SiCw / 2124Al COMPOSITE FABRICATED BY POWDER METALLURGY TECHNIQUE①

Bi, Jing Ma, Zongyi Lu, Yuxiong Shen, Hongwei Gao, Yinxuan

Institute of Metal Research, Academia Sinica, Shenyang 110015, China

ABSTRACT

Microstructure and properties of SiCw / 2124Al composite fabricated by powder metallurgy technique were systematically investigated. The results indicate that the matrix in the composite preserves the microstructural characteristics of microcrystalline aluminum powder. SiC whiskers are uniformly distributed in the matrix and the interfacial bonding is excellent. Because of the addition of SiC whisker the strength and modulus of the composite increase by 45% and 76% respectively, and the coefficient of thermal expansion decreases by 35%.

Key words: microstructure properties Al composite powder metallurgy

1 INTRODUCTION

Whisker reinforced aluminum alloy composite, which has the distinct advantage of being both machinable and workable using conventional deformation processing method, is gaining increasingly importance. The powder metallurgy (P / M) technique for producing this composite has also been significantly advanced with the improvement in the processes of ultrasonic gas atomization of aluminum powder and fabrication of SiC whisker[2, 3]. It is indicated that SiCw / 2124Al composite has excellent comprehensive properties and is considered to be a promising structural material. The 2124 aluminum alloy reinforced by SiC whiskers was fabricated by P / M technique, the microstructure and properties of the composite were systematically investigated.

2 EXPERIMENTAL PROCEDURES

The reinforcer — β–SiC whisker bought from Tokai Carbon Co. Ltd, Japan, is 0.1~1.0 μm in dia. and 30~ 100 μm in length. The matrix material is ultrasonic Ar gas atomized 2124 aluminum alloy powders (−280 mesh) with composition (wt−%) of 4.01Cu−1.60Mg −0.45Mn−0.08Zr−0.10Si−0.16Fe. The 20 vol. −% SiCw / 2124Al composite was fabricated by mixing SiC whiskers with aluminum alloy powders, and then hot pressed in vacuum, hot extruded to rod with a reduction ratio of 20:1. Samples were taken from the composite rods and polished for metallographic examination. The extrudates were T6-treated (solutionized at 500 ℃ for 1 h, water quenched and immediately aged at 170 ℃ for 5 h), and then machined into tensile specimens. The tensile tests

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at different temperatures were carried out at a constant strain rate of $8.33 \times 10^{-4} s^{-1}$. The fracture surfaces of the tensile specimens were examined with SEM. The elastic modulus of the composite was measured with machined rods 8 mm in diameter and 180 mm in length using resonance technique. The coefficient of thermal expansion of the composite was measured. Thin foils for TEM were prepared by ion-milling technique. The foils were observed with a Philips EM420 electron microscope at 100 kV.

3 RESULTS AND DISCUSSION

3.1 *Matrix Microstructure*

Fig.1 shows the metallograph of the SiCw / 2124Al composite. It is indicated that the matrix in the composite preserves the microstructural characteristics of microcrystalline aluminum powders and has extra-fine grains of ASTM 12 grade. The fine-grain structure increase the strength of the composite and provides the necessary basic condition for the superplastic deformation of the composite[4]. The extra-fine grains in the SiCw / 2124 Al composite can be accounted by two factors: one is that the matrix material used is atomized aluminum alloy powders having extra-fine grain structure, which is the basis for the existence of the extra-fine grains in the composite matrix, and the second is that hot press was carried out below the solidus temperature in the fabrication of the composite, no liquid phase and solidification appeared. This fabrication process avoids the solidification segregation and ensures the preservation of the microstructural features of the microcrystalline aluminum powders. TEM observations indicate that the interface between SiC whisker and aluminum alloy matrix is clean and interfacial bonding is good (Fig.2a). The fine particles at the interface may be the precipitates of the matrix. A high density of dislocation was found close to the SiC / Al interface. The dislocation density decreased with increasing distance from the interface (Fig.2b). The increase in strengh of the composite has been attributed to the high dislocation density in the composite matrix[5, 6].

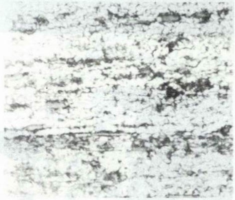


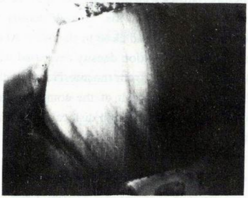
Fig.1 Metallograph of the SiCw / 2124Al composite, × 900 (polished and etched)

3.2 *Distribution and Damage of Whisker*

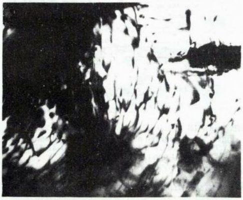
The whiskers are uniformly distributed in aluminum matrix and aligned along the extrusion direction (Fig.3). The uniform distribution of the whiskers is due to sound mixing of SiC whiskers and aluminum alloy powders. The alignment of the whiskers caused by hot extrusion increases the longitudinal strength. Hot extrusion also caused great damage to the whiskers and the average aspect ratio of the whiskers was reduced to 5.3 (Fig.4) which decreases the reinforcement potential of whiskers.

3.3 *Tensile Properties and Fractography*

Fig.5 shows that the SiCw / 2124Al composite has a significant increase in strength compared to 2124Al alloy, its reproductivity of strength is good and the scatter of strength of five tensile specimens is within 3%, which indicates fully that P / M technique is an effective process for producing this high-performance composite. The ductility of the compo- site, however, is much reduced.



(a) × 73,800



(b) × 94,500

Fig.2 TEM photographs of SiCw / 2124Al composite

a—interface; b—high dislocation density

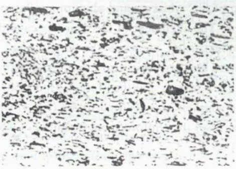


Fig.3 Metallograph of SiCw / 2124Al composite

(× 900)

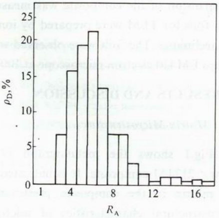


Fig.4 Distribution range (ρ_D) of SiC whisker aspect ratio (R_A)

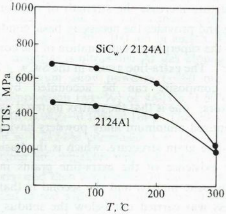


Fig.5 Temperature (T) dependence of strength (UTS) for SiCw / 2124Al composite and 2124Al alloy

SEM observations indicate that the morphological features of the fracture surfaces of the SiCw / 2124Al composite are quite different from those of the matrix alloy. The low magnification fracture surfaces of the composite showed brittle pattern because of low ductility, but the high magnification fracture surfaces were still of dimple pattern. The fracture surfaces consisted of fine equiaxed dimples having the sizes consistent with the whisker diameters (Fig.6). The whisker ends are the sites of severe stress concentration due to 90 (°) sharp corner and intense localized plastic strain due to rigid whisker inhibition of plastic deformation of matrix and crack propagation, which causes microcrack initiation on the ends of SiC whiskers[7]. The fine dimples were caused by localized deformation at the ends of the whisker and final pull-out of the whiskers which were covered with a coating of aluminum matrix. The whiskers exposed on fracture surfaces were quite few, which illustrated excellent interface binding between whisker and matrix.

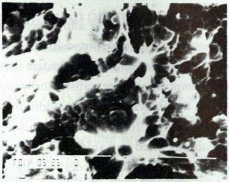


Fig.6 SEM photographs of tensile fracture surfaces for SiCw / 2124Al composite

3.4 *Physical Properties*

Fig.7 shows the 2124Al alloy reinforced by SiC whisker can achieve higher elastic modulus than unreinforced 2124Al alloy, e.g. the ambient temperature modulus of 20 vol.−% SiCw / 2124Al composite is increased by above 76% than that of 2124Al alloy. Like monolithic alloy the elastic modulus of the composite decreases with the increasing of temperature.

The coefficients of thermal expansion of 20 vol.−% SiCw / 2124Al composite and 2124Al alloy are shown in Table 1. The CTE of the composite decreases by about 35% than that of unreinforced alloy. The excellent thermal stability makes the composite applicable in precision instruments and optical systems[8].

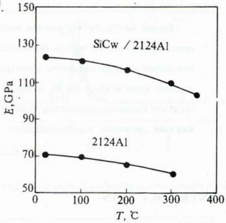


Fig.7 Temperature (*T*) dependence of elastic modulus (*E*) for 20Vol.−% SiCw / 2124Al composite and 2124Al alloy

Table 1. CTE of 20 vol.−% SiCw / 2124Al and 2124Al (10^{-6} / ℃)

Composite	T, ℃			
	RT−100	RT−200	RT−300	RT−400
SiCw / 2124Al	13.3	13.6	13.8	14.0
2124Al	21.3	21.4	21.5	21.7

4 CONCLUSION

(1) The matrix in the SiCw / 2124Al composite fabricated by P / M technique preserves the microstructural characteristics of microcrystalline aluminum powder and has extra-fine grains of ASTM 12 grade.

(2) SiC whiskers are uniformly distributed in the matrix and aligned along the extrusion direction. The interfacial bonding is good.

(*To be continued on page 75*)