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EBSD Characterization of the Laser Remelted Surface Layers in a Commercially Pure Mg

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Laser surface melting has been applied on a commercially pure Mg. The microstructure and texture modifications encountered in the surface layers were carefully investigated by using electron backscattered diffraction (EBSD) technique. Due to the melting followed by rapid solidification and cooling, a layer having graded microstructures and texture formed. At the bottom of the melted layer, the solidified Mg grains have an elongated shape with a <0001> basal fibre texture nearly parallel to sample normal direction, while equiaxed grains were observed in the top melted layer having a much weaker basal fibre texture. Solidification twinning and deformation twinning were found in the vicinity of the melt/substrate interface where the Mg grains grow larger due to the heating. In addition, no epitaxial type grain growth was observed at the melt/substrate interface.

KEY WORDS: Pure Mg; Laser surface melting; Solidification; Texture

1. Introduction

In the past decade, the research, development and application of Mg based alloys have attracted worldwide attention. Compared to other metallic materials, Mg alloys have their own advantages, such as low density, high specific strength and stiffness as well as other functional properties (e.g. good electromagnetic shielding, good damping ability). These properties make Mg alloys the potential substitutes for ferrous or even aluminium alloys to be used in automotive, aerospace and electronic industries for weight and energy saving purposes[1,2]. However, Mg alloys are also known to have poor ductility due to the anisotropic deformation mode of their hexagonal crystal structure and the development of so called “based texture” during deformation [3]. Besides, the poor wear and corrosion resistances of Mg alloys also limit their further industrial applications. These surface related properties are important factors determining the service life time of work pieces made by Mg alloys. Generally, good mechanical properties and good surface properties can hardly be achieved in one Mg alloy through simple alloying or heat treatment. Therefore, it is essential to apply surface modification techniques on those commercial Mg alloys so that their global performances can be improved. It is already established that physical vapour deposition, chemical vapour deposition, sol–gel methods, anodic oxidation and pulsed energetic beam treatment techniques can be used to generate protective layers onto Mg alloys with improved wear or corrosion resistances[2,4,5]. However, these layers are usually quite thin, often in micrometre scale. Also, their quality is not easy to be controlled, including the porosity, the defects in films and the adhesion between films and Mg substrates.

Laser surface melting and laser cladding have also been used to treat Mg alloys and improved surface properties are obtained. The advantages of using laser surface treatment lie in the thick treated layer and the strong metallurgical bonding between the treated layer and the Mg substrates[6,7]. Gao et al.[8] have attempted laser cladding on Mg alloys and improved wear and corrosion resistances were obtained. However, the mechanisms related to the microstructure development and grain growth behaviours during laser melting and solidification in the remelted layer are still not clear yet. Considering the above, laser surface melting was applied on a commercially pure Mg in the present work. The aim was to investigate the microstructure modifications and grain growth behaviours in the laser melted layer. The microstructure and texture modifications in the laser remelted layer were investigated in details by using electron backscattered diffraction (EBSD) technique.

2. Experimental

2.1. Sample preparation

Commercial purity magnesium was selected in the present work to prevent any other side effects from alloying elements

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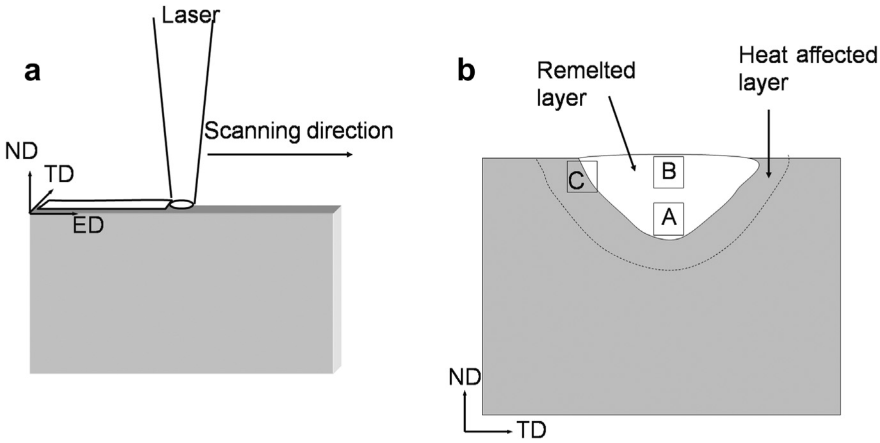

Fig. 1 Sketches showing the laser surface treatment (a) and selected areas A, B, C on the cross section analyzed by EBSD (b).

and precipitates. Samples with a cube shape (dimension: 10 mm × 9 mm × 12 mm) for laser treatments were cut from a hot extruded bar. The longest dimension was set parallel to the extrusion direction (ED). It was also set perpendicular to the laser beam and parallel to the beam scanning direction for the laser treatment. A sketch map showing the laser treatment on the Mg sample is given in Fig. 1(a). Prior to the laser remelting treatment, samples were heat treated at 723 K for 30 min in argon atmosphere in order to obtain a homogenised and fully recrystallized microstructure.

An HL-2000 type CO_2 laser beam source was used to do the laser surface melting treatment on pure Mg samples. The laser beam parameters were set as follows: beam diameter 5 mm, beam power 1000 W, scanning speed 6 mm/s. Pure Ar was used as the protective gas during laser treatment in order to prevent the oxidation of Mg.

2.2. EBSD characterizations

After laser treatment but prior to the EBSD and scanning electron microscopy (SEM) observations, one face of the samples, perpendicular to the scanning direction, was ground by standard emery paper from 600 to 1200 grades and further polished using a 1 μm diamond suspension. This was followed by electrolytic polishing in a Nital solution (10% nitric acid in ethanol) using the following parameters: applied voltage ∼30 V, current density ∼0.8 A/cm^2 and duration 30−40 s. A Hitachi S-570 scanning electron microscope equipped with an HKL EBSD system was used to observe the microstructure and gain more information about crystallographic orientation of grains in the selected areas. A sketch showing the areas selected from cross section of the treated sample is given in Fig. 1(b). Three areas were chosen to be analyzed by EBSD. They were labelled by A, B, C and located at the bottom of the melted layer, the top of the melted layer, and the melt/substrate interface, respectively. For the EBSD analysis, the SEM was operated at 15 kV with the sample tilted by 70°. The recording and indexing of the pseudo-Kikuchi lines were made with the software CHANNEL5. For all the EBSD maps shown here, low angle boundaries, from 2° to 15°, are shown in white while high angle ones (>15°) are shown in black. Also, the orientation maps are all plotted for crystallographic directions parallel to the normal direction (ND).

3. Results

Fig. 2(a) shows a typical EBSD orientation map taken on the initial sample, prior to laser treatment. The colours of the grains represent the crystallographic orientations parallel to the compression direction as illustrated by the standard triangle shown in Fig. 2. After annealing at 723 K for 30 min, the fully recrystallized sample shows a nearly equiaxed structure with an average grain size of about 85 μm. It is worth noting here that some of the grains are much larger than their surrounding grains, as arrowed in Fig. 2(a). They may result from abnormal grain growth at high temperature. Such unusually large grains were

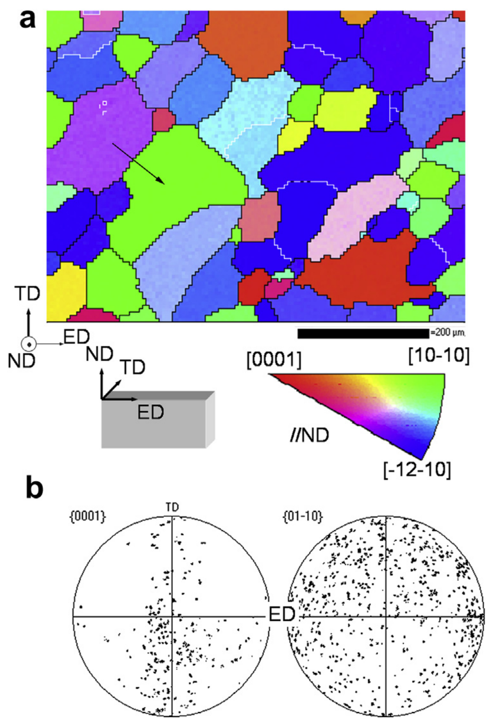

Fig. 2 (a) EBSD map of the initial sample after annealing at 723 K for 30 min showing high angle (black) and low angle (white) boundaries (CD refers to the compression direction of the sample); (b) {0001} and {10−10} stereographic pole figures corresponding to (a), where CD is again horizontal.