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Zn-Al Alloy Coating Induced by Ultrafast Laser Heat Treatment

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Abstract

In this study, Zn-Al alloy composite coating was fabricated on AZ31 magnesium alloys substrate by ultrafast laser heat processing. The ultrafast laser system were performed with 30% overlap. The microstructures were examined by optical microscope and SEM, and phase constitution of the samples was investigated by X-ray diffraction. The results showed that the average size of coarse grain is about 150 μm, and microstructure of AZ31 magnesium substrate consisted of coarse dendrites and interdendritic structures. The light dendrites were α-Mg solid solution, while β-$Mg_{17}Al_{12}$ phases as precipitated secondary phase were distributed in the interdendritic structures. SEM image exhibited continuous corrugation on the surface of Zn-Al alloy coating. The results of XRD pattern indicated that the Mg_7Zn_3, $MgZn_2$, $Mg_{17}Al_{12}$, and Mg_3Al_2 phases were generated after ultrafast laser treatment.

Keywords

Ultrafast laser, Magnesium alloy, microstructure, Zn-Al alloy.

1. Introduction

The excellent properties of magnesium alloys are considered as good candidates for many structural components in industry. In addition, AZ31 magnesium alloys are attractive increasingly for their combination of outstanding properties such as low density, high specific strength and stiffness and high mechanical damping capability [1,2]. However, its poor surface property was the main factors limiting the application of magnesium alloy. In order to further expand the application of magnesium alloys, surface modification processes such as chemical conversion coatings [3], plasma electrolytic oxidation [4,5], thermal spray technology [6], PVD [7] and laser surface treatment [8,9] have been applied to improve surface properties of Mg alloy.

The Zn-Al alloy has been shown to possess favorable combination of physical, mechanical and technological characteristics with low melting point, high strength, exceptional castability, easy machinability, high corrosion resistance, as well as excellent bearing and wear resistance properties [10,11]. Furthermore, this alloy also exhibits good ultimate strength and elongation percent at room and elevated temperatures [12]. The ZA27 alloy coting can be used to improve surface property of Mg alloy. It was reported [13]that the wear and corrosion resistance of magnesium alloy were markedly enhanced by Zn-Al thermal diffusion coating.

Hence the aim of this work was to produce Zn-Al alloy coating on the surface of AZ31Mg alloy by ultrafast laser treated, which can overcome the application limition of Mg alloy. The surface microstructure of Zn-Al alloy coating was observed, and phase constitution and chemical composition were confirmed.

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2. Materials and Methods

2.1. Coatings Preparation

The Zn-Al alloy foils were used as coating material with dimensions of 15 mm × 15 mm × 0.1 mm. And the chemical compositions of Zn-Al alloy foil were Zn 27 wt.% and Al 73 wt.%. The commercially AZ31 Mg alloys were used as matrix material with the chemical compositions of Al 3.07 wt.%, Zn 0.90 wt.%, and Mg the balance, which were cut into 15 mm × 15 mm × 10 mm and ultrasonically cleaned with acetone (5 min) and methanol (5 min) orderly, respectively. The Zn-Al alloy foils were pressed on the surface of AZ31 Mg substrate.

2.2. Ultrafast Laser Treatment

These prepared samples were attached to a sample holder and mounted on a mobile platform driven by two orthogonal micrometer precision axes with computer controlled motors. Fig. 1 shows a schematic of the ultrafast laser treatment. A frequency-tripled, Q-switched, single-mode Nd:YAG laser (Spectra-Physics) with a 355 nm emission wavelength, 10 Hz frequency and 10 ns pulse duration was used for these experiments.

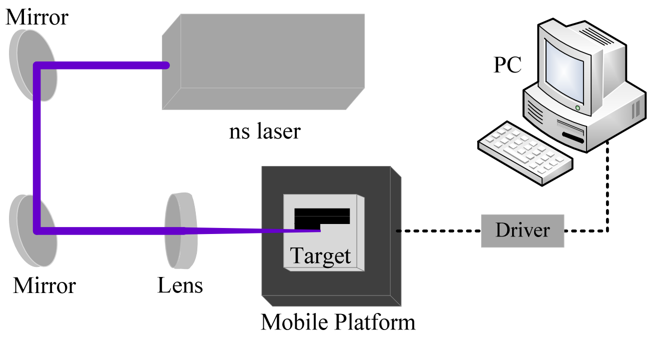

Fig. 1. Schematic for the ultrafast laser treatment system

A focal ns laser beam was used to irradiate the samples by using a lens with a 100 mm focus. A 15 mm × 15 mm rectangle was obtained by moving the two-dimensional platform in S-line sweep to change the laser spot position on the sample surface. The translation of the sample under the laser beam in perpendicular directions was depicted schematically in Fig. 2. The average number of laser pulses on any part of the surface was determined from the scan speed, laser spot size on the sample surface laser repetition rate, and the interval of two adjacent lines. Therefore, the number of deposited pulses was determined from the scan speed in these experiments. Most of the experiments in this work were performed with 30% overlap.

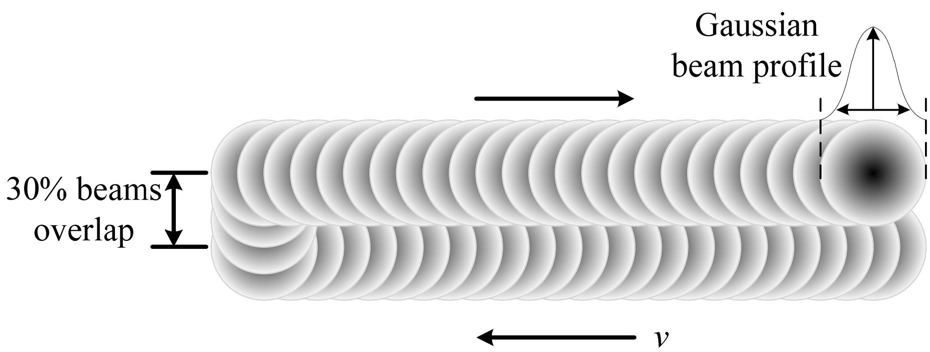

Fig. 2. Schematic for the ultrafast laser treatment system

2.3. Microstructural Characterization

Microstructure of Mg substrate was characterized by an optical microscope (OM), and the surface morphology and elemental analysis of the Zn-Al alloy coatings via treated ultrafast laser pulses were conducted using SEM. Phase analysis of the samples was identified by X-ray diffraction (XRD; D/Max 2500PC, Rigaku, Japan) with Cu Kα radiation. The scanning range was 15° to 80° with a continuous scanning speed of 2 °min^{-1}, and the working voltage and current were 40 kV and 250 mA, respectively.

3. Results and Discussion

An optical morphology of AZ31 Mg substrate is shown in Fig. 3a, from which it can be seen that microstructure of AZ31 Mg substrate is composed of coarse dendrites and interdendritic secondary phase.The average size of coarse grain is approximately 150 μm. According to the Mg-Al binary alloy phase diagram, the dark interdendritic precipitated phase is β-$Mg_{17}Al_{12}$ phase. The light microstructure in Fig. 3a is α-Mg solid solution, which can be identified by XRD pattern of AZ31 Mg substrate as shown in Fig. 3b.

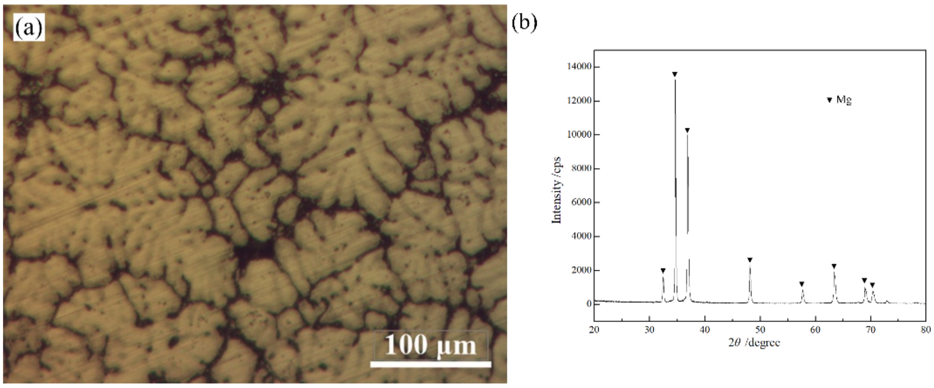

Fig. 3. (a) Optical microstructure (b) XRD pattern of AZ31 Mg substrate

Fig. 4a displays the SEM surface morphology of Zn-Al alloy coating on AZ31 Mg substrate treated by ultrafast laser pulses. As can be seen from Fig. 4a, the surface SEM image of Zn-Al alloy coating exhibits conspicuous corrugation features, the main cause of this structures is recast phenomenon in the ablation region via ns laser pulses irradiation. Moreover, compared to the XRD pattern of untreated of AZ31 substrate, the Mg_7Zn_3, $MgZn_2$, $Mg_{17}Al_{12}$, and Mg_3Al_2 phases can be found from the XRD pattern as seen in Fig. 4b.

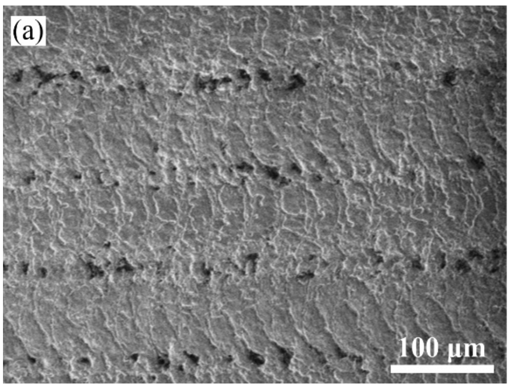

Fig. 4. (a) SEM image of AZ31 Mg alloy surface coated by Zn-Al alloy

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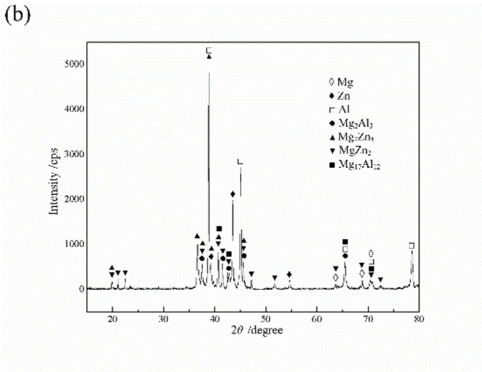

(b) XRD pattern of Zn-Al alloy coating

4. Conclusion

The Zn27Al alloy coating was successfully fabricated on the AZ31 magnesium alloy by ultrafast laser treatment. The experimental results indicated that some new phases were generated, such as Mg_7Zn_3, $MgZn_2$, $Mg_{17}Al_{12}$, and Mg_3Al_2 phases. In addition, continuous corrugation microstructures were formed on the surface of AZ31 Mg substrate.

Acknowledgements

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References

[1] M.K. Kulekci: Magnesium and its alloys applications in automotive industry: Int J Adv Manuf Technol, Vol. 39 (2008), p. 851-865.

[2] J. Wang, R.D. Liu, T.J. Luo, Y.S. Yang: A high strength and ductility Mg-Zn-Al-Cu-Mn magnesium alloy: Materials and Design, Vol. 47 (2013), p. 746-749.

[3] B.S. Liu, Y.H. Wei, L.F. Hou: Formation mechanism of discoloration on die-cast AZ91D components surface after chemical conversion: J Mater Eng Perform, Vol. 22 (2013) No. 1, p. 50-56.

[4] P. Bala Srinivasan, L. Liang, C. Blawert, M. Störmer, W. Dietzel: Development of decorative and corrosion resistant plasma electrolytic oxidation coatings on AM50 magnesium alloy: Surface Engineering, Vol. 26 (2010) No. 5, p. 367-370.

[5] A. Ghasemi, N. Scharnagl, C. Blawert, W. Dietzel, K.U. Kainer: Influence of electrolyte constituents on corrosion behavior of PEO coatings on magnesium alloys: Surface Engineering, Vol. 26 (2010) No.5, p.361-367.

[6] M. Parco, L.D. Zhao, J. Zwick, K. Bobzin, E. Lugscheider: Investigation of HVOF spraying on magnesium alloys: Surf Coat Tech, Vol. 201 (2006), p. 3269-3274.

[7] H. Altum, S. Sen: The effect of PVD coatings on the corrosion behavior of AZ91 magnesium alloy: Materials and Design, Vol. 27 (2006), p. 1174-1179.

[8] C. Taltavull, B. Torres, A,J, López, P. Rodrigo: Selective laser surface melting of a magnesium-aluminium alloy: Materials Letters, Vol. 85 (2012), p. 98-101.

[9] B.J. Zheng, X.M. Chen, J.S. Lian: Microstructure and wear property of laser cladding Al+SiC powders on AZ91D magnesium alloy: Opt Laser Eng, Vol, 48 (2010), p.526-532.

[10] E.J. Kubel Jr.: Expanding horizons for ZA alloys: Adv Metal Prog, Vol. 7 (1987), p. 51-57.

ISSN: 2688-8653

[11] E. Gervais, R.J. Barnhurst, C.A. Loong: An analysis of selected properties of ZA alloys: JOM, Vol. 11 (1985), p. 43-47.

[12] S.Q. Yan, J.P. Xie, Z.X. Liu, W.Y. Wang, A.Q. Wang, J.W. Li: Influence of different Al contents on microstructure, tensile and wear properties of Zn-based alloy: J Mater Sci Technol, Vol. 26 (2010) No. 7, p. 648-652.

[13] A. Sun, X.M. Sui, H.T. Li, Q. Wang: Interface microstructure and mechanical properties of zinc-aluminum thermal diffusion coating on AZ31 magnesium alloy: Materials and Design, Vol. 67 (2015), p. 280-284.