Fabrication of SiC_p/Cu Composites with SiC_w/SiC_{np} hybrid addition

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Abstract. SiC_p/Cu hybrid composites were fabricated by hot press sintering technology. Micron SiC particle (SiC_p), SiC wisker (SiC_w) and nano SiC particle (SiC_{np}) were chosen as hybrid reinforcement. The reinforcement distributed uniform in the substrate after electro-less plating. XRD, SEM and Vickers hardness apparatus were utilized to character phase constitution, surface morphology and hardness of SiC_p/Cu composites. The result showed that addition of nano-SiC_p improve Vickers' hardness and bending strength compared with SiC_w and $SiC_{(w+np)}$ hybrid material.

Keywords: Electro-less plating; Copper matrix; Hot-press sintering; Hybrid addition.

1. Introduction

Metal copper was wider applied in the many industry fields, such as electronic packaging, heat sink, etc. The inherent weakness of copper with low wear resistance and mechanical strength limited application range [1, 2]. Based on above consideration, alloying treatment was put forward in the last two decades. However, introduction of alloying element into Cu matrix resulted in improvement of wear resistance and reduction of electrical and thermal conductivity. Recently, copper composites with SiC as reinforcement had superimposed performance by SiC and copper, so it attracted researcher's widespread attention. Zhang, et al [3] prepared SiC/Cu composites by pressure infiltration and measured wetting behaviors. More endeavors was carried out resolve weak wettability problem between SiC and Cu matrix. K. K. Gan, et al [4] treated SiC particle with tungsten coated by sol-gel method. Compared with other methods, electro-less plating technology had better advantages, such as convenient operation, coating object with non-selectivity, etc. In this investigation, SiC_p, (SiC_w) and SiC_{np} was treated by the electroless plating method, then $SiC_{(w+np)}$ hybrid β-SiC_p/Cu composites were fabricated by hot-press sinter technology. The effect of $SiC_{(w+np)}$ additions on the microstructure, relative density and mechanical properties of β-SiC_p/Cu composites were surveyed.

2. Material synthesis and Characterization

SiC_p, SiC_w and SiC_{np} (hybrid additions) were treated by electro-less copper plating. The electro-less plating process was referred to Ref. [5]. Copper powder (PHI=78μm) and reinforcement were SiC_p (PHI=60μm, abbreviate SiC_{np}), SiC_w (ratio of length to diameter 10~20:1) and SiC_{np} (PHI=40nm). Hybrid additions after electroless plating and Cu powders were mixed according to Table 1.The hybrid compound powders were treated by planetary ball mill. ZrO_2 ball was used as grinding media. Ball milling speed was controlled at 240 RPM/min and time was adjusted in 8h. After ball milling, Mixture powders were dried in the vacuum condition and sieving treatment was carried out with 60mesh. SiC_p/Cu composites were sintered by uniaxial hot press molding with 30MPa. Temperature was about 800℃ and hold time was adjusted in 60min. The argon gas was applied as protected gas. Phase composition of $SiC_{(w+np+p)}$/Cu composites were analyzed by X ray diffraction (D8 Advance). Surface morphology of $SiC_{(w+np+p)}$ /Cu composites were observed by SEM (JSM-6360LV). Relative density of $SiC_{(w+np+p)}$/Cu composites were calculated according to Archimedes principle. Hardness tester and universal testing machine were used to measure hardness and bending strength.

Table 1 Design of mixture of SiC and copper powder (Vol. %)

Specimen	SiC_p(μm)	SiC_{np}	SiC_w	Cu
S1	45	0	0	55
S2	40	0	5	55
S3	40	5	0	55
S4	40	2.5	2.5	55

3. Results and Discussion

SEM photo of SiC_{np} and SiC_w was shown in Fig.1. Fig.1 a) and c) represented received SiC_{np} powder and SiC_w. SiC_{np} powder and SiC_w after electroless plated treatment was listed in Fig.1 b) and d). It was obvious to observe surface morphology after electroless copper plating treatment. The surface of received SiC_{np} and SiC_w was smooth, while surface of SiC_{np} and SiC_w became rough. So electroless plated treatment changed surface roughness. Meantime, diameter of SiC_w became bigger compared with received SiC_w.

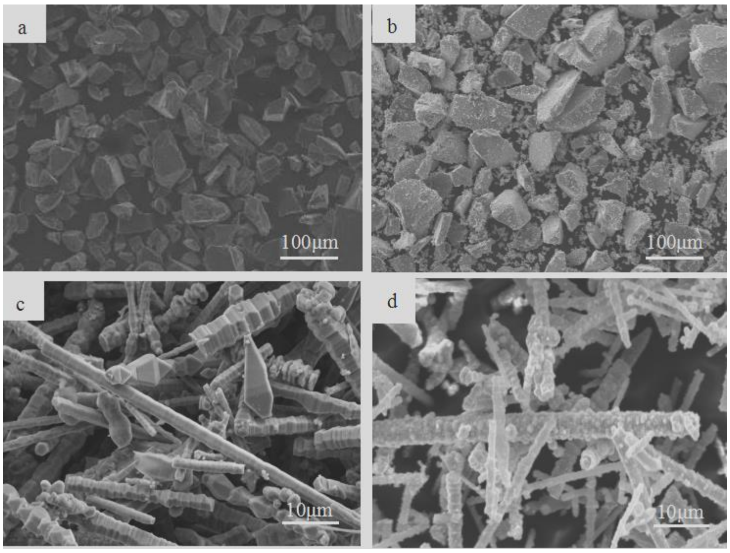

Fig. 1 SEM of SiC_{np} and SiC_w. a) received SiC_p, b) SiCp after electroless plate treatment, c) received SiC_w, d) SiC_w after after electroless plating.

XRD patterns of different kind of (SiC_w+SiC_{np}) hybrid composites were recited in Fig.2. For all composites, copper (No.04-0836), α-SiC phase (No.29-1127) and β-SiC (No.29-1129) were main crystal phase. α-SiC phase was detected due to the introduction of micron-grade α-SiC powders. CuO and Cu_2O phase was not detected in all hot-pressed specimens.

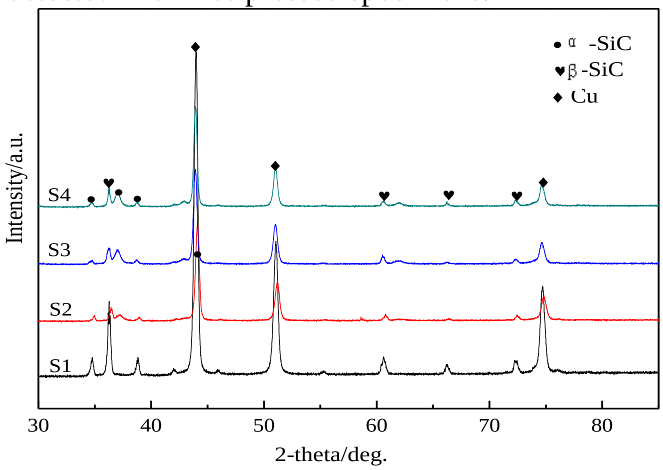

Fig. 2 XRD of hybrid composites, a)~d) represented specimen S1, S2, S3 and S4.

SEM photos of different hybrid composites were illustrated in Fig.3. The micron-grade α-SiC powders were distributed uniformly in the copper matrix. It was regret that nano-grade SiC particles were difficult to be detected thanks to small size effect. It was noticeably that all hybrid powders were treated by the electro-less plated copper. Electro-less plated copper treatment would improve homogeneity of hybrid reinforcement. There was no obvious porosity in the hybrid SiC_p/Cu composites.

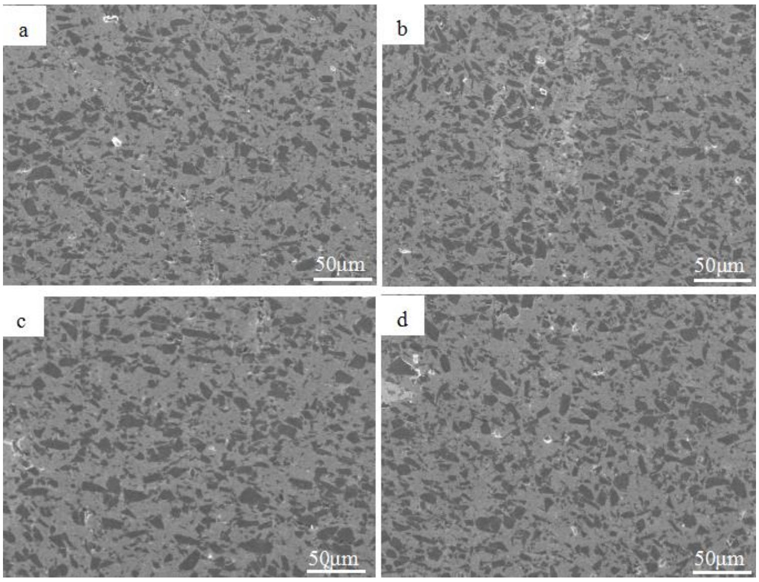

Fig. 3 SEM of hybrid composites. a), b), c) and d) represented S1, S2, S3 and S4.

Fig.4 gave SEM photos of SiC_w+SiC_{np} hybrid copper matrix composites. For all hybrid composites, the interface between SiC particles and Cu substrate was distinct, so the low sintered temperature was difficult to result in interface reaction. Meanwhile, the interface wettability between SiC_p and copper substrate can be improved after electro-less copper plating treatment.

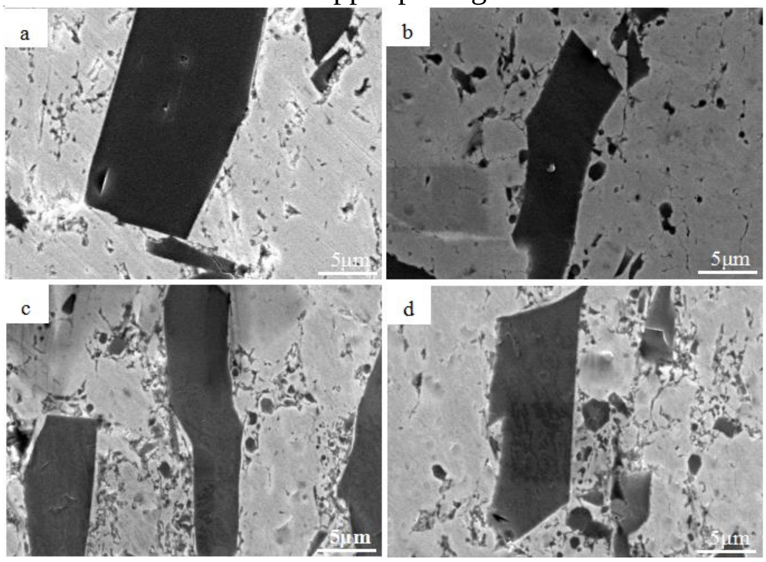

Fig. 4 SEM of fracture surface of hybrid composites, a), b), c) and d) represented specimen S1, S2, S3 and S4.

Relative density and mechanical properties of SiC_p/Cu composites was listed in Fig.2. Relative density of S1, S2, S3 and S4 were 89.45%, 85.27%, 96.47% and 87.26%, respectively. In view of plug product effect of nano-SiC_p during hot-press sintered process, specimen S3 obtained higher relative density. While SiC_w resulted in high porosity and low compactness, relative density of S2 samples was lowest. Vickers hardness of S1, S2, S3 and S4 were 94HV, 102HV, 132HV, and 118HV, respectively. SiC_{np} was distributed in the grain boundary, which played a role of pinning effect. S3 showed higher Vickers hardness. Introduction of SiC_w didn't improve Vickers hardness obviously. Bending strength of S1, S2, S3 and S4 were 331±4.5MPa, 314±3.7MPa, 281±6.2MPa and 297±3.4MPa, respectively. The addition of SiC_w effectively improved flexural strength of SiC_p/Cu composites, but content of SiC_w was relatively low and relative density of $SiC_{(w+p)}$/Cu composite was relatively low, so contribution of SiC_w on flexural strength was not obvious.

Table 2 Relative density and mechanical properties of hybrid SiC_p/Cu composites

Specimen	Relative density	Hardness(HV)	Flexure strength(MPa)
S1	91.56%	94	331±4.5
S2	85.27%	102	314±3.7
S3	96.47%	130	281±6.2
S4	87.26%	118	297±3.4

4. Summary

Hybrid SiC_p/Cu composites were prepared by hot-pressed sinter technology. After SiC powders was treated by electro-less copper plating, hybrid SiC_p was distributed in the Cu substrates. The addition of SiC_{np} improved relative density and Vickers hardness of SiC_p/Cu composites. As a small amount of SiC_w was introduced into hybrid composites, variation of bending strength and hardness was not obvious.

Acknowledgements

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