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Microstructure of laser melted $Al_{18}B_4O_{33}$w/2024Al composite

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Abstract

The microstructure of a laser treated $Al_{18}B_4O_{33}$w/2024Al composite has been investigated using transmission electron microscope (TEM), low-angle (glancing angle) X-ray diffraction (XRD) techniques. Various surface microstructures were observed in the laser treated composite. The $Al_{18}B_4O_{33}$ whisker on the surface of the composite was decomposed during laser surface melting, various decomposition products were studied in the laser treated composite. Eutectic phases and the precipitation in the matrix of the composite with laser-treated were observed. The main phases detected in the molten zone were aluminum and decomposition products Al_2O_3. The effect of laser treatment on the hardness of the composite was also examined. A surface hardness of 400 Hv was noted.

Keywords: $Al_{18}B_4O_{33}$w/2024Al composite; Laser treatment; Microstructure; Hardness

1. Introduction

In recent years there has been interest in improving the corrosion performance of metal and metal matrix composite by laser techniques [1,2]. The techniques principally involved are laser surface melting (LSM) and laser surface alloying (LSA). A range of unique microstructures is produced by these techniques resulting from the non-equilibrium cooling conditions established when the relatively thin laser melted surface layer is allowed to resolidify in contact with the unaffected substrate which provides a large heat sink.

Pinto et al. [3] studied the variations of microstructure and hardness throughout samples of an aluminium–copper alloy submitted to a laser surface melting treatment. Mechanical Vickers hardness measurements had been carried out along the laser-treated cross-sections, and it was found that values of hardness can be increased greatly compared with the original substrate, confirming the effectiveness of the laser treatment.

As a new material, alumina borate whisker ($Al_{18}B_4O_{33}$w) reinforced aluminum composites have been attracted interest because of their good mechanical properties, thermal expansion coefficients and low cost [4–7]. However, little research has been carried out on the effect of laser treatment on the microstructures and properties of composites.

A detailed study was needed on the laser-treated microstructural evolution. Thus, the objective of the present communication was to analyze the microstructural characterization and evolution of a laser melted $Al_{18}B_4O_{33}$w/2024 composite developed in the present study.

2. Experimental procedures

The material used in this study was a 20 vol.% $Al_{18}B_4O_{33}$ whisker reinforced AA2024 composite, which was fabricated by squeeze casting. The whisker with 0.5–1 μm diameter and 10–30 μm length was provided by a Japanese chemical company (Shikoku Chemical Co. Ltd.). The composition of the selected 2024 alloy is as follows: 4.4 wt.% Cu, 1.5 wt.% Mg, 0.6 wt.% Mn, 0.5 wt.% Si, <0.5 wt.% Fe and balance Al. The preheating temperature of the mold and perform was about 500 °C, and the melting 2024 alloy was 700–750 °C, die pressure was about 100 MPa. The composite microstructure is shown in Fig. 1. It can be seen that the whisker is uniformly distributed in the composite.

A pulsed YAG laser installation was used to produce surface treatment on the composite. The pulse laser has a wavelength of 1064 nm, laser surface treatment was performed under N_2 surroundings with a flow rate of 120 L/min. Pulse duration was

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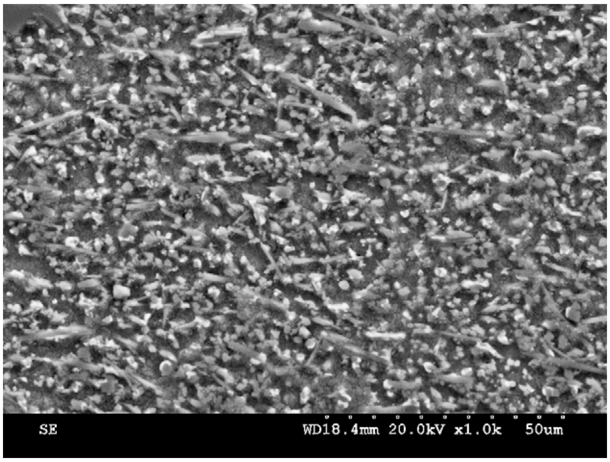

Fig. 1. The microstructure of the $Al_{18}B_4O_{33}$/2024Al composite.

fixed at 4.5 ms, and pulse frequency was fixed at 16 Hz. A 1.9 mm diameter laser beam with laser power of 1900 W was used to scan over the surface of the specimen at velocity of 255 mm/min, and a 25% overlap condition was used.

Transmission electron microscope (TEM) analysis of the microstructures of the surface layer by laser melting was carried out on a Philips CM12 TEM with an operating voltage of 120 kV. Energy dispersive analysis of X-ray (EDAX) was employed during TEM observation to examine the phase composition in laser melted surface layer. The surface of the laser-treated specimen for TEM observation was ground with 1000 grit SiC paper lightly, so that the coarse surface as a result of laser melting can be removed. Thin TEM slices, was mechanically abraded to a thickness of 30 μm from the bottom of the specimen relative to the laser melted surface. This was followed by ion milling, which was performed by Ar^+ bombardment at 5 KeV using a precision polishing system. Initially, the angle of ion milling was set at 10°; at the final stage, an angle 5° was used and processing was performed at 3 KeV.

Before and after the laser treatment, the crystalline phases of the composite were determined using a low-angle (glancing angle was fixed at 1°) X-ray diffraction measurement technique.

Microhardness tests were performed on the cross-sections of the composite with laser-treated with a Vickers tester using a 0.2 kg load.

3. Results and discussion

3.1. Laser melting microstructure

Fig. 2 shows the morphology and corresponding selected area diffraction pattern (SADP) of the whisker with incomplete shape and the interfacial phase (interphase) with regular shape. The SADP identifies the incomplete whisker as $Al_{18}B_4O_{33}$ and the interphase as θ-phase (Al_2Cu), the EDAX analysis also indicated the atomic ratio of Al and Cu in the interphase was 2:1, so the interphase can be determined as the θ-phase (Al_2Cu). The θ-phase is precipitation at the interface in the composite during squeeze casting, which has been well studied [8]. The presence of the incomplete whisker (shown in Fig. 2) indicated that the decomposition of whisker can occur during laser process.

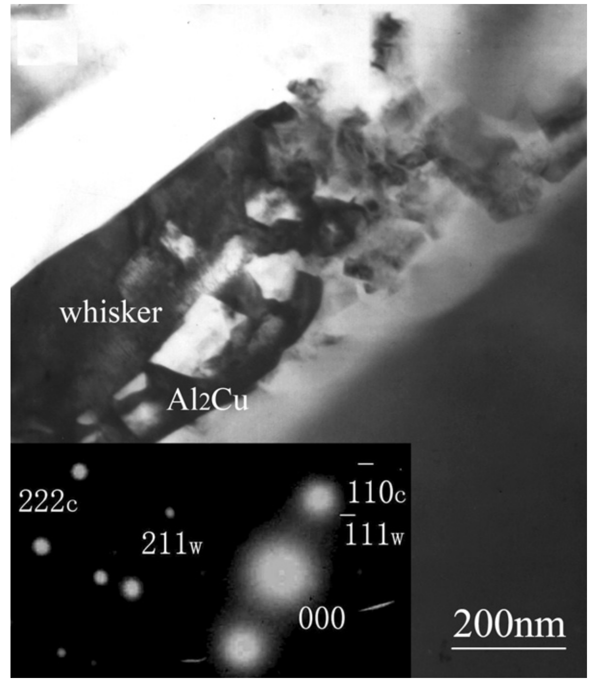

Fig. 2. TEM micrograph and corresponding SADP of the whisker with incomplete shape and the interphase with regular shape (W: whisker; C: Al_2Cu).

Fig. 3 is the TEM morphologies and corresponding SADPs of the bulk-shape decomposition products. They are determined as B_2O_3 (as shown in Fig. 3(a)) and γ-Al_2O_3 (as shown in Fig. 3(b)), respectively. The presence of γ-Al_2O_3 and B_2O_3 in the composite with laser-treated indicated that the whisker in the laser-treated composite had been decomposed due to laser radiation. The $Al_{18}B_4O_{33}$ decomposition can be described as follows:

$$Al_{18}B_4O_{33} \rightarrow 9\gamma\text{-}Al_2O_3 + 2B_2O_3 \quad (1)$$

Fig. 4 shows the X-ray diffraction profiles of the surface layers of the untreated and the laser treated specimens. For the untreated specimen, diffraction peaks assigned to Al, $Al_{18}B_4O_{33}$ whisker and Al_2Cu, were clearly identified. After laser treatment, the amount of whisker peaks reduced markedly, and the Al_2Cu peaks were absent basically. Many of new diffraction peaks appeared in Fig. 4. The new peaks belonging to γ-Al_2O_3 and α-Al_2O_3 were clearly defined for the laser treated specimen. The results of XRD give a further proof that the whiskers in the laser-treated specimen had been decomposed and the decomposition products of whiskers contain Al_2O_3.

There is no difficulty to understand a fact that a high temperature can be generated at the surface with laser-treated since laser radiation, thus the transformation of γ-Al_2O_3 (as the decomposition produces of whiskers) to α-Al_2O_3 can occur at the laser melted surface owing to α-Al_2O_3 is more steady at high temperature than that of γ-Al_2O_3. The existence of γ-Al_2O_3 and α-Al_2O_3 can be confirmed according to the results of X-ray analysis for the laser treated specimen.