Effect of Sintering Temperature on Friction Performance of Cu-based Nanometer Composites Reinforced by Nano SiO_2 Particles

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Abstract. The Cu-based nanometer composites reinforced by 1.0 wt% nano-SiO_2 particles (Cu/n-SiO_2) were prepared by powder metallurgy at different sintering temperature. The friction performance of the composites were studied by ball-disk friction tester. The results indicate the dynamice friction coefficient and wear rate of the composites gradually increase with the sintering temperature increasing (between 800 and 950 ℃).

Intorduction

The nano SiO_2 particles are amorphous inorganic non-metallic materials, which have excellent properties such as wear resistance and corrosion resistance because of its small size effect, surface and interface effect and so on. The nano SiO_2 are widely used in high polymer, ceramics, coatings and biomedical fields [1-2]. In recent years, nano-SiO_2 particles are gradually used in Cu-based composites. Besides keeping copper's original excellent conductivity, thermal conductivity and elastic-plastic properties, nano-SiO_2 can enhance the strength and wear resistance of the composites significantly[3-4]. The Cu-based composites reinfoced by nano-SiO_2 have been widely used in electronics, mechanical and electrical, aerospace, transportation fields and so on [5-7].

At present, the researches about nano-SiO_2 enhanced copper matrix composites (Cu/n-SiO_2) focus on exploring the influence of nano-SiO_2 form, content, etc. [8-10] on the performance of the copper matrix. This paper aims to study the effect of sintering temperature on the Cu/n-SiO_2 composites, and then research sintering process, strengthening mechanism of nano-particles reinforced copper matrix composites.

Experiment

Specimen. The raw materials are electrolytic copper powder (purity 99.8%, average particle size is about 74μm) and n-SiO_2. The n-SiO_2 particles are produced by Zhoushan Mingri Nano Co., Ltd., its particle size is 30 ± 5nm. The mixed composite powders were milled for 5 h (speed 60 r/min) by GMJ/B-type rolling mill machine, and then were sintered into specimens of size Φ20 × 5mm by hot pressing sintering furnace in the condition of 30 MPa at different temperatures (800 °C, 850 °C, 900 °C, 950 °C), with holding time of 5 min.

Testing Methods. Friction and wear properties were studied by WTM-2E type micro-tribometer with dual head GCr15 chrome steel ball (diameter 5mm). The experimental conditions: loaded quality 400 g, speed 500 r/min, radius of gyration of 6mm. The morphology of Cu/n-SiO_2 composites after friction and wear were studied by Zzeiss Ultra 55 field emission scanning electron microscope(FSEM).

Results and Discussion

Friction and Wear Performance. The curve of dynamic friction coefficient and sintering temperature is shown in Fig. 1. The figure shows that dynamic friction coefficient of the composites

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increase with sintering temperature increasing. The nano SiO_2 particles diffuse more uniformly in the copper matrix and the strength of the composites can be enhanced in the higher sintering temperature, which enhance the dynamic friction coefficient of the composites. According to the friction theory [9-10], the soft copper on the surface will be worn firstly and then the nano SiO_2 particles arrive the friction surface and increase the frictional resistance. Meanwhile, uniformly distributed nano SiO_2 particles make the friction surface more stable. These factors cause the dynamic friction coefficient inincreaing as the sintering temperature rising.

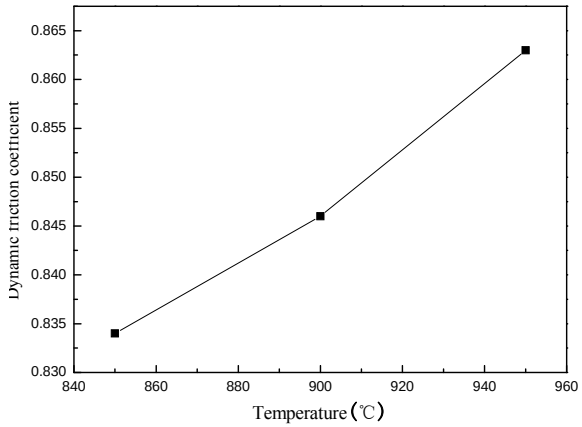

Fig.1 Curve of dynamic friction coefficient and sintering temperature

The curve wear rate of the copper matrix composites and sintering temperature is shown in Fig. 2. The wear rate of the composites increases with the sintering temperature increasing . Because the dynamic friction coefficient increase and the friction resistance is enhanced with the sintering temperature increasing, which make wear rate of the composite materials increase.

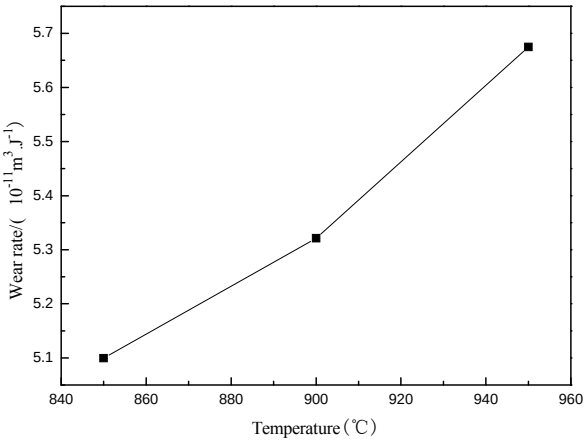

Fig. 2 Curve of wear rate and sintering temperature

Surface Morphology. Figure 3 shows the surface morphology of the composites sintered at different temperatures. It can be seen that a large number of flake elastic and plastic deformation and some wear debris on the surface. The wear mechanisms of the composites are adhesive and abrasive wear.

To further study the distribution of nano SiO_2 in copper matrix, the surfaces were observed through field emission scanning electron microscope (FESEM). The magnification morphology are shown in Fig. 4. In the pictures, the gray areas are copper and the black areas are agglomerated nano SiO_2 particles. Obviously, the nanoparticles on the worn surface of Cu/n-SiO_2 composite sintered at 850℃distributed unevenly and there are many fine cracks on the surface.

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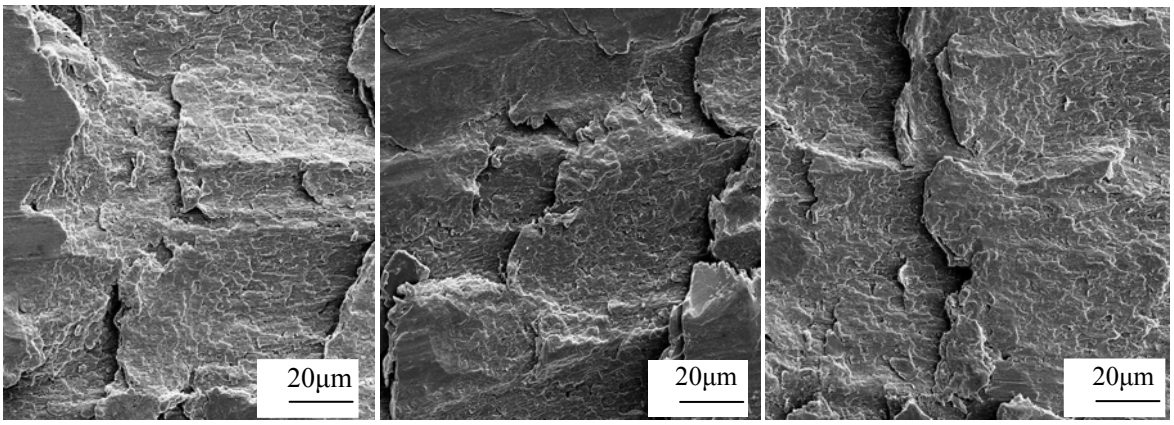
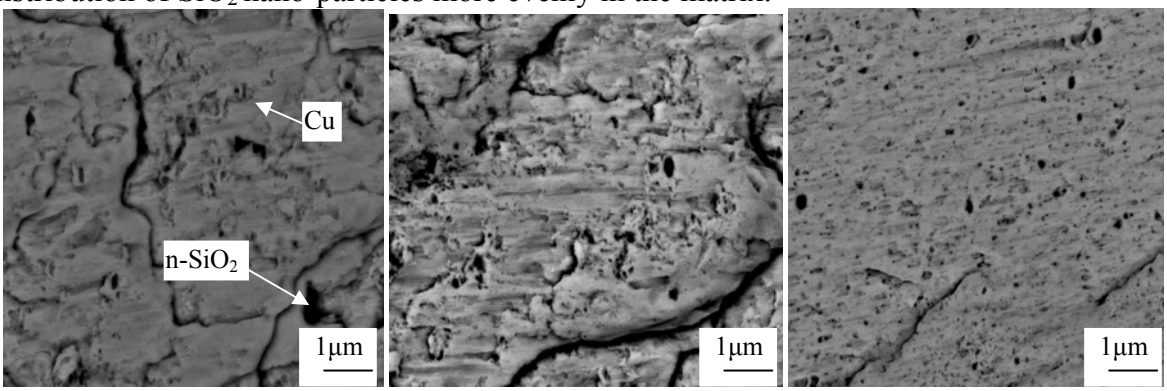


(a) (b) (c)

Fig. 3 Surface morphology of the composites after friction and wear (a) 850℃ (b) 900℃ (c) 950℃

The dispersion of the black area of the composites sintered at 900℃ is slightly improved and become more diffuse in the composite sintered at 950℃.At the same time, there are few micro-cracks in the latter composite than that of the former two materials. With the sintering temperature increasing, the proliferation activity of copper atoms in the materials greatly is enhanced, which make the distribution of SiO_2 nano-particles more evenly in the matrix.



(a) (b) (c)

Fig. 4 Surface morphology of the composites under high magnification after friction and wear (a) 850℃ (b) 900℃ (c) 950℃

Analysis and Discussion

For the Cu/n-SiO_2 powder metallurgy composites (nano-SiO_2 content of 1%) hot pressing sintered between 850~950℃, in the friction process, the dual indeater becomes to contact the surface small bulge of the copper matrix composites, which makes a tangential resistance. To overcome this resistance, adhesive wear will appear and soft copper matrix is worn first. With the friction sustain, nano-SiO_2 particles protrude on the surface. To overcome this resistance coming from these hard particles, the dual indeater continue sliding friction and makes one side of copper matrix of hard nano-SiO_2 particles continuously squeezed, loosen, and finally appear fine cracks in the matrix. Afterwards, nano-SiO_2 fall off from the matrix and become hard wear debris to promote abrasive wear or are pressed into the copper matrix to enhance strength of the matrix. Then abrasive wear bringing by the hard SiO_2 debris draw furrows on the surface and prompt a coarsening and propagation of the original fine crack at the same time.

It was found that wear rate of the specimen sintered at 950℃ was largest. As sintered at relatively higher temperature, the copper atoms of these composites get more active diffusion, which lead to uniform distribution of SiO_2 nano-particles and improve the whole strength of the material. Therefore, under the same conditions of friction and wear experiments, dynamic friction coefficient and wear

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rate of Cu/n-SiO_2 composites sintered at 950℃ are both the highest of three secimens, while due to its larger strength of the surface, the delamination fracture phenomenon on the surface get improved compared to materials sintered at 850℃ or 900℃.

Conclusions

The dynamic friction coefficient and wear rate of the nano SiO_2 reinforced composites increase gradually with sintering temperature rising. Within the range of 850 to 950℃, the higher temperature does favor to the dispersion of SiO_2 nanoparticles in copper matrix, which improve the strength of copper matrix. Therefore the surface intensity of Cu/n-SiO_2 composite sintered at 950℃ is better.

Acknowledgements

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