LASER CLADDING OF $Cu_{0.5}$NiAlCoCrFeSi HIGH ENTROPY ALLOY ON AZ91D MAGNESIUM SUBSTRATES

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Introduction

High entropy alloys (HEAs) made up of more than five principal metallic elements in equimolar or near-equimolar ratios were first fabricated by Yeh [1, 2]. These alloys are unique for they have simple solid solution structures, essentially BCC and/or FCC phases [3]; moreover, they exhibit good wear resistance, excellent corrosion resistance, excellent oxidation resistance, low electrical conductivity, low thermal conductivity and low coefficient of thermal expansion. Up to the present, most of the studies of HEAs have been concerned with the microstructure and properties of cast materials and only a limited number of studies focused on using them for surface modification. In this study, laser cladding was employed to deposit $Cu_{0.5}$NiAlCoCrFeSi HEA on AZ91D magnesium substrates with the aim of improving the wear and corrosion resistance of the Mg alloy.

Experimental

Laser cladding of mixed powders of Cu, Ni, Al, Co, Cr, Fe and Si was conducted on AZ91D Mg substrates. The powders were premixed by means of ball milling with the nominal composition of $Cu_{0.5}$NiAlCoCrFeSi. The mixed powder was pre-placed on the Mg substrate using a pasting binder. A high power Rofin TR050 CO_2 laser was employed for track melting under an Ar-shielding atmosphere. The laser spot diameter and laser power were kept constant at 4mm and 3000W, respectively. The wear resistance of the laser-clad coating was evaluated using a block-on-ring dry sliding wear tester; the ring was made of a hardened bearing steel (Fe-1.0C-1.5Cr-0.25Si-3.0Mn) with a hardness of $HV_{0.1}$700.

Results and discussion

Fig. 1 shows the interface between the laser-clad HEA coating and the Mg substrate, which reveals that no major defects, such as cracks and porosity were present. The coating has a fine dendritic structure (Fig. 2a) with a band of cellular dendrites growing from the bottom of the coating (Fig. 2b) in a direction towards the substrate. Such a backward cellular growth phenomenon in laser cladding has been reported by the author previously [4], and was attributed to the presence of a relatively low melting point liquid phase at the coating interface. An XRD analysis showed that intermetallic compounds: hexagonal $(Si,Al)_2Cr$, cubic Al_4CrNi_{15}, rhombohedral $Al_{58.5}Cr_{10.3}Fe_{31.2}$, cubic FeNi and hexagonal $AlNi_6Si_3$ were present. A TEM study revealed that most of these intermetallics are in nano scale (Fig. 3), and they are embedded in a simple BCC solid solution structure of the matrix.

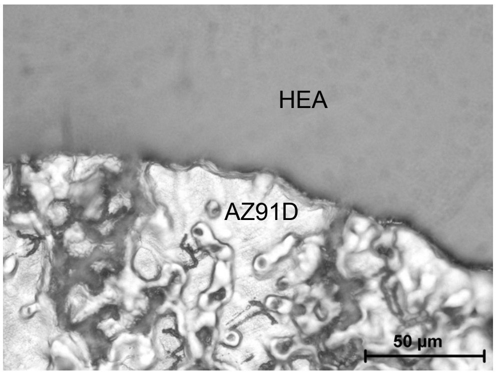

Fig. 1 The interface between the HEA coating and the Mg substrate.

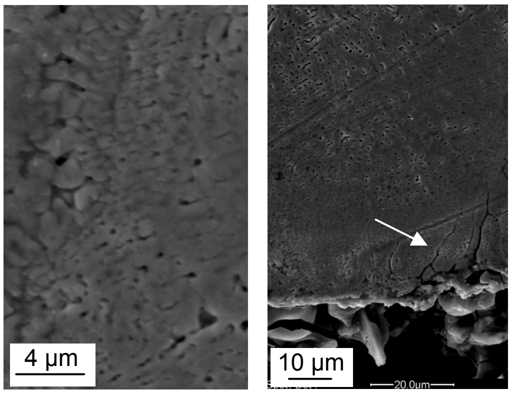

Fig. 2 (a) Coating dendritic structure, (b) Cellular growth at the interface.

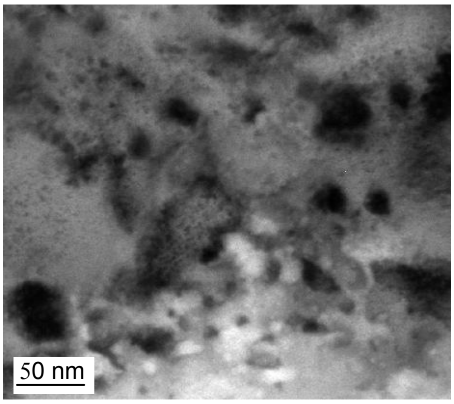

Fig. 3 TEM image of a HEA coating, showing nano size compounds.

Fig. 4 presents the hardness of the HEA coating as a distance from the laser-clad surface. The results showed that the hardness of the coating was approximately ten times higher than that of the substrate and was even higher than that of the $Cu_{0.5}$NiAlCoCrFeSi HEA fabricated by arc melting (860HV). The extremely high hardness of the laser-clad coating was attributed to the presence of a relatively large amount of nano-size intermetallics.

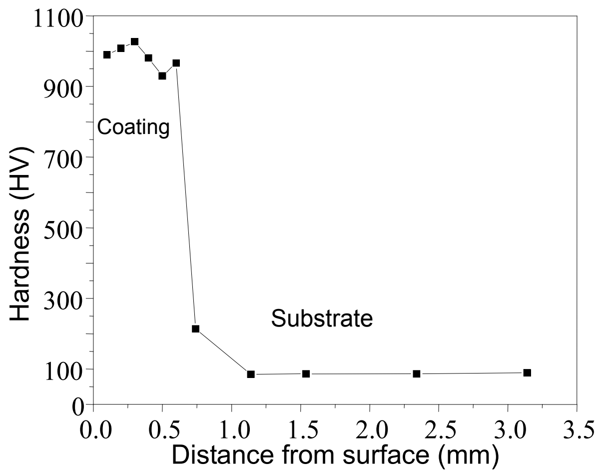

Fig. 4 Hardness across the HEA coating.

Fig. 5 shows the wear test weight loss results of the laser-clad HEA specimen and the uncoated specimen. The results showed that the wear resistance of the HEA coating was superior to that of the AZ91D substrate, and the weight loss of the former was some five times less than that of the latter and this is in accord with their corresponding hardness. An examination of the worn surface of the laser-clad specimen showed that it suffered severe abrasive wear. This is evident by having a considerably amount of small particles of wear debris found on the surface. The results of an EDS analysis showed that these particles were mainly iron oxides. Since the hardness of the HEA coating is higher than that of the hardened bearing steel ring, a fair amount of iron was sheared off and formed oxides on the worn surface of the coating. At the same time, the intermetallic compounds of the coating would be broken up by the sliding action and smeared along the surface. In fact, high temperature oxidation would also occur in the wear process.

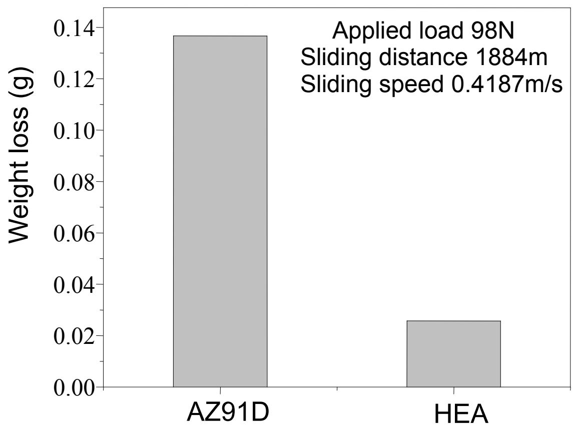

Fig. 5 Weight loss measurements.

Conclusion

The $Cu_{0.5}$NiAlCoCrFeSi HEA coating was successfully fabricated on AZ91D magnesium substrates by laser cladding using mixed powders of Cu, Ni, Al, Co, Cr, Fe and Si. The HEA coating consists of fine dendrites with a large amount of nano-size intermetallics. Under the dry sliding wear condition, the wear resistance of the laser-clad HEA coating was significantly higher than that of the uncoated magnesium material. The main wear mechanism of the HEA coating was dominant by abrasive wear.

Acknowledgements

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