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Short communication

Relation between thermal effect and phase transformation of aluminium matrix surface composite adding Al-based amorphous fabricated by FSP

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ABSTRACT

Thermal analysis and phase transformation of aluminium matrix surface composite adding Al-based amorphous fabricated by FSP was studied. The test result indicated that the surface composite mainly is composed of a large number of nano structures. Al–Cu–Mg precipitated phases and incomplete crystallization amorphous phases form the in a nano-structure matrix. The exothermic area of base metal is bigger than the one of the surface composites. The incomplete crystallization amorphous materials could experience the liquification and endothermic process: $Al_{84.2}Ni_{10}La_{2.1} \rightarrow$ fcc-Al + $NiAl_3$ + La_3Al_{11}. Moreover, the thermal stability of the surface composites is higher than that of the base metal.

Friction stir welding (FSW) is a solid state joining method particularly well suited for aluminium alloys, which was invented by the Welding Institute in 1991 [1]. During FSW, the material to be joined experiences an elevated temperature, large plastic deformation and stress. Friction stir processing, FSP, which is based on the basic principles of friction stir welding, has attracted a lot of attention as a new solid-state processing technique for microstructural modification and preparation of composites. FSP has been also successfully used to obtain the metal matrix composites and the surface composite [2,3]. In our previous studies [4], a novel aluminium matrix surface composite adding amorphous $Al_{84.2}Ni_{10}La_{2.1}$ strip was fabricated by friction stir processing. The surface composite added the amorphous strip had the lower *i*corr, corrosion current density, and the higher passivation current than the surface composite without amorphous strip added. In addition, a large number of ultrafine grains which was composed of the α-Al and α-Al amorphous structures were observed in the surface composite. The grain size range of them is 90–400 nm. However, some questions still need to be discussed and analyzed. For example, how did the change of these interesting amorphous structures caused? What is the reason to enhance the surface corrosion resistance? Therefore, some factors as the relation between the ultra-fine grain and the original structure, the crystallization of the amorphous strip and the phase transformation still need to be analyzed and discussed. In this letter, the differential thermal analysis (DSC), X-rays diffraction analysis (XRD) and transmission electron microscope (TEM) were used to study the relation between the thermal process and the phase constitutions of the surface composites produced by FSP. The aim is to show the micro-mechanism of the microstructural transformation and thermal effect.

The test materials are 5A06 aluminium alloys and $Al_{84.2}Ni_{10}La_{2.1}$ amorphous materials. The thin Al–Ni–La amorphous strip (65 μm) is used as an auxiliary material. According to our previous research [4], a groove, which is 0.5 mm width and 1.0 mm depth, was prepared at the edge of the pin in the advancing side. Then, the amorphous strip with 0.5 mm–0.8 mm width was embedded in the test plate before processing. At last, these workpieces were fixed at an operation table. At this time, a stir tool with the columnar shape shoulder (18 mm) and the screwed pin (4 mm) penetrated into the test plate until the head face of the shoulder reaches 0.5 mm under upper surface. The rotational speed of the stir tool is 500–1000 rpm, and the travel speed is 70 mm/min along the center line. After processing, a surface composite with 6 mm depth can be obtained. A series of specimens were cut from the surface composite along a longitudinal direction by lining cutting machine and

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made into metallographic samples.

The microstructure of the surface composite was observed and analyzed by means of TEM. Phase constituents of the surface composite were analyzed by XRD using the X-ray diffraction instrument of Rigaku-2500 type was used. Fine microstructure characterizations of the surface composite were performed by a Hitachi H-800 TEM. The thermal analysis of the surface composite was performed by means of a Netzsch thermal analysis instrument.

According to our previous research [4] by TEM analysis, a typical structure different from base metal shows between the Al-based amorphous reinforced materials and the substrate metals. A large number of fine structure shows a polygonal and irregular bulk shape. By means of the simple calculation, the grain size range of these bulk structures is 90–400 nm, and reaches to nanometer level. The a-Al phase and a-Al amorphous structure mainly constitutes the nano structures. The zone axis of these nano structures is B = [110] [4]. This indicates that these nano structures observed were closely related to Al-based amorphous reinforced materials.

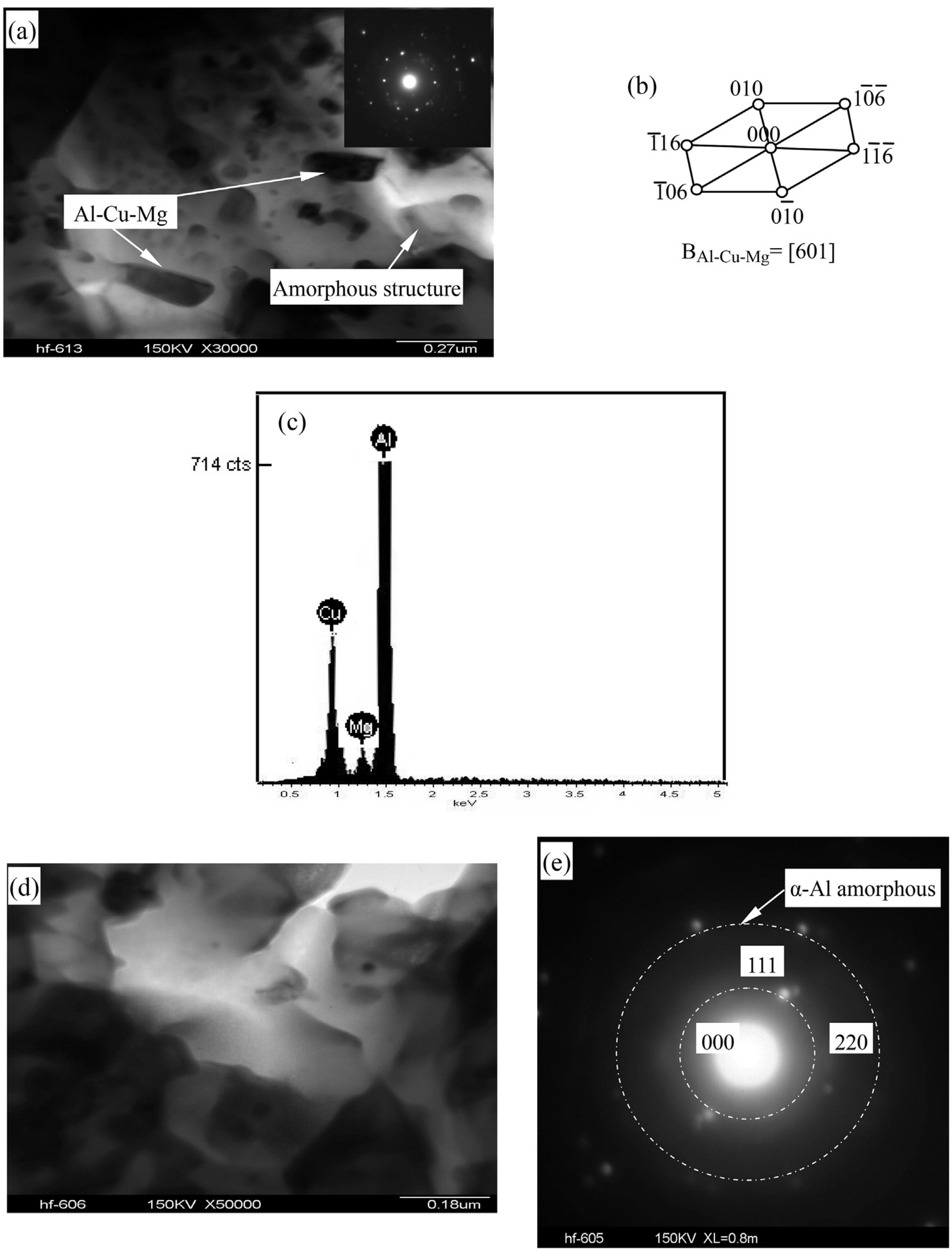

Fig. 1. TEM analysis of Al–Cu–Mg phase with amorphous structure: (a) TEM image and electron diffraction pattern of composite; (b) schematic index diagram of panel for Al–Cu–Mg precipitated phases; (c) EDS results of Al–Cu–Mg precipitated phases; (d) TEM image for α-Al amorphous; (e) electron diffraction pattern and schematic index diagram of panel for fcc-Al and α-Al amorphous.