PROPERTIES OF SINTERED Cu/SiC COMPOSITES

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Abstract

The paper presents the results of research on the preparation of composites based on copper matrix reinforced with silicon carbide (SiC) contents of 0, 5, 10 and 15 wt%. Materials were compacted by one-sided pressing, followed by sintering at a temperature of 800 °C for one hour. One-sided pressing was used, with pre-set pressure of 60 kN and the rate of 200 N/s. The examinations of the composites included macroscopic and microscopic examinations (LM, SEM), XRD measurements, determination of density, hardness measurements, and a compression test. Microscopic examinations were performed using light microscopy (LM, 2D and 3D images), and scanning electron microscopy (SEM). XRD measurements were aimed to evaluate phase composition. The composites were measured using a Seifert 3003T/T X-ray diffractometer with radiation generated by a tube with a cobalt anode(λ_{Co}= 0.17902 nm). X-ray examinations were performed, with the measurements based on the symmetric Bragg-Brentano geometry. The computer software and the DHN PDS crystallographic database were used for phase identification. Hardness measurements were made using the Brinell method. The test results showed that the optimal content of silicon carbide in Cu / SiC composites is 10 %.

Keywords: Cu/SiC sinters, light microscopy, XRD, mechanical properties

1. INTRODUCTION

With continuous advances in technology, the need arises for developing new materials with improved properties compared to conventional solutions. With requirements of the automotive, aerospace, shipbuilding and energy industries, researchers have to face new challenges, with their efforts directed towards the development of composite materials, commonly known as composites [1-6]. Currently, many research centers focus not only on the examinations of very expensive composites using, for example, carbon nanotubes [7], graphene, etc., but also those that can be made from much cheaper components, e.g. basic metal powders (Cu, Fe, Al and SiC ceramics, Al_2O_3, ZrO_2) [8-17].

Metal-based composites can be produced both using conventional casting methods and powder metallurgy. Nowadays, powder metallurgy offers many technologies to obtain materials, from the simplest and cheapest solutions consisting in uniaxial pressing and sintering to the more advanced and complex HIP or SPS methods [18-20].

Composites based on copper obtained by means of powder metallurgy can offer an interesting alternative to its conventional alloys.. Due to the low hardness or abrasion resistance of pure copper, these properties can be attempted by modifying the proportion of the reinforcing phase, e.g. ceramic particles. This combination should allow the partial retention of typical metal properties, such as plasticity or thermal conductivity, and the increase in properties such as hardness or abrasion resistance.

2. MATERIAL AND METHODS

The first stage of the study was the preparation of an appropriate amount of copper powder and silicon carbide powders to obtain compacts of varying mass composition (0, 5, 10 and 15 wt% SiC content). The size of the

powders was presented in paper [21]. The blend of copper and SiC powder was compacted. One-sided pressing was used, at pre-set pressure of 60 kN and the rate of 200 N s^{-1}. Specimens were pressed using a ZwickRoell Z100 testing machine. The next stage consisted in sintering of the compacts at 800 °C for 1 hour. The design of one-sided moulding was presented in paper [21].
Thorough examinations of the composites comprised:

- microscopic examinations performed using light microscopy (LM, 2D and 3D images), and scanning electron microscopy (SEM).
- XRD measurements aimed to evaluate phase composition; the composites were measured using a Seifert 3003T/T X-ray diffractometer with radiation generated by a tube with a cobalt anode(λCo= 0.17902 nm). X-ray examinations were performed, with the measurements based on the symmetric Bragg-Brentano geometry. The computer software and the DHN PDS crystallographic database were used for phase identification.
- the density of the composites was determined using a hydrostatic scales (at ambient temperature, with distilled water used as a reference liquid)
- hardness measurements were made using the Brinell method with a ball with a diameter of 2.5 mm and a load of 153.2N in accordance with current standards
- static compression test (The static compression test was carried out on a ZwickRoell Z100 testing machine with a compression rate of 100 N·s^{-1})

3. RESULTS AND DISCUSSION

The results of density tests showed that the density of the sinters was decreasing with the increasing content of silicon carbide (**Table 1**). This can be attributed to e.g. uneven distribution of porosity in the sinter. Sintering process led to a decrease in the pore volume in the material. Large pores disappeared while a higher number of finer pores were formed, which was the most noticeable in the case of the copper powder. Detailed results of structural tests for these sinters were presented in the paper [21]. Furthermore, studies have shown that a smaller amount of porosity was observed at the side of the upper stamp, mostly in the copper matrix. However, the opposite effect was observed near silicon carbide. The pores were changing into gaps at the interface between the copper matrix and SiC particles. This was most evident in the case of the addition of 15 % of silicon carbide [21]. Furthermore, density and quantity of individual powders has also an effect on density of the composites.

Brinell hardness was measured at the area of the side of the upper and lower stamps used in the moulding process. The results showed an increase in hardness of the sinters, with an increase in the SiC content to 10 wt% (**Table 1**). The addition of silicon carbide to 15 wt% caused a slight decrease in hardness. Furthermore, slightly higher values of hardness were observed from the upper stamp side. The X-ray diffractograms obtained for the compacts and sinters confirmed the presence of inhomogeneities in the structure, as evidenced by the varying intensity of the peaks coming from these phases (**Figure 1**).

Table 1 Density and hardness of sinters

Mass composition	Density (g/cm^3)	HB (Sinter from upper stamp)	HB (Sinter from bottom stamp)
100 % Cu	6.966	21.1	18.4
95 wt% Cu / 5 wt% SiC	6.764	26.9	22.4
90 wt% Cu / 10 wt% SiC	6.289	39.9	38.1
85 wt% Cu / 15 wt% SiC	5.782	38.2	36.4

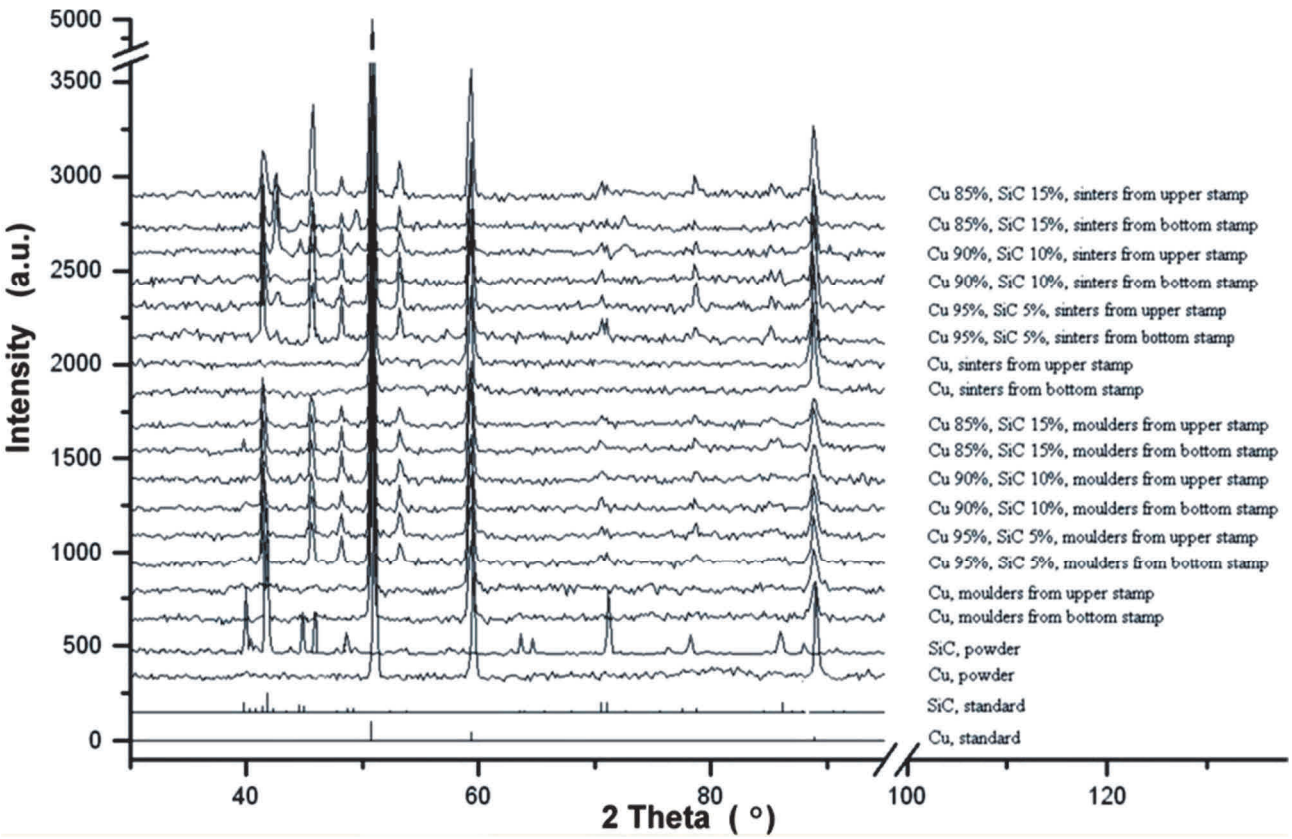

Figure 1 X-ray diffractions of researched materials

Due to the high plasticity of the pure copper specimens, a static compression test was carried out by loading the specimens with a pressure of 560MPa, followed by macroscopic and microscopic observation of their external surfaces (**Figure 2 and 3**). The results of macroscopic (LM) and microscopic examinations (SEM) after the compression test showed that the addition of 10 % SiC is an optimal choice, which was confirmed by previous results published in the study [21]. No microcracks were observed after the compression test, both in the case of pure copper and copper with an addition of 5 and 10 wt% silicon carbide. Furthermore, the addition of SiC in the amount of 15 wt% led to the appearance of a significant number of microcracks, which were visible on the outer layer of the specimen. In some places, the cracks were so large that they caused local chipping of up to 400 μm. However, no microcracks were observed in the core material. In the paper [15], researchers documented similar findings. These authors examined the effect of the content and size of SiC used for the frictions materials based on the Cu-Fe matrix obtained using powder metallurgy. The strengthening effect of nano-silicon carbide was greater than that of micro silicon carbide. The friction coefficients of friction materials increased with the increasing nano-SiC content. However, the wear rate decreased with the increasing nano-SiC content and then increased when the content of nano-SiC particle exceeded 10 wt%. The specimen containing 10 % of nano-SiC had the best tribological properties in different testing conditions [15].

Microscopic 2D and 3D observations of upper surfaces (**Figure 4**) were confirmed by macroscopic (LM) and microscopic observations using scanning electron microscope (SEM). No microcracks were found inside the specimens (**Figure 4**), but cracks were observed at the lateral surface in the specimen containing 85 wt% Cu and 15 wt% SiC (**Figure 3**).

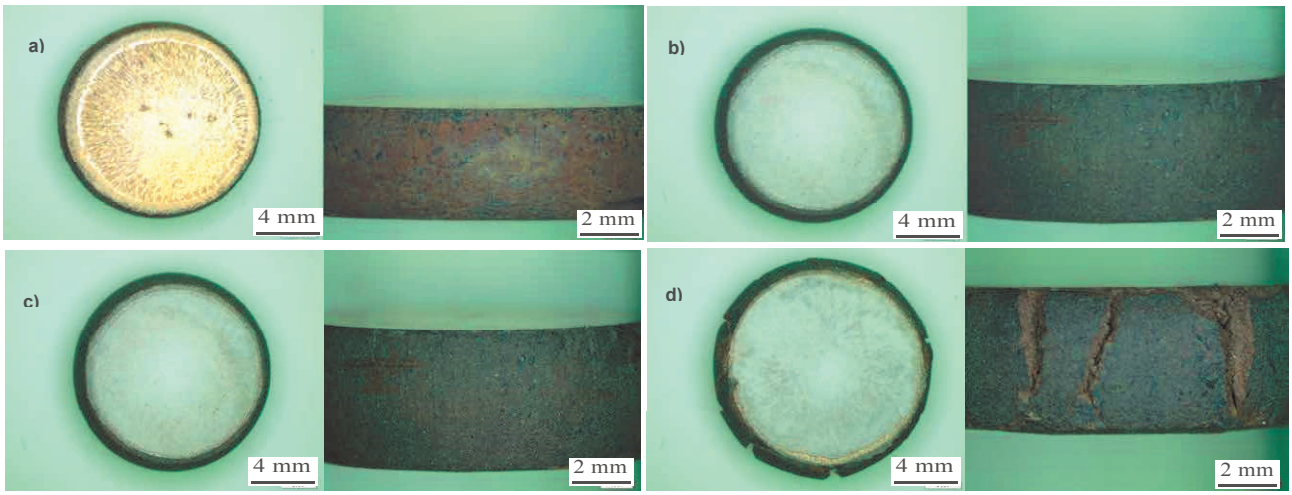

Figure 2 Macro images after compression test view from above and side view: a)100 % Cu, b) 95 wt% Cu / 5 wt% SiC, c) 90 wt% Cu / 10 wt% SiC, d) 85 wt% Cu / 15 wt% SiC

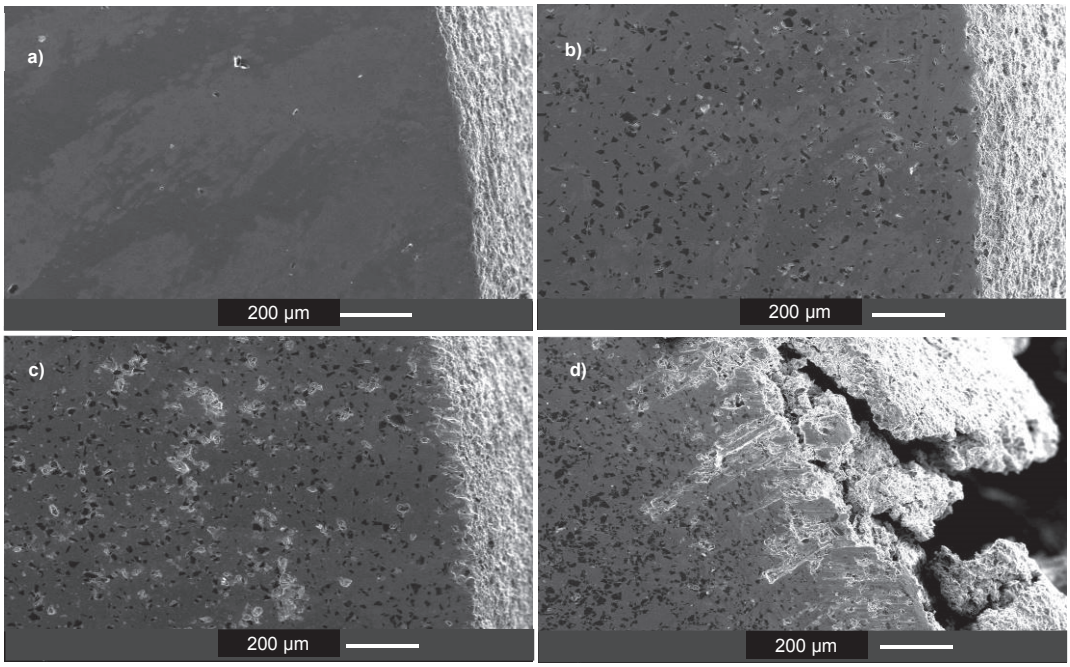

Figure 3 SEM images after compression test, top view: a)100 % Cu, b) 95 wt% Cu / 5 wt% SiC, c) 90 wt% Cu / 10 wt% SiC, d) 85 wt% Cu / 15 wt% SiC

4. CONCLUSION

Based on the study carried out, it was found that:

- with the increase of silicon carbide reinforcement phase, the density of sinters obtained decreased,
- an increase in hardness was found along with an increase in the SiC content to 10 wt%, a higher addition of this phase causes a reduction in hardness, which is caused by a rapid increase in porosity around SiC particles,
- the compression test carried out confirmed that the optimum SiC content is 10 wt%, higher contents cause cracking and crushing of the sintered product under the effect of compressive stresses.

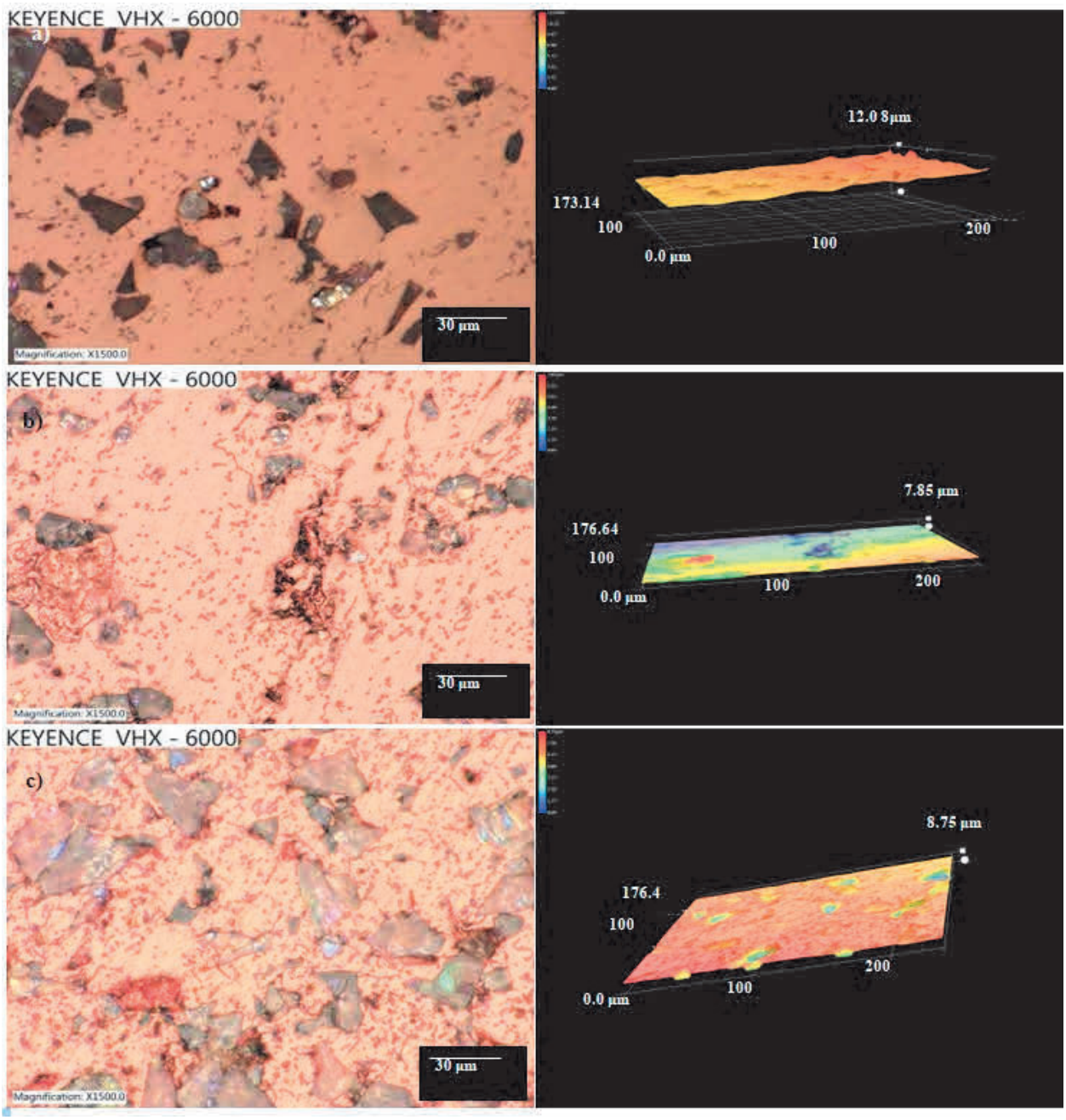

Figure 4 Example of microscopic images after compression test, top view 2d and 3d: a) 95 wt% Cu / 5 wt% SiC, b) 90 wt% Cu / 10 wt% SiC, c) 85 wt% Cu / 15 wt% SiC

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