mixer. To obtain a fully homogeneous mixture, steel balls were introduced into containers. The time of mixing was 96 hours. A very good bond was obtained between the tuff and copper particles. Mixtures were homogeneous and tuff particles were significantly reduced in size. The tuff powder fully coated the surface of copper particles, and fine ceramic particles were observed to penetrate into the soft surface of the copper powder. Figure 2 below shows the distribution of Si and Al elements present in the tuff on the surface of copper particles. A uniform coating of copper with tuff is well visible.

After mixing of powders and compaction, the next step covered the sintering process carried out at 900 °C for a period of 1 hour. These trials failed due to the presence of very tight ceramic coating produced on the copper powder particles. Samples could not be sintered because of the ceramic coating acting as an insulation on the surface of copper particles.

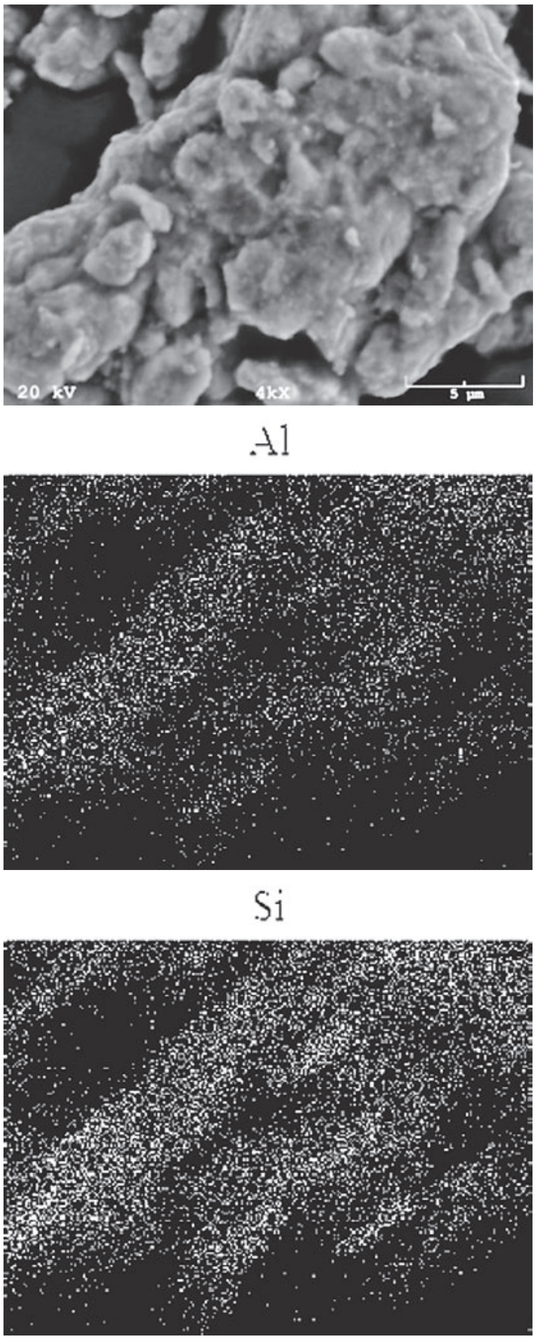

Figure 2 Distribution of elements present in the tuff on the surface of copper particles (5 % tuff).

Figure 3 shows fracture of copper sinter with 30 % addition of volcanic tuff. The lack of bond between copper particles is well visible in these pictures. Due to the ceramic coating produced on copper particles (oxides present in the tuff), the sintering process was not running correctly.

In the next stage of the research, sinters were made from mixes prepared without the use of Turbula mixer. In this case, the particles of volcanic tuff were not reduced to a form so fine and coating on the particles of copper was not so tight. The sintering process was successful.

Figure 4 shows fractures of sinters made from the powder mix without the use of Turbula mixer. A strong bond between copper particles is visible.

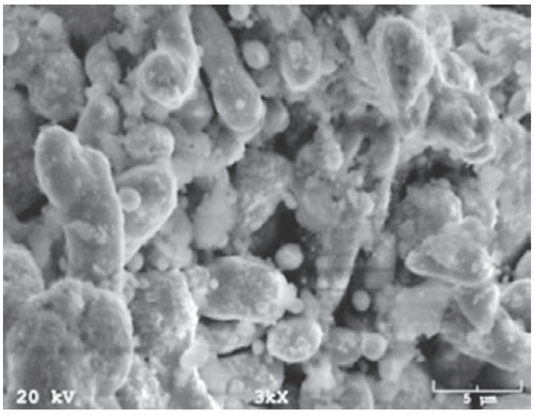

Figure 3 Copper sinter with 30 % tuff addition fractography - mixing in a Turbula.

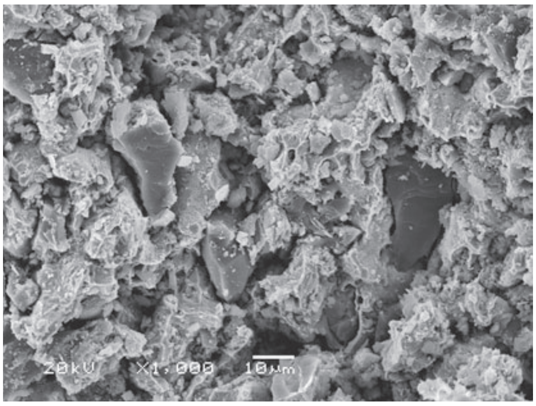

Figure 4 Copper sinter with 30 % tuff addition fractography – mixing without of Turbula.

The durability of electrodes made from the tuff-containing composite was evaluated according to PN-EN ISO 8166. The preliminary studies showed that the consumption of composite electrodes was not deviating from that observed in the commonly used Cu-Cr-Zr electrodes. With several hundred welds deposited, only slight deformation was observed on the working surface of the electrodes, which had no major effect on the joint quality. These results suggest that copper matrix composites containing tuff will offer perfect performance when used for parts of the welding electrodes.

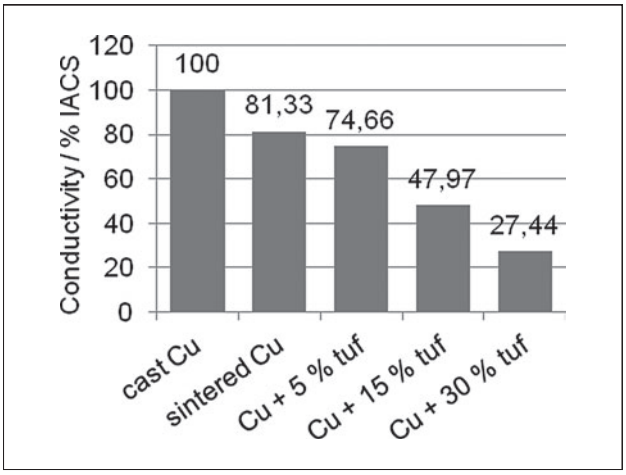

Figure 5 The results of conductivity tests.

The results of conductivity tests are shown in Figure 5. Due to the presence of pores, the electrical conductivity of pure copper sinter was lower by about 20 % compared with the solid copper. The addition of tuff in an amount of 5 % slightly reduced the conductivity compared to pure copper sinter, but the requirements of ISO 5182 (materials for resistance welding electrodes) were still satisfied.

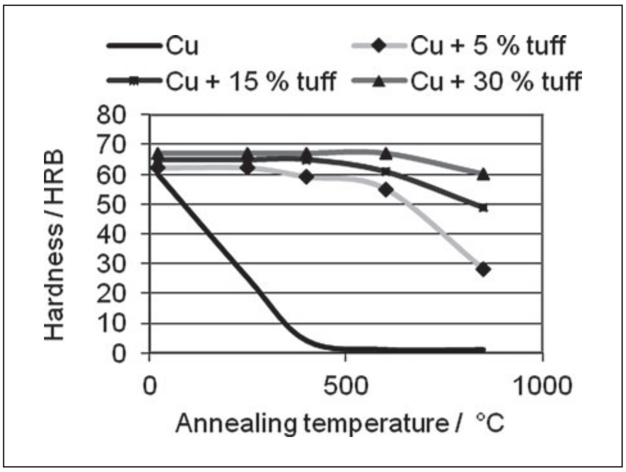

Figure 6 The results of hardness tests were performed after exposure to elevated temperatures.

For copper matrix composites made with different additions of volcanic tuff, hardness tests were performed after exposure to elevated temperatures. The results are presented in Figure 6. The composite materials containing volcanic tuff retain their strength at a temperature above 600 °C, while copper without the addition of tuff loses its mechanical properties at a much lower temperature.

CONCLUSION

As demonstrated by the studies, volcanic tuff is an interesting material for copper matrix composites. It obviously improves the softening point of composites while maintaining adequate conductivity meeting the standard requirements for resistance welding electrodes. Composite materials of this type can be successfully used for tips of the electrodes operating in resistance welders. The use of these materials will confer to the electrodes higher wear resistance and the production process due to the availability of tuff and its low cost will not be expensive or complicated. Of course, in the production process, some problems may naturally occur when copper powder is mixed with tuff. Composites of this type can be successfully produced by the technology of powder metallurgy, though attention should be paid to certain factors that may affect the sintering process when conducted on copper with volcanic tuff. Treatments to obtain very fine tuff particles should be carried out before these particles are mixed with the particles of copper. The use of Turbula mixer and steel balls for the tuff fragmentation to obtain a homogeneous mixture will produce a tight coating on the surface of copper particles formed by oxides present in the tuff. This is a serious obstacle in proper running of the sintering process.

Composites made by the technique described in this study are characterised by high softening point, long life and electrical conductivity corresponding to the commercial copper alloys used for resistance welding electrodes.

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Note: The responsible translator for English language is K. Bany, Cracow, Poland