Effect of $SiC_{p(Cu)}$ addition on the property of the $SiC_{p(Cu)}$/Cu composites

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Abstract. The continuous copper film on the ß-SiC powder was obtained by magnetron sputtering technology. $SiC_{p(Cu)}$/Cu composites was fabricated by hot-press sintering method. The phase constitution, fracture morphology, relative density, porosity, Vickers hardness of $SiC_{p(Cu)}$/Cu composites with different $SiC_{p(Cu)}$ addition were analyzed. The results showed that $SiC_{p(Cu)}$ with higher fraction in the $SiC_{p(Cu)}$/Cu composites decreased relative density and increase porosity, then it also improved Vickers hardness.

1. Introduction

In recently, SiC had became an important candidate material for high temperature applications due to more superior performance such as high specific strength, modulus, et al. SiC was chosen as the reinforcement of metal matrix composites [1, 2]. Recently, surface modify technologies were developed to improve interface performance, for example, electroless plating, magnetron sputtering, and so on [3, 4]. At present, magnetron sputter method was wider investigated as surface modification route. Magnetron sputter technology was investigated to form thin coating and/or films on the different materials. SiC_p/Cu composites had attracted much attention in thermal management application and wear resistance application [5, 6]. The main techniques to prepare SiC_p/Cu composites were hot pressing and liquid metal infiltration. In the present investigation, we put focus on the preparation of SiC_p with copper coating by magnetron sputtering method. Other target was aimed to fabricate $SiC_{p(Cu)}$/Cu composites by hot-press sintering method and analyze effect of $SiC_{p(Cu)}$ fraction on the thermal physical properties. The phase constitution, fracture morphology, relative density, porosity and Vickers hardness of $SiC_{p(Cu)}$/Cu composites with different $SiC_{p(Cu)}$ addition were observed and analyzed.

2. Material Fabrication and Characterization

The self-made magnetron sputtering equipment was executed to prepare copper films on the SiC_p surface. The circular pure was chosen as target material and was put on the holder with cooling circulating water device. β-SiC powders (PHI=75μm) was set into sample container and target distance was 170mm. The vacuum pressure was suction filtration to 10^{-3}Pa. Argon gas was introduced into reaction equipment with flow 20sccm and puttering pressure was about 1.0Pa. Magnetron sputtering parameters were designed by orthogonal experimental method. The optimum magnetron sputtering parameters were determined as follows. Sputtering time was 60min, sputtering power was 370W and substrate temperature was 270°C. SiC_p with copper film under above optimum magnetron sputtering parameters was defined as $SiC_{p(Cu)}$ sputtered powders. Then sputtered powders and pure Cu powders were mixed by ball-milling method. The volume ratio of sputtered powders to mixed powders was adjusted as 10%~50%. Ball milling parameter was 120r/m for 8h. Prior to sinter process, mixture powders was cold pressed into a cylindrical compact in a metal die of 30mm in diameter with pressure of 30MPa. $SiC_{p(Cu)}$/Cu composites were sintered at 750°C for 60min in multi-functional hot-press sintering furnace with argon gas protection and heating rate was about 20°C/min. Phase composition of $SiC_{p(Cu)}$/Cu composites were identified by X-ray diffraction. Scanning speed was 4°/min and step length was 0.02°. To determine hardness of $SiC_{p(Cu)}$/Cu composites, Vickers indentor was applied with a load of 196N for 15s using hardness testing machine.

3. Result and Discussion

Phase constitutions of $SiC_{p(Cu)}$/Cu composites with different $SiC_{p(Cu)}$ fraction were given in Fig.1. The main phase for initial copper was tested in Fig.1 a). It was seen from Fig.1 b) ~ f) that there was no other component except Cu and SiC in the $SiC_{p(Cu)}$/Cu Composites. SiC peaks became clear with increasing $SiC_{p(Cu)}$ fraction. No oxide peak was observed in the $SiC_{p(Cu)}$/Cu composites sintered at 750℃for 1h. There was not any formation of copper oxide and silicon dioxide. For engineer application view of electrical conductivity materials, $SiC_{p(Cu)}$/Cu composites without other oxide phase improved electrical conductivity performance.

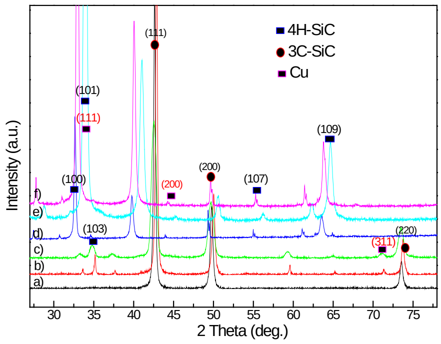

Fig.1 XRD of $SiC_{p(Cu)}$/Cu composites. a), b), c), d), e) and f) were presented $SiC_{p(Cu)}$ fraction with 0, 10%, 20%, 30%, 40% and 50%.

Fracture surface of $SiC_{p(Cu)}$/Cu composites were shown in Fig.2. When $SiC_{p(Cu)}$ was lower than 20vol.%, ductile rupture at copper matrix was mainly fracture mechanism. While $SiC_{p(Cu)}$ was higher than 30 vol.%, ductile rupture at copper matrix and debonding of SiC_p/Cu interface were mainly fracture behaviors. Especially, more $SiC_{p(Cu)}$ particles can be found as $SiC_{p(Cu)}$ was higher than 30vol.%. Pulling out of SiC_p and big dimples can be clearly seen on the fracture surface. $SiC_{p(Cu)}$/Cu composites exhibited brittle fracture mechanism. Some SiC particles gathered with pores were observed. Other SiC particles were bonded with Cu matrix. Interfacial bond was weak in near pore region. Weaker bonding strength of SiC_p/Cu was the primary factor, which was responsible for low flexural strength. Severe ductile deformation in the Cu matrix was main fracture mechanism.

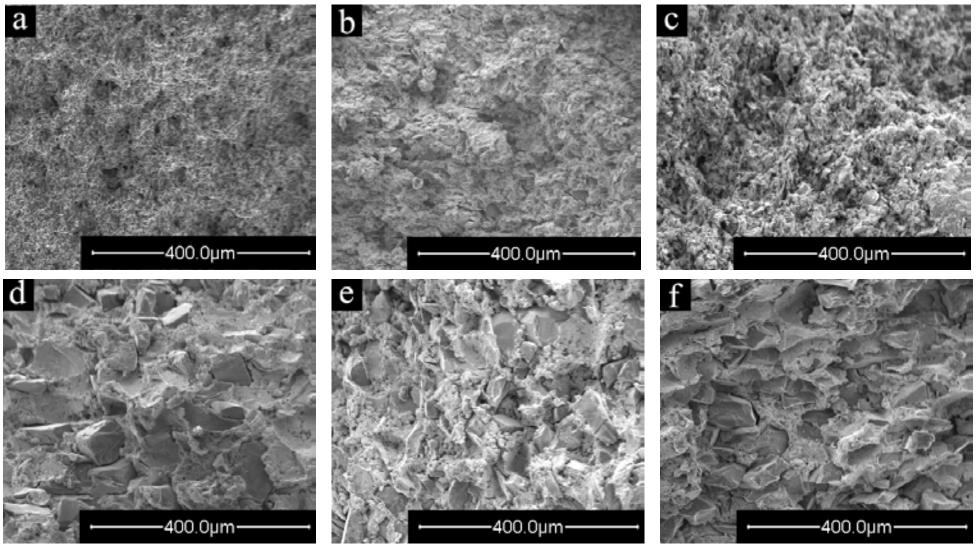

Fig.2 Fracture surface of $SiC_{p(Cu)}$/Cu composites. a) ~ f) were presented $SiC_{p(Cu)}$ fraction with 0 ~ 50%.

The evolution of relative density and porosity as a function of $SiC_{p(Cu)}$ fraction was reported in Fig.6. Relative density decreased with $SiC_{p(Cu)}$ fraction increasing. For all $SiC_{p(Cu)}$ composites, relative density was higher than 96%. Even if $SiC_{p(Cu)}$ fraction reached 50%, relative density was about 96.4%. In $SiC_{p(Cu)}$ composite with lower $SiC_{p(Cu)}$ fraction, less interface between Cu and $SiC_{p(Cu)}$ meant less copper atom diffusion barrier, copper atoms diffused conveniently, then it resulted in a higher densification of $SiC_{p(Cu)}$ composites. With increasing fraction of $SiC_{p(Cu)}$, porosity of $SiC_{p(Cu)}$ composites increased, hence diffusion barriers of $SiC_{p(Cu)}$ composites increased and relative density decreased.

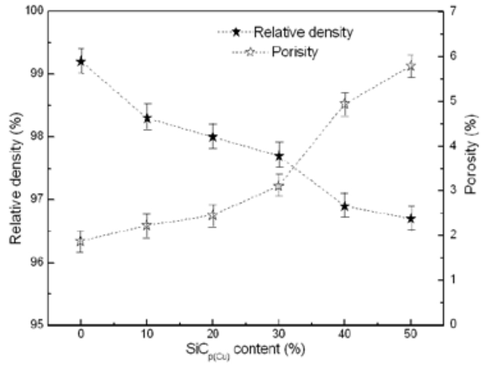

Fig.3 Porosity and relative density of $SiC_{p(Cu)}$/Cu composites. a), b), c), d), e) and f) were presented $SiC_{p(Cu)}$ fraction with 0, 10%, 20%,30%,40% and 50%.

Vickers hardness of $SiC_{p(Cu)}$/Cu composites was plotted as a function of $SiC_{p(Cu)}$ fraction in Fig.4. An increase in vicker hardness with increasing $SiC_{p(Cu)}$ fraction was observed for $SiC_{p(Cu)}$/Cu composites. Compared with sintered Cu materials, Vickers hardness was about 33Kgf/mm^2.While $SiC_{p(Cu)}$ fraction reached 50%,Vickers hardness of $SiC_{p(Cu)}$/Cu composites was 132Kgf/mm^2. $SiC_{p(Cu)}$/Cu composite exhibited higher Vickers hardness than uncoated SiC_p/Cu composite at 20Kgf load. Therefore, addition of $SiC_{p(Cu)}$ improved Vickers hardness of $SiC_{p(Cu)}$/Cu composite, especially at high $SiC_{p(Cu)}$ fraction. Hardness of copper improved considerably with additions of SiC_p at the expense of their ductility, which was attributed to higher hardness of SiC_p. Higher amount of ceramic particles resulted in more dislocations, which increased hardness of $SiC_{p(Cu)}$/Cu composites.

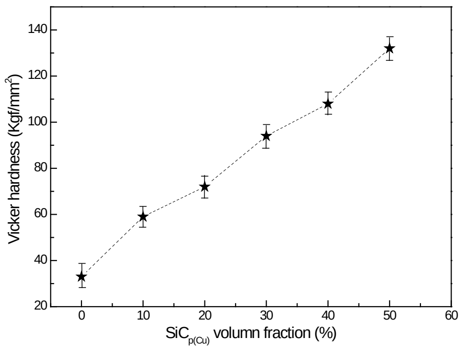

Fig.4 Vicker hardness of $SiC_{p(Cu)}$/Cu composites with different fraction $SiC_{p(Cu)}$

4. Conclusion

Hot-press sintering was utilized to fabricate $SiC_{p(Cu)}$/Cu composites at 750℃ for 60min. Relative density decreased and porosity of $SiC_{p(Cu)}$ composites increased as fraction of $SiC_{p(Cu)}$ increased. For all $SiC_{p(Cu)}$/Cu composites, relative density was higher than 96%, so hot-press sintering method was effective to fabricate compact $SiC_{p(Cu)}$ composites. The addition of $SiC_{p(Cu)}$ improved Vickers hardness of $SiC_{p(Cu)}$/Cu composite, especially at high $SiC_{p(Cu)}$ fraction.

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