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Development of SLM 3D printing system using Galvano scanner for pure copper additive manufacturing by 200 W blue diode laser

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Abstract

Selective laser melting (SLM) is one of laser additive manufacturing technologies. Because absorptance of blue light on pure copper materials is higher than that of conventional near-infrared light, a blue diode laser is expected to effective in shaping pure copper parts. In our previous study, we developed a high power and high intensity blue diode laser with the wavelength of 450 nm. Output power and fiber core diameter was 200 W and 100 µm, respectively. In this study, we have developed a SLM machine using Galvano scanner and the 200 W blue diode laser. The number of stacked layers were changed to form a pure copper parts in the SLM method, and the influence of them on the cross-sectional area of the parts was investigated.

Keywords: SLM; blue laser; copper

1. Introduction

It is anticipated that additive manufacturing (AM) will become one of the next generations of manufacturing technologies. The powder bed fusion process is an additive manufacturing process. In the field of materials processing with lasers, this is called selective laser melting (SLM). In most SLM machines, single-mode fiber lasers with the wavelength of 1.07 µm are used as light sources to melt metal powders. Stainless steel, aluminum, titanium, nickel base and cobalt alloys can be fabricated by SLM with the fiber laser. From the

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perspective of additive technologies, copper is one of the most attractive materials for its unique physical properties, such as high thermal and electric conductivity. However, due to low infrared light absorption, higher laser power is needed for fabrication of dense parts. Meiners et al., stated that the minimum laser power for a successful copper SLM should not be less than 300 W.

In our previous study, we have developed a blue diode laser with the wavelength of 450 nm and a SLM machine with the blue laser [Hori at al., 2021]. The absorptivity of blue light on copper material is more than 60 % [Weber et al., 2003]. 3D objects made of pure copper were produced with the system. However, to increase the laser intensity at the focal point, the laser focusing head was driven by gantry type XY stage. Low acceleration and poor positioning accuracy of the XY stage prevented high quality 3D printing.

In this study, a high-power blue diode laser and a SLM 3D printing system using Galvano scanner was developed. The laser output power was 200 W. The laser propagate through an optical fiber whose core diameter and NA were 100 µm and 0.22, respectively. By using Galvano scanner, the acceleration and positioning accuracy were more than 100 times higher than the gantry type XY stage.

Pure copper is a material with high thermal conductivity, and it is considered that it is difficult to form objects with a high density because of heat diffusion. Therefore, we investigated the effect of thermal diffusion on the density of different sized objects.

2. Experimental setup

2.1. SLM equipment

Schematic diagram of SLM 3D printing system using Galvano scanner is shown in Fig. 1. This SLM system employed a blue diode laser with a maximum output of 200 W and a wavelength of 450 nm. The Galvano scanner is a 3-axis controlled unit, and the spot diameter at the processing point is 250 µm at full width at half maximum (FWHM). The pure Cu powder was supplied and then smoothed with a squeegee on baseplate. The laser irradiated and melted the powder bed to form 2D structures, and then repeated these processes to build up 3D objects Scanning speed can be varied up to 1000 mm/s. Layer thickness can be varied from 50 µm to 200 µm.

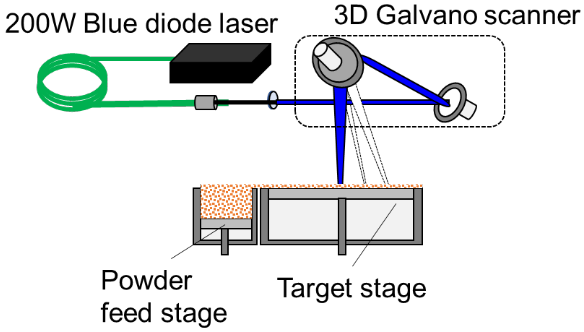

Fig. 1. Schematic diagram of 3D printing system with a 200 W blue diode laser

2.2. SLM processing

The experimental conditions are shown in Table 1. The laser power, scanning speed, hatching distance, hatch rotation angle, layer thickness, and shielding Argon gas flow rate were 200 W, 200 mm/s, 100 µm, and 10 L/min, respectively. The size of the formed object was kept at 5 mm in the depth direction, and the width was varied to 1, 3, and 5 mm. The number of layers was changed to 8, 16, and 32. The density of fabricated object was determined by optical microscopy of polished cross-sections.

Table 1 List of fixed and varied parameters in the experimental conditions

Fixed Factors	Value
Laser power [W]	200
Spot diameter (FWHM) [µm]	250
Scanning speed [mm/s]	200
Hatching distance [µm]	200
Hatch rotation angle [°]	90
Layer thickness [µm]	100
Shielding Argon gas flow rate [L/min]	10
Substrate material	SUS 304
Depth of sample size [mm]	5
Variable Factors	**Value**
Width of sample size [mm]	1, 3, 5
Number of layers	8, 16, 32

3. Results

A cross-sectional view of the samples is shown in Fig. 2

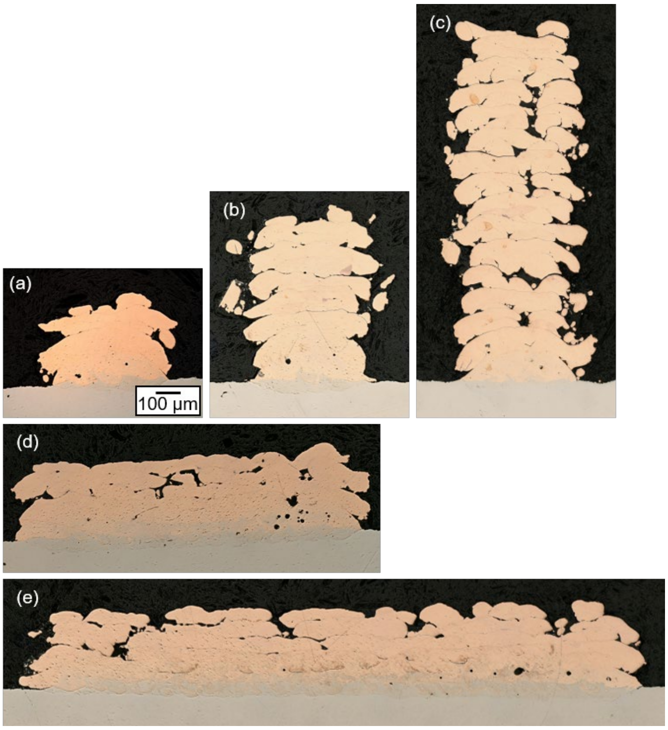

Fig. 2. Optical microscopy images of the cross section of samples in which the width, the depth, and the number of layers were (a) 1mm, 5mm, 8 layers, (b)1mm, 5mm, 16 layers, (c) 1mm, 5mm, 32 layers, (d) 3mm, 5mm, 8 layers, (e) 5mm, 5mm, 8 layers, respectively

When the number of layers and width were 8 and 1 mm (Fig. 2(a)), the density was 99.5%, but when the number of layers was increased to 16 (Fig. 2(b)) and 32 (Fig. 2(c)), the densities were 99.0% and 96.5%, respectively. It was found that the density decreased with the number of layers. When the width of the sample of 3 (Fig. 2(d)) or 5 (Fig. 2(e)) mm were compared, the densities were recorded to 98.6% and 98.1%, respectively. This indicated that the density depended on the size of build samples.

Image of the 3D printed samples fabricated from 3D CAD data are also shown in Fig.3. We were able to form a lattice structure mad by copper with a width of 32 mm, a depth of 32 mm, a height of 15 mm, and a beam thickness of 1.8 mm.

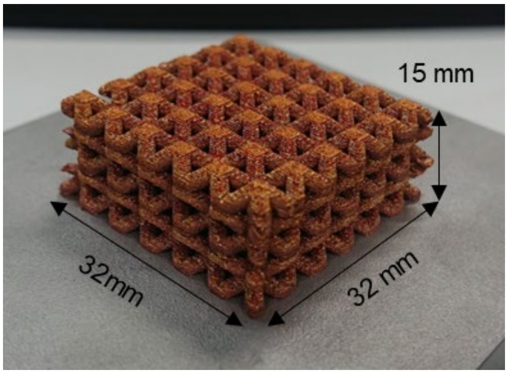

Fig. 3. Image of the 3D printed pure copper lattice structure sample

4. Conclusions

We developed a SLM 3D printer with Galvano unit using a blue diode laser with 200 W output power. Pure copper structure was fabricated with the SLM 3D printer and it was found that there was a dependency between the size of the fabricated object and the density. A lattice structure (32 x 32 x 15 mm^3) was formed from 3D CAD data.

Acknowledgements

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