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Synthesis and characterization of FeCoNiCrCu high-entropy alloy coating by laser cladding

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The influences of Si (1.2 mol.%), Mn (1.2 mol.%) and Mo (2.8 mol.%) additions on the microstructure, properties and coating quality of laser cladded FeCoNiCrCu high-entropy alloy coating have been investigated. The multi-component alloy coating is found to be a simple face-centered cubic (FCC) solid solution with less component segregation and high corrosion resistance, microhardness and softening resistance properties. For the coating without Si, Mn and Mo additions, the microstructure is mainly composed of columnar and equiaxed grains with uniformly distributed alloying elements. The microhardness reaches 375 $HV_{0.5}$, which is about 50% higher than that of the same alloy prepared by arc melting technique. But the coating quality is very poor. While for the coating with Si, Mn and Mo additions, the coating quality is greatly improved, the microhardness increases to 450 $HV_{0.5}$, but the microstructure transforms to dendrite due to a slightly increase in component segregation.

1. Introduction

High-entropy alloys (HEAs) are defined as the alloys that contain at least five principal elements with each elemental concentration ranging from 5 to 35 at.%. Because of the high mixing entropy, these alloys are usually composed of simple solid solution phase rather than complex brittle phases after solidification. These particular structures with proper composition may offer the HEAs with promising applications due to high strength, low electrical conductivity and good resistances to oxidation and corrosion [1–3].

So far, arc melting technique or casting methods have been adopted to make the HEAs bulk ingots in most published works [4,5]. These techniques have a limited size of ingot, because the formation of simple solid solution phase in the HEAs requires high cooling rate. In addition, as the alloys containing many expensive elements, it costs much high in the preparation of bulk materials. Therefore, it is attractive to prepare high performance HEA coatings on the low-cost steel substrates. Recently, it has been reported that the HEA films were successfully prepared by magnetron sputtering [6] and electrochemical methods [7]. The thickness of the films prepared by these techniques is too thin to meet the mechanical requirements in the machinery industry.

Laser cladding, as a rapidly developed surface treatment technique, is to fuse a designed alloy coating with about 1–5 mm thickness on the surface of a substrate. It has the advantage of rapid solidification rate (10^4–10^6 °C s^{-1}), fine microstructure, excellent metallurgical bonding and little intermixing with the substrate. Furthermore, the rapid laser solidification process will lead to significant effect of non-equilibrium solute trapping, avoiding component segregation and improving solubility of the coating [8,9]. In this work, the laser cladding was used to prepare a high-entropy alloy coating with a nominal composition of FeCoNiCrCu. The effects of Si, Mn and Mo additions on the cladding quality, microstructure and hardness of the coating were also investigated.

2. Experimental procedures

2.1. Preparation of the coatings

The equiatomic Fe, Co, Ni, Cr, and Cu of the powder mixture, were prepared by mechanically mixing commercially pure elemental powders (99.7 wt.% minimum). The particle sizes of the powders were about 50 to 120 μm. The additives of Si (1.2 mol.%), Mn (1.2 mol.%) and Mo (2.8 mol.%) were added into the mixed FeCoNiCrCu powders as master alloys: ferrosilicon (Si: 77 wt.%), ferromanganese (Mn: 75 wt.%) and ferromolybdenum (Mo: 62 wt.%). The reason for using master alloys is to avoid the different melting points and densities of the nonmetallic elements. The mixed powders were pre-placed onto the surface of Q235 steel substrate (C: 0.17, Mn: 0.08, Si: 0.37, S: 0.039, P: 0.036, Fe: balance in mass percentage) to form powder bed with the thickness of 1.7–2.0 mm.

5 kW TJ-HLT5000 type continuous-wave CO_2-laser system was used for cladding. High-purity argon gas was used as shielding

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