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Copper layer formation with multi beam laser metal deposition with blue diode lasers for contribution of carbon neutral society

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Abstract

Copper is expected to have many applications due to its virus inactivation properties, but it has been difficult to produce thin layer with high bonding strength. To add a new function of virus inactivation property to the surface keeping the strength, it is necessary to develop a coating technology to form a copper layer on the surface. A multi-beam blue diode laser installed laser metal deposition (B-LMD) system was newly developed with an output power of 200W. As a result, Cu-Zn alloy layer was formed on the stainless-steel plate with no pores at the output power of 40 W and scanning speed of 4 mm/s. It was found that the cross-sectional area of coating layer was increased with increase the output power of laser in the Cu-Zn alloy coating. The addition of zinc to copper improves the energy efficiency for layer formation, and zinc concentration is found to be a factor that increases the energy efficiency.

Keywords: Copper; Blue diode laser; Coating; Cu-Zn alloy

1. Introduction

Copper is widely used in many electric parts such as a solenoid due to having a high thermal conductivity and a high electrical conductivity. As electric cars become more prevalent, the market demand for welding, cladding, and cutting of copper is increasing. Furthermore, the copper has excellent properties such as super antibacterial action and virus inactivation [(1-3)]. It is expected to be applied to parts that many people touch, such as handrails and doorknobs, for the prevention from infectious diseases. Therefore, many papers on copper film formation have been reported. Mizoshiri et al. reported that copper thin films form from CuO nanoparticles in a reduction reaction with a femtosecond laser [(4)], but the purity of copper is low since CuO

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remains in the layer. Mao et al. reported that the copper layer was deposited on the substrate by the chemical vapor deposition method with CO2 laser. It was difficult to form a thick layer over 1 µm [(5)]. In plasma transfer arc welding (PTA), copper or cop-per alloy thin films is possible to be formed on the metal substrate, since a plasma arc is used as a heat source. However, the plasma arc is difficult to control the heat input, and excessive heat input causes dilution of the substrate material into the layer [(6,7)]. Molleda et al. reported a furnace brazing process coated copper on carbon steel [(8)]. In their method, the original characteristics of the materials such as Cu and carbon steel are not exhibited be-cause the sample depends on the blazing material. Another issue with copper is that it oxidizes when exposed to the atmosphere, resulting in a black discoloration of the surface. Thus, we tried to form a Cu-Zn alloy layer with the addition of zinc to improve discoloration resistance by using a blue direct diode laser induced laser metal deposition method system [B-LMD].

2. Experimental setup for Cu alloy layer formation

2.1. Power material

A pure copper powder and Cu-Zn alloy powder, which were prepared via a pre-mixed atomization process from Mitsui Kinzoku co., were used in this study. The pure copper powder having a purity of 99.99%, was produced by a gas atomized method. The powder size was measured with a particle size distribution analyzer. The powder had a spherical shape with a particle size around 35 µm and standard deviation of 12 µm as shown in Fig.1(a). zinc was added into copper power to 20 wt% and 30 wt % to form the Cu-Zn alloys. Fig.1 (b) shows the Cu-Zn powder for addition of the 20 wt% zinc into copper.

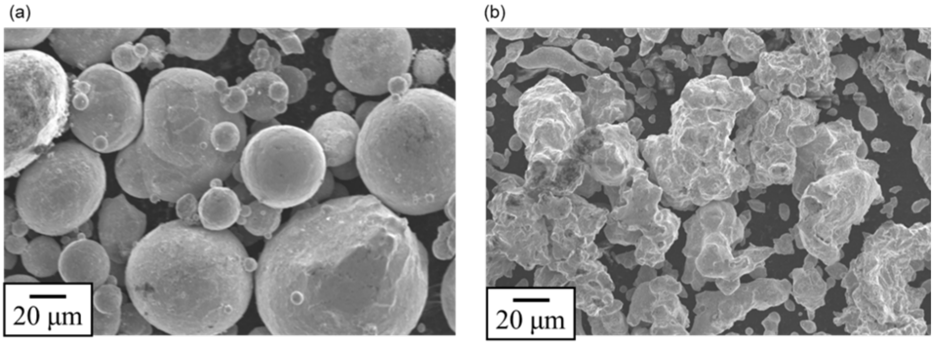

Fig.1. SEM image of power of (a) pure copper, (b) 80Cu-20Zn alloy

2.2. Experimental setup for copper layer formation with B-LMD

Figure 2 (a) shows the schematic diagram of experimental setup for a copper layer formation with B-LMD [(9-15)]. Two diode laser modules were employed. The output power and wavelength for the one module were 100 W and 450 nm, respectively. The two lasers were guided to the focusing head with optical fibers. Each fiber had a core diameter of 200 µm. The beam profile at the focal point of the combined two lasers was set to a spot diameter of 590 µm in the x axis direction and 530 µm in the y axis direction at full width at half maximum by a CCD camera. The processing head supplied the powder at a focal point from a center nozzle. A stain-less steel-type 304 substrate with a 1.0-mm thickness was used. When laser irradiation and powder feeding were simultaneously performed toward to the substrate, the powder melted and solidified on the substrate to form a copper layer. The output power was varied from 20 to 40W. The laser scanning speed and the powder feed rate were kept constant at 4 mm/s and 12 mg/s, respectively, and Ar gas was flowed at a rate of 10 L/min as a shield gas to prevent oxidation.

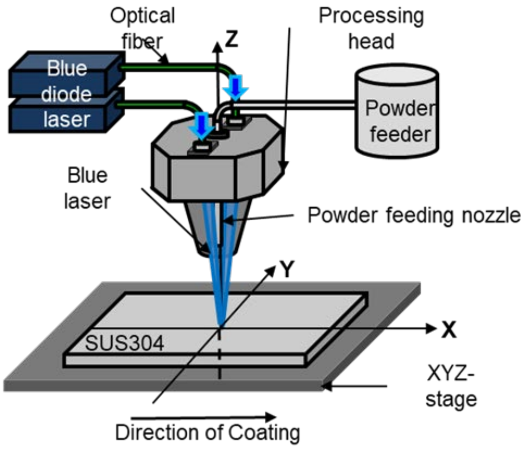

Fig.2. Experimental setup for copper alloy coating with multi-beam type LMD system.

3. Results and discussions

Figure 3 show the correlation between output power of laser and cross-sectional area of coating bead. In the case of pure copper coating, the cross-sectional area was linearly increased with increase the output power. The cross-sectional area of Cu-Zn alloy layer was increased as the output power increased, 3.5 times larger than that of pure copper. Furthermore, as the amount of zinc increased, the molten pool behavior became unstable, and behavior that appeared to be zinc evaporation was observed in some cases.

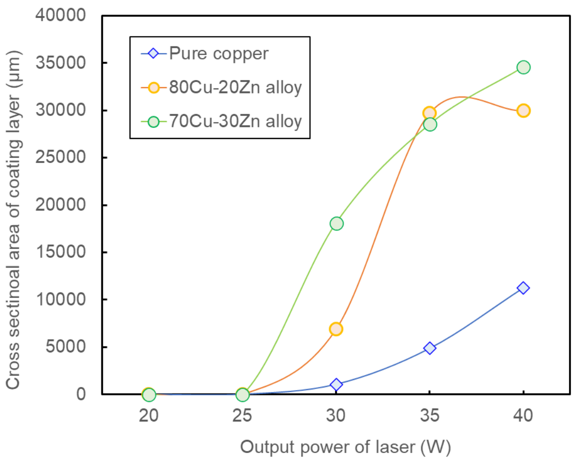

Fig.3. Correlation between the output power and cross-sectional area of Cu coating with B-LMD at the laser scanning speed of 4mm/s and powder feed rate of 12 mg/s.

Figure 5 shows photographs of pure copper, 80Cu-20Zn alloy, and 70Cu-30Zn alloy after coating on SS304 substrate. Here, the laser power is 40 W, the laser scanning speed is 4 mm/s, and the powder feed rate is 12 mg/s. In the pure copper, a dense layer was formed with the thickness of 140 µm. On the other hand, the layer thickness of the copper alloy became 164 µm for 80Cu-20Zn, and 182µm for 70Cu-30Zn alloy. The addition of zinc to copper improves the energy efficiency, and zinc concentration is found to be a factor that increases the energy efficiency.

(a) (b) (c)

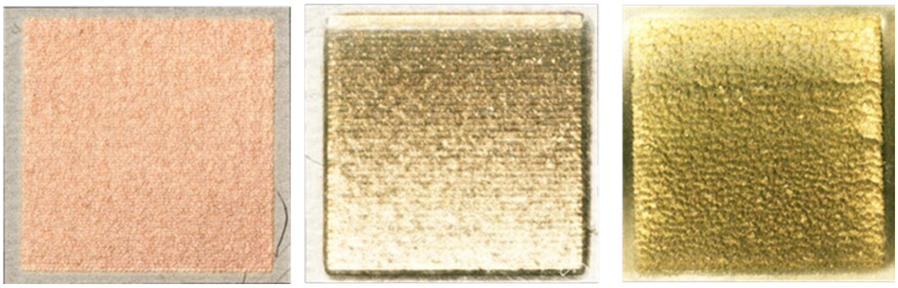

Fig.5. Optical images of copper coating of (a) Pure copper, (b)80Cu-20Zn alloy and (c) 70Cu-30Zn alloy

Summary

Copper alloys are expected to have many applications because of their virus inactivation properties similar to copper, but it has been difficult to produce dense coatings with high bonding strength. In this study, we tried to coat Cu-Zn alloys on the SS304 substrate using a multi-beam LMD system with blue diode lasers with 450 nm wavelength. As the results, in the Cu-Zn alloy coating, the cross-sectional area of coating layer was increased with increase the output power of laser. It is expected that these results will lead to the application of Cu-Zn alloys in a wide range of fields.

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