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Effect of SnO_2 coating on the damping capacity and tensile property of alumina borate whisker-reinforced aluminum composite at room temperature

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ABSTRACT

Pure aluminum matrix composites reinforced with SnO_2-coated alumina borate whisker were fabricated by squeeze casting. The influence of the coating contents on the tensile properties and damping capacities of the coated composites at room temperature was investigated. The results indicate that the interfacial states of the coated composites can be modified by the introduction of the coatings on whisker surfaces. The tensile properties of the coated composites observably increase with the coating contents. The damping values of the coated composites rapidly increase with the strain amplitude but decline with the coating contents, when strain amplitude exceeds 1×10^{-3}. A new damping peak in the coated composites at low strain amplitude (about 3×10^{-4}) has been observed, which could be ascribed to the dislocation mechanism.

1. Introduction

High damping capacity is one of the most important properties of materials used in engineering structure. It is well known that the high damping is associated with a weak mechanical strength. It would be of interest to search for new materials simultaneously exhibiting good mechanical properties and high damping capacities [1–3]. Such a compromise can be achieved by the development of metal matrix composites (MMCs) in which each phase plays a specific role: damping or mechanical strength.

The nature of the reinforcement/matrix interface within a composite often has a profound effect on its overall properties. In fact, the development of high performance composite systems has come from interfacial modification and associated property enhancement. The proper selection or design of the interfacial phase plays a vital role in optimizing the final properties of MMCs [4,5].

MMCs have been extensively investigated since their properties can be enhanced by the addition of selected reinforcements. Recently, alumina borate whisker-reinforced aluminum matrix composites ($Al_{18}B_4O_{33}$w/Al) have been attracting attention because of the lower price of whisker and excellent properties of the composites [6,7]. In the composites, the whisker coatings are commonly implemented for several objectives: firstly, to improve the bonding strength between whisker and matrix, and then to prevent the interfacial reaction; secondly, to improve the formability of the composites, such as hot extrusion and hot compression. The stress distribution and microstructure around the whisker/matrix interface in the composites are also affected by the coatings [8–11]. In these cases, the overall properties of the composites can be altered.

The effect of reinforcement (fibers or particles) coatings on damping behaviors of MMCs has been investigated by Zhang et al. [12,13]. They found that the damping capacities of the composites can be improved by the reinforcement coatings. Their results also indicated that the coatings on reinforcement surfaces affected not only the damping capacities but also the damping mechanisms of composites.

Although there are some investigations on the damping capacity of MMCs with coated reinforcements, little previous research was emphasized on the damping response of MMCs with the presence of the surface coatings of whiskers. Our previous study suggested that pure aluminum matrix composites reinforced with SnO_2-coated alumina borate whisker exhibited a higher damping capacity than that of the non-coated one [14], and the results indicated that the damping capacities of the coated composites strongly depend on the coating contents at the testing temperature ranges.

In this paper, the effects of the coating contents on the damping capacities and tensile properties of the coated composites at room temperature were investigated and the damping mechanisms of the coated composites were also discussed.

2. Experimental

SnO_2 was coated on the surface of whisker with a diameter of 0.5–1.5 μm and length of 10–30 μm using a chemical method [14].

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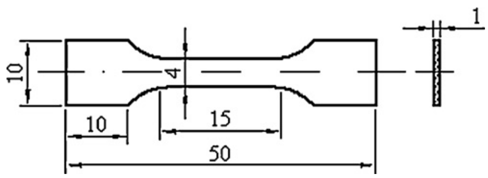

Fig. 1. The dimension of tensile specimen.

The whisker pre-form was sintered at 1000 °C for 1 h to obtain a high strength pre-form.

The pure aluminum matrix composites reinforced by SnO_2-coated ABOw were fabricated by squeeze casting and the volume fraction of ABOw in these composites was about 20 percent. The mass ratios between ABOw and SnO_2 were set as 6:1, 10:1 and 20:1, respectively. The corresponding abbreviations are listed in Table 1.

The microstructures of the coated composites were observed using a Philips CM-12 transmission electron microscopy (TEM), the specimens for TEM observation were thinned by ion milling. The morphologies of the coatings and the tensile fractographs were examined by a Hitch S-4700N scanning electron microscope (SEM).

Tensile tests were performed on an Insrton 5590 test machine. The dimension of tensile specimen is shown in Fig. 1. All the tests were carried out at a strain rate of 1 mm per minute. Three specimens were tested for each composite at room temperature.

The damping tests were carried out by using a dynamic mechanical analyzer (DMA) (Model TA Q800, USA) with a single cantilever vibration mode. The dimensions of the damping specimen were 38 mm × 4 mm × 1 mm. The damping capacity was determined by $Q^{-1} = \tan\phi$ [15], where ϕ was the lag angle between the applied strain and response stress. The damping capacity at room temperature was measured, the test conditions were set as the vibration frequency f was 0.5–15 Hz, the strain amplitude ε was 4×10^{-4} and 4×10^{-5}, respectively. In addition, the damping capacity at room temperature was also measured when the strain amplitude ranged from 4.5×10^{-6} to 1.5×10^{-3} and from 1×10^{-3} to 4×10^{-3} at a constant frequency of 1 Hz.

3. Results

3.1. Microstructure

Fig. 2(a) shows the surface morphology of SnO_2-coated ABOw by SEM observation. Fine SnO_2 particles can be clearly seen, which discontinuously distributed on the whisker surfaces. Moreover, it was found that a small amount of SnO_2 particles were not coated on the whisker surfaces. The presence of SnO_2 on whisker surfaces is confirmed by XRD examination (as shown in Fig. 2(b)).

TEM micrographs of the coated composites are shown in Fig. 3. It is noticed that the coatings distributed at the whisker/matrix interface (see Fig. 3(a) and (b)). Fig. 3(c) is the selected area electron diffraction pattern (SADP) corresponding to the coatings in Fig. 3(a). Sn and Al_2O_3 can be indexed by the SADP. Our previous study also displayed that Sn particles existed in the coated composites, and Al_2O_3 was also discovered in the coated composites using the XRD technique [14].

Fig. 4 is the matrix morphologies in the coated composites. Dislocation states of the Al matrix adjacent to the interface in 10ABOw/SnO/Al composite are shown in Fig. 4(a). There are plenty of dislocations in the matrix adjacent to the interface. Dislocations can be clearly seen in the matrixes of all the coated composites. As we know, the coefficients of thermal expansion (CTEs) are different between whisker and aluminum matrix. As the composite is cooled from higher temperatures, the great difference of CTEs will result in a higher density of dislocations at whisker/Al interface [16,17], so higher dislocation densities are also present in the coated composites. It is also worthwhile noting that a small amount of Sn is formed at the Al matrix grain boundaries in 6ABOw/SnO/Al composite as shown in Fig. 4(b). This indicates that some of the SnO_2 particles were not coated on the whisker surfaces, resulting in Sn particles existing not only at the interface but also at the grain boundaries of the matrix.

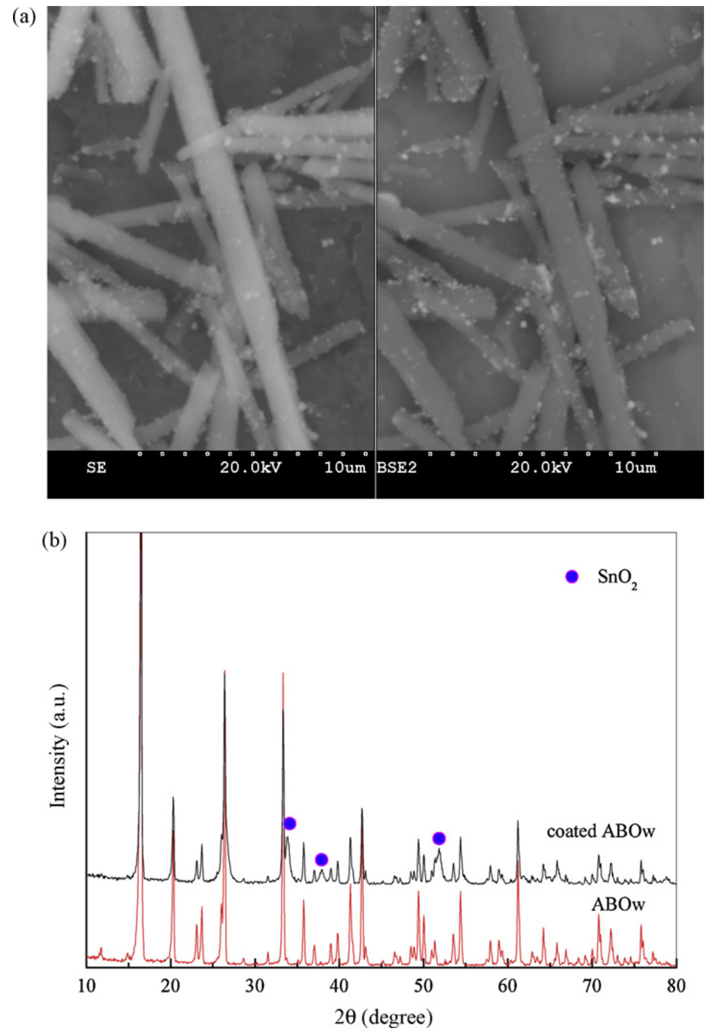

Fig. 2. Surface morphology and phase compositions of SnO_2-coated ABOw (a) morphology and (b) XRD patterns.

According to the above analysis, it can be concluded that SnO_2 coatings can react with molten Al during squeeze casting process, the reaction equation may be as follows:

$$4Al + 3SnO_2 \rightarrow 3Sn + 2Al_2O_3 \quad (\Delta G = -1621.35\,\mathrm{KJ/mol} < 0) \qquad (1)$$

Table 1
Specification for ABOw/Al composites with different SnO_2 coating contents.

Mass ratio between whisker and coating	SnO_2 coating contents in composites (mass%)	Composites
6:1	3.45%	6ABOw/SnO/Al
10:1	2.10%	10ABOw/SnO/Al
20:1	1.06%	20ABOw/SnO/Al