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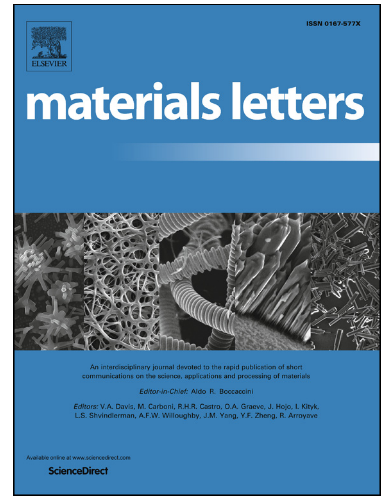

Microstructure evolution of copper/steel gradient deposition prepared using electron beam freeform fabrication

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Microstructure evolution of copper/steel gradient deposition prepared using electron beam freeform fabrication

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Abstract : Additive manufacturing of copper and steel gradient materials by electron beam freeform fabrication is a novel exploration. T2 copper was deposited on AISI-304 stainless steel in the experiment and the gradient depositions were obtained successfully. The results showed that the distribution of iron element was more uniform with the increase of copper layers. No iron-rich α phase could be found when the number of copper layer was greater than three. The supersaturated ε phases precipitated in globular α phases while there was no ε phase found in dendritic one. $FeCu_4$ metastable phases were found in the depositions duo to low cooling rate and ordering transformation.

Keywords: Electron beam freeform fabrication; Functional; Microstructure; Dissimilar materials; Gradient materials; Copper and steel

1. Introduction

Additive manufacturing (AM) have been developed rapidly in recent 20 years [1,2]. Wide range of materials had been fabricated using AM technology including steel [3,4], aluminum [5,6], titanium [7-9], Ni-based superalloys [10] and other metallic materials [11]. Electron beam freeform fabrication (EBF^3) has the advantage of large power, high efficiency and high energy utilization which makes it be well suitable for the rapid prototyping of refractory metal and large components. Besides, vacuum is beneficial to the manufacture of reactive metals.

A large number of dissimilar metal joints are required in the aerospace field. The joining of copper and steel is widely applied to the nozzle of high thrust rocket engine. It is difficult to obtain the joints of copper and steel with better performance by traditional welding methods because of the difference of physical properties between them. Copper would be burned seriously during electron beam welding (EBW) of copper and steel due to its low melting point, resulting in collapse of weld surface and other defects.

The copper/steel gradient material can be used as the transition joint in welding of copper and steel or other dissimilar materials, reducing the difficulty of joining of dissimilar materials, and providing a method for the preparation of gradient materials. The joining of copper and steel was mainly by welding, especially in lasering welding and EBW. For laser welding of copper and stainless steel (SS). The laser beam was deflected to the steel surface with 0.2mm deviation. Therefore, quite little amount of copper was found in the fusion zone [12]. Copper/SS joints could be obtained without any cracks and the iron side could grow into the weld with a local change in size [13]. Melting of copper in a small amount might be beneficial for the back-filling of microcracks, but the increase of the amount of molten copper would increase the number of microcracks [14]. Thick (25mm) copper/SS joints without defects were obtained using EB welding with high beam current (375mA) and low beam voltage (15kV) [15]. Electron beam welded copper/SS joints made with beam oscillation at optimum oscillation diameter (1 mm) possessed 100% more elongation at elevated temperature (400 ℃) and 67% more impact strength than its counterpart carried out without beam oscillation [16]. Copper and 304 SS dissimilar joints with sufficient strength were achieved and the maximum tensile strength was 250MPa [17].

The present study focuses on the microstructure evolution of electron beam freeform fabricated deposition of copper (T2) and AISI-304 SS. The microstructures of the deposition and interfaces between the neighboring layers were investigated in details.