Friction Performance of SiCp/Cu Hybrid Materials with Compound Additive

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Abstract: Copper alloy material had excellent electrical and thermal characteristics, but its poor wear resistance and low hardness limited its wider application. So it was necessary to improve wear resistance of copper alloy. In this paper, compound additives $La_2O_3/Al_2O_3/CeO_2$ were introduced into SiCp/Cu composites and hot-press sintering method was executed to synthesize SiCp/Cu composites. The influence of rare earth oxides on the phase constitution, micro structure and coefficient of friction of SiCp/Cu composites were investigated.

1 INTRODUCTION

Metal composites were developed into prime candidate as functional materials. Metal-ceramics composites exhibited superior performance such as high specific strength, high elastic modulus and wear resistance. Copper alloy were utilized as functional materials with high thermal electrical properties (Wang, 2011). However, the poor wear resistance limited wider engineering application. Some ceramic particles were used as reinforcement, such as metal carbides (WC, SiC, TiC), metal nitrides (TiN, Si_3N_4), metal borides (ZrB_2, WB, TiB_2) and metal oxides (Al_2O_3, ZrO_2). SiC particles were utilized in the Cu matrix considering the special properties of SiC_p on account of high hardness, good wear, low density (Dhokey, 2008). So SiC_p/Cu composites were developed as functional material due to their excellent electrical and thermal conductivity, good wear resistance (Zhang, 2008). At present, more reports on SiC_p/Cu composites were widespread (Zhu, 2007). Copper-based composites reinforced with 15-35wt.% SiC were fabricated by mechanical alloying, so an increase in milling time and SiC content (up to 25 wt.%) lead to a higher hardness of Cu matrix materials due to homogenization of microstructure and refinement of reinforcing particles (Perumal, 2015). The effect of SiC content and particle size on the density, hardness and electrical conductivity were investigated (Peng, 2012). The structure and particle size of copper based composite reinforced with a high content (15-35wt%) of silicon carbide and prepared by mechanical alloying in the high energy planetary mill (Prosviryakov, 2013). However, the reports about addition of rare earth oxides to SiC/Cu composites were relatively scarce. In this work, $La_2O_3/Al_2O_3/CeO_2$ were introduced into SiC_p/Cu composite. The density, phase constitution, micro structure and coefficient of friction of SiC_p/Cu composites were investigated.

2 EXPERIMENTAL PROCESS

The initial materials were domestic copper powders (D_{50}=38μm), SiC powder (D_{50}=38.5μm), Al_2O_3 powders (D_{50}=0.5μm) and La_2O_3 powders (D_{50}=0.5μm). The initial powders were mixed in accordance with the composition ratio designed in Table 1 in which mass ratio of Al_2O_3 and La_2O_3 was 1:3. The content of CeO_2 was about 2wt.%. For comparison specimen S5 without compound additives was also studied. The initial powders were mixed by ball-milling machine. The milling was 320rpm for 8h. Before sintering process, the mixture was cold pressed into a cylindrical compact in a die of 40mm in diameter with pressure of 200MPa. SiC_p/Cu composites were sintered in a graphite die at 840℃ for 1h in hot-press sinter furnace with argon gas and heating rate was about 30℃/min. Density measure was carried out according to Archimedes principle. Microstructure of composites was observed by SEM. Phases constitution were analyzed by X-ray(Bruker

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D8, Germany). The coefficient of friction of SiC_p/Cu composites were measured by SFT-2M type pin plate friction and wear tester. The friction pair was GCr15 steel balls with a diameter of 6mm. Test parameters: linear velocity is 200r/min, rotation radius was 3mm, the load was 200g and the friction time was 600 seconds. S1, S2, S3, S4 represented SiC_p/Cu composites with different compound additive and S5 represented SiC_p/Cu composites without compound additive after friction experiment.

Table 1: Designation of SiCp/Cu materials (wt.%)

Designation	Cu	SiC	La_2O_3	Al_2O_3	CeO_2
S1	75.2	18.8	3	1	2
S2	73.6	18.4	4.5	1.5	2
S3	72	18	6	2	2
S4	70.4	17.6	7.5	2.5	2
S5	80	20	0	0	0

3 RESULTS AND DISCUSSION

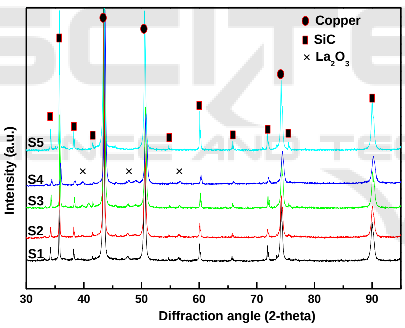

Figure 1: XRD pattern of SiC_p/Cu composites with different compound additive.

XRD pattern of SiC_p/Cu composites with different compound additive was showed in Figure 1, Cu and SiC peaks were detected as main phase, and La_2O_3 was formed as trace phase. Other phase such as Al_2O_3 and CeO_2 was not found in the SiC_p/Cu composites. The intensity of diffraction peaks of SiC and Cu phase was not obvious even if compound additive content was different. Copper was main crystal phase and its diffraction peak corresponds to the standard card of copper synthesis (JCPDS 04-0836). The diffraction peak of 6H-SiC standard card (JCPDS 29-1131). The intensity of diffraction peaks of La_2O_3 phase increased as the content of compound additive content was higher.

Figure 2 revealed density of SiCp/Cu composites with different content of compound additive. From the data of the density, the density varied from 5.73~6.05g/cm^3. As the total content of the compound additive was beyond 8%, (La_2O_3 > 4.5%), the density reduced due to more porosity and defects. The density variation was not distinct. For improving the density, too high or low additive was unsuitable. Especially when La_2O_3 content was about 4.5%, the density was higher.

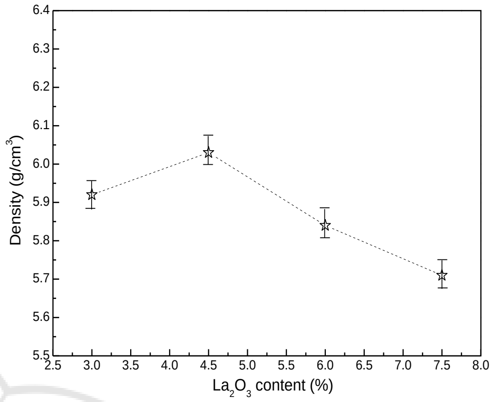

Figure 2: Density of SiC_p/Cu composites with different content of compound additive.

The microstructure of SiC_p/Cu composites with different content of compound additive was listed in Figure 3 a), b), c) and d) represented S1, S2, S3, S4 for SiC_p/Cu composites with different compound additive. White particles were SiC_p and grey part was Cu matrix. Moreover, Cu matrix was continuous and no obvious hole appeared. It was difficult to distinguish distribution variation of SiC_p in the Cu matrix, considering that proportion of SiC introduced in the composition does not change significantly.

Figure 4 showed high magnification SEM photos of S2 and S5 specimen. As the compound additives were introduced into the SiC_p/Cu composites, the interface was more clear and more tightly integrated between SiC and Cu matrix (shown in Figure 4a) As a contrast, more defects and holes were found on the interface between SiC and copper of SiC_p/Cu composites without compound additive. So the introduction of composite additives with appropriate content can improve interfacial adhesion between SiC and copper matrix. The SiC particle were distributed uniformly in the Cu matrix (shown in Figure 4c) For all experimental specimens, SiC particles was distributed uniformly in the Cu matrix.

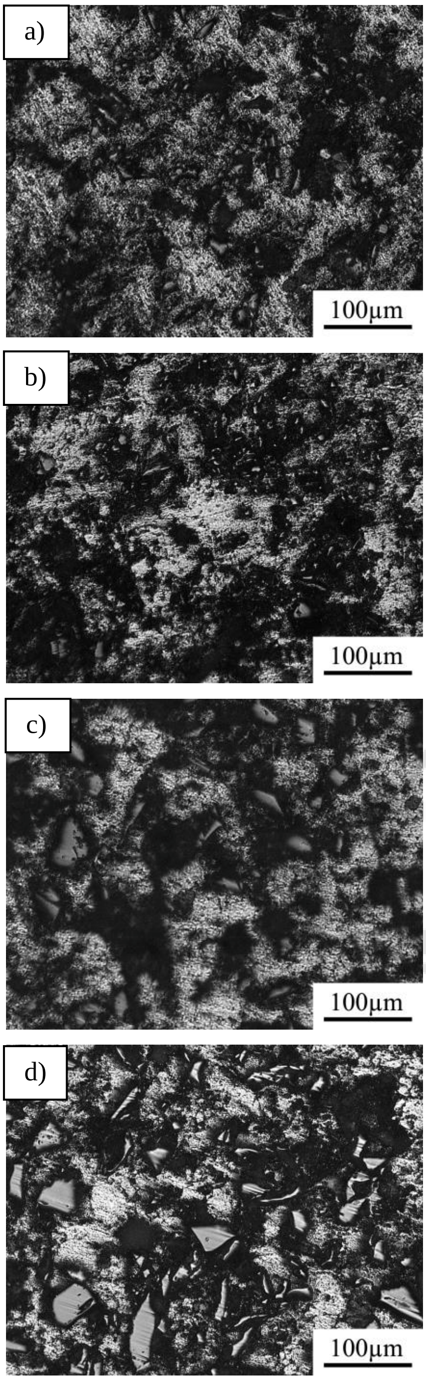

Figure 3: Microstructure of SiC_p/Cu composites with different content of compound additive. a), b), c) and d) represented S1, S2, S3, S4.

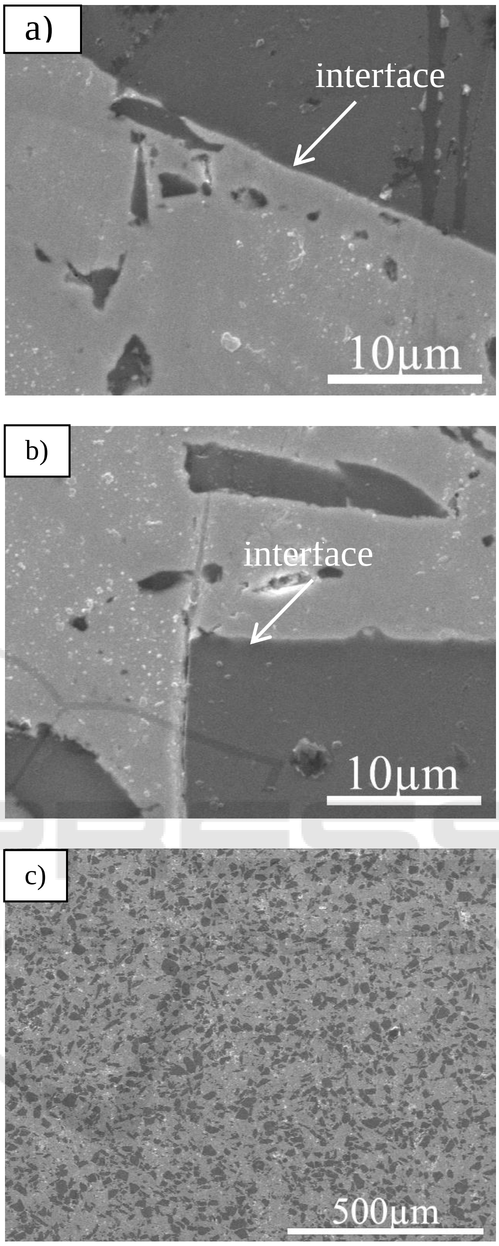

Figure 4: High magnification SEM photos of S2, S5 and S4 specimen. a), b) and c) represented S2,S5 and S4.

Figure 5 showed friction coefficient of SiC/Cu materials with different content of compound additive. As a comparison, friction coefficient of S5 was about 0.6~0.7. In comparison, friction coefficient of SiC/Cu materials decreased significantly when compound additive was introduced into SiC/Cu materials. For four different SiC/Cu hybrid materials, friction coefficient varied between 0.08~0.18. Especially, when content of additive La_2O_3 was 4.5%, its friction coefficient was about 0.07~0.09.

The friction coefficient of SiC/Cu composites without compound additive was high. The addition of compound additive played an important role, so it effectively relieved plastic deformation of Cu matrix during the friction process and improved wear resistance, thus the abrasion resistance improved.

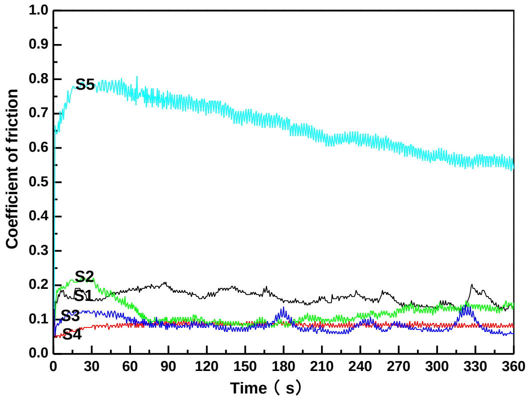

Figure 5: Friction coefficient of SiC/Cu materials with different content of compound additive.

4 CONCLUSIONS

SiC_p/Cu composites were fabricated by hot-press sinter method. The introduction of compound additive played an important role on the friction coefficient. Micron SiC_p were distributed uniformly in the Cu matrix. Compared with SiC_p/Cu without compound additive, friction coefficient of SiC_p/Cu materials with compound additive was low, so it meant that SiC_p/Cu materials with moderate compound additive had better wear resistance.

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