

The influence of heat treatment on the microstructure and mechanical properties of cold sprayed coatings

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In this paper Cu and Ti coatings were deposited by cold spray process. The influence of heat treatment temperature on the coating microstructure and mechanical property were investigated. The experiment results show that heat treatment temperature give significant influence on Cu coating microstructure. The Cu coating with stress-strain characteristic comparable to the bulk material can be obtained at the heat treatment temperature of 500°C. However, the Ti coatings exhibit no significant change on the stress-strain characteristics against the heat treatment temperature although the coating microstructure changed. The different effects of heat treatment to the Cu and Ti coating mechanical property were discussed by combining the change of coating microstructure.

1 Introduction

In cold spray process spray particle impact to the substrate in the solid state. The characteristics of high particle impact velocity as well as the very little oxidation and no phase transformation contribute to form a coating with good mechanical properties. However, the coating microstructure and mechanical properties are also significantly influenced by the spray conditions. The residual stress and defects in the coating such as pores will also lowering coating properties. Heat treatment is a feasible method to improve the coating microstructure and properties. In this paper, the Cu and Ti coatings were deposited by the cold spray. The effect of heat treatment temperature on the coating microstructure and mechanical property were investigated.

2 Experimental procedures

The SEM images of Cu and Ti powders used in the experiment are shown in figure 1. The cold spray system used in the experiment was developed by Plasma Giken Co., Ltd. Nitrogen gas was used as the propellant gas. To characterize the coating mechanical property, the influence of heat treatment temperature on the coating stress-strain characteristic was investigated. Fig. 2 show the preparation of the tensile specimen. The coating with thickness over

5 mm was deposited on an aluminum tube with a size of ϕ 100 x L100 mm. A strip was cut from the tube as shown in figure 2 and then machined to a tensile specimen according to the JIS Z2201. Fig. 3 shows the shape and size of the tensile specimen. The heat treatment to the tensile specimen was performed in an argon atmosphere. Table 1 shows the cold spray and heat treatment conditions.

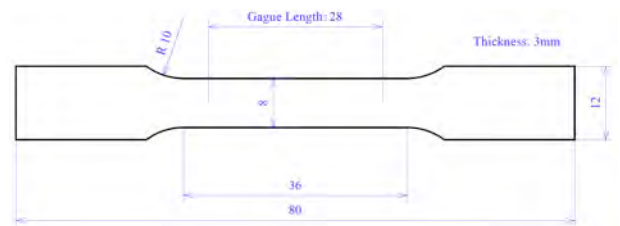


Fig.3. The shape and size of tensile specimen

Table: Cold spray and heat treatment conditions

	Cu	Ti
Gas pressure (MPa)	3.0	3.0
Gas pressure (°C)	800	900
Heat treatment temperature (°C)	500, 700	600,1000
Heat treatment time (h)	4	4

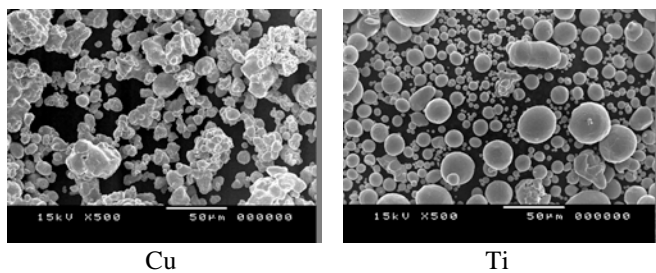


Fig. 1. Powder SEM images.

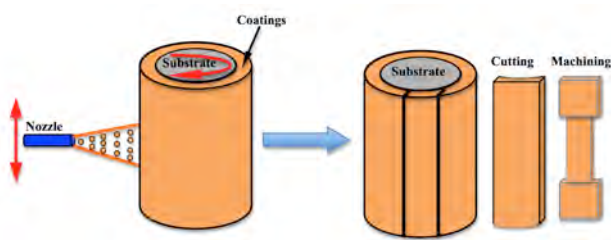


Fig. 2. Preparation of the tensile specimen

3 Experimental results and discussions

The tensile stress-strain curves of Cu coatings and Cu bulk are shown in figure 4.

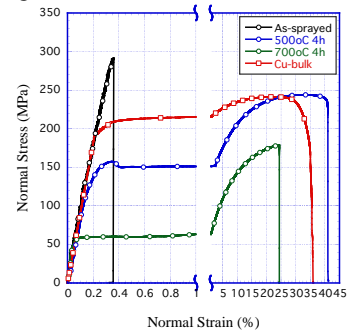


Fig.4. Cu coatings and Cu bulk tensile stress-strain curves

The as-sprayed Cu coating has a high tensile strength of 290 MPa while it exhibits almost no strain. For the heat treatment temperature of 500°C, the coating tensile strength decreased to 245 MPa but the strain increased dramatically to 40% which is even higher than that of the Cu bulk material. With the further increase of heat treatment temperature to 700°C the coating tensile strength and strain

inversely decreased to 180MPa and 24% respectively compared to the tensile specimen of 500°C heat treated.

Fig. 5 shows the tensile stress-strain curves of Ti coatings and Ti bulk. Coating tensile strength increased from 122MPa of the as-sprayed coating to 133MPa and 192MPa respectively corresponds to the heat treatment temperature of 600°C and 1000°C. However the coating strain exhibit no significant change against the heat treatment temperature. Compared to the tensile strength of 400MPa and strain of 40% for the Ti bulk, the mechanical property of as-sprayed and the heat treated Ti coatings is insufficient.

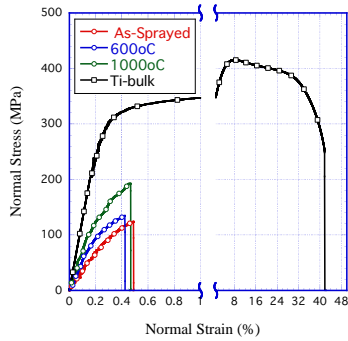


Fig.5. Ti coating and Ti bulk stress-strain curves

The tensile test results show that the effect of heat treatment to the Cu and Ti coating stress-strain characteristic is different. Fig. 6 and 7 show the Cu and Ti coating cross section microstructure and fracture surface morphology respectively. For the Cu coatings the particle in the as-sprayed coating exhibit well deformed shape due to high particle impact velocity. There is almost no obvious pores or cracks in the coating which contributed to a high coating tensile strength. While the fracture surface morphology indicated clearly that the fracture occurred at the particle interface and the particles exhibit no significant elongation along the tensile direction. At the heat treatment temperature of 500°C the interface between the particles disappeared and the grain size in the coating is obviously fine than that of the as-sprayed coating. It may be attributed to the diffusion and recrystallization of the grains. The fracture surface morphology exhibit typical dimple pattern with features of plastic fracture. As a result the coating exhibit good combination of tensile strength and ductility at heat treatment temperature of 500°C. For the heat treatment temperature of 700°C the grain grows obviously, meanwhile the dimple size increased but the number of dimples decreased which lead to the reduction of coating tensile strength and ductility.

Due to the high elastic modulus of the Ti material, the Ti particle impact velocity drove by N₂ gas is not high enough to provide sufficient particle deformation. As a result the particles in the as-sprayed coating keep approximately spherical shapes like the feedstock powders as shown in figure 1 and 7. It exists many visible interface and a few pores between the particles. With the increase of heat treatment temperature from 600°C to 1000°C the amount of interface significantly decreased but the pores numbers exhibit no obvious decrease. For the as-sprayed coating the fracture surface morphology show that the fracture occurred at the particle interface. At the heat treatment temperature to 600°C and 1000°C, although a fraction of fracture occurred in the particle there is no obvious dimple pattern

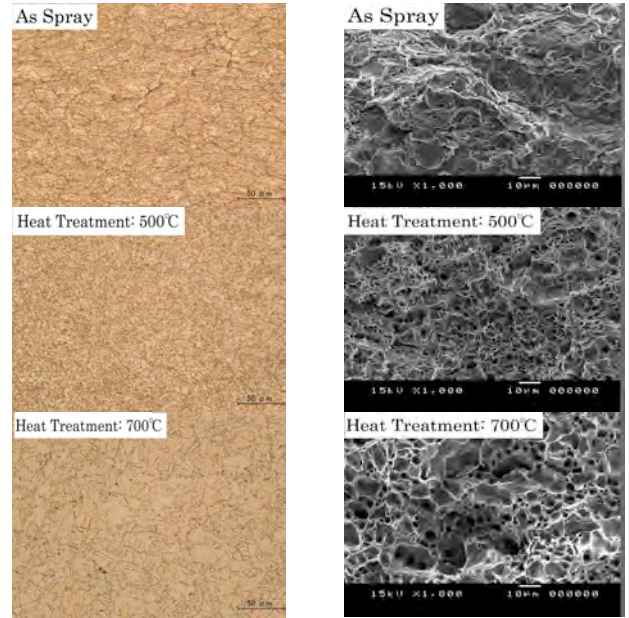


Fig. 6. Cu coatings cross section microstructure and Fracture surface morphology

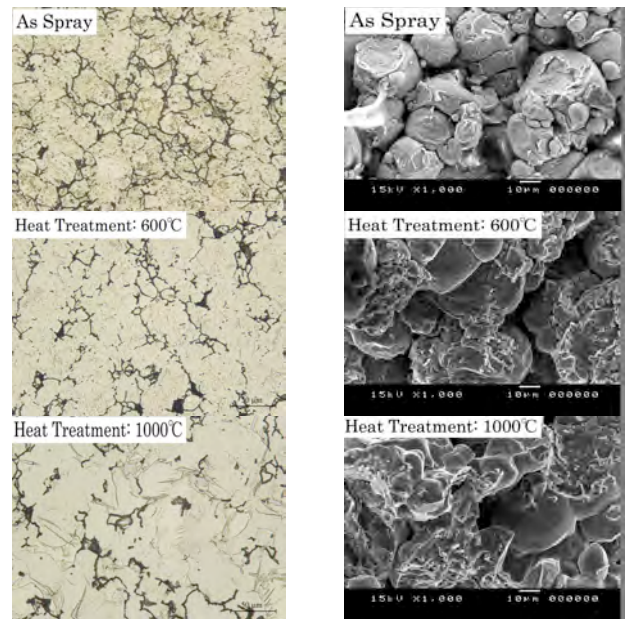


Fig. 7. Ti coatings cross section microstructure and Fracture surface morphology

can be observed. There are still some defects in the coatings. All the fracture patterns for the Ti coatings exhibit brittle fracture. As a result the coating tensile strength increased but the coating ductility did not change appreciably.

3 Conclusions

The influence of heat treatment temperature on Cu and Ti coatings stress-strain characteristic were investigated. As to the Cu coatings the heat treatment temperature of 500 °C improve the coating mechanical property due to diffusion, grain refinement and transition to ductile fracture pattern. As to the Ti coating the heat treatment give significant influence on the coating tensile strength but not coating strains which can be attributed to the similar brittle fracture pattern even at heat treatment temperature of 1000 °C.

4 References (omitted)