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Effect of baseplate temperature on molten titanium particle for development of sputter-less SLM

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Abstract

Dynamics of molten titanium irradiated with laser was investigated experimentally by a synchrotron radiation analysis; because it is important to analyze a process of a molten metal for a 3D material fabricated by a selective laser melting (SLM), such as one of additive manufacturing technology. A contact angle with molten titanium was measured by synchrotron radiation at 30 keV while the laser irradiation. The size of Ti particle and laser spot diameter was same as 200 micro-meters. The Ti particle was place on the SUS304 substrate in a vacuum chamber. The chamber was evacuated at the pressure of 1 Pa. In this condition, the laser was vertically irradiated on the Ti particle. A baseplate temperature was varied from 25 to 500 degree Celsius. As the results, the baseplate temperature was increase with decrease the contact angle. At the baseplate temperature of 500 degree Celsius, the contact angle with molten Ti became small to 32 degrees.

Keywords: Selective laser melting, synchrotron radiation, dynamics of molten metal;

1. Introduction

Selective laser melting (SLM), which is an additive manufacturing technology, is attractive due to its ability to freely form shapes. SLM can fabricate complicated shapes because it builds a 3D material layer-by-layer from a powder [1-6]. However, some issues have yet to be resolved, including dimensional accuracy, surface finishes, processing time, and mechanical properties such as surface roughness, hardness, and crystal orientation. Many studies have investigated these issues. Nakamura et al. developed a hybrid processing system that combines the milling and SLM processes to improve the dimensional accuracy [7]. Buchbinder

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et al. reported a SLM machine with a 1-kW solid-state laser to save time [8, 9]; the build rate with a 1-kW laser increased five-fold compared to that with a 400-W laser. Although the SLM process has been improved, research on sputtering in the SLM process is limited. We have shown that using the SLM process in a vacuum can inhibit the sputtering [10, 11]. Especially it was also found that the sputtering tends to be suppressed as the baseplate temperature is higher. The sputter-less fabrication was improved to surface roughness to 0.6μm from 30um. However, the mechanism of sputter-free process for SLM in a vacuum has been not clarified. Thus, the dynamics of molten metal, while a laser was irradiated, were investigated experimentally by a synchrotron radiation analysis. As the results, it was found that a wettability of molten metal were dependent on a baseplate temperature.

2. Experimental

Fig.1 shows the experimental set up for capturing the dynamics of molten Ti particle. Ti particle, which size was 200 μm, was employ in this experiment. Ti particle was set on the SUS plate in a vacuum chamber. Then the chamber was evacuated at a pressure of 1 Pa. A direct diode laser at the wavelength of 915 nm and power density of $4x10^4$ W/cm^2 was irradiated to the Ti particle. The focusing diameter were set to 200 μm same as the Ti particle. A baseplate temperature was varied from 25 to 500 degree Celsius. A contact angle with molten titanium was measured by synchrotron radiation at 30 keV while the laser irradiation, as shown in Table 1.

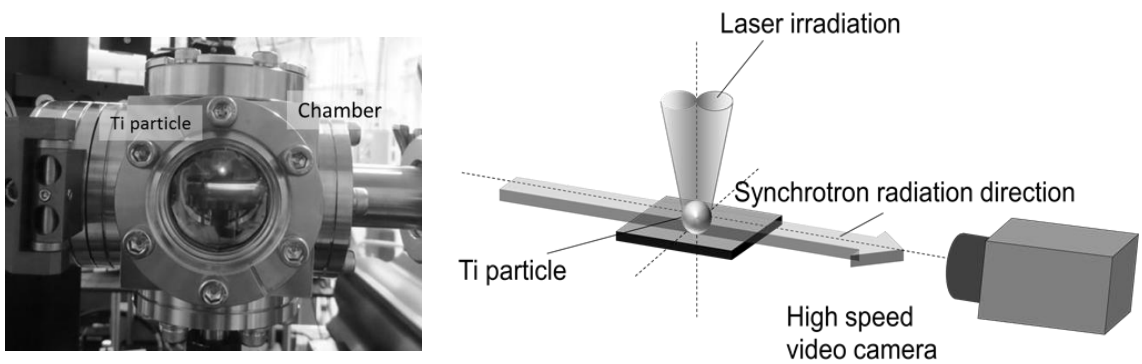

Fig.1. Experimental set up for capturing the dynamics of molten Ti particle.

Table 1. Experimental condition

characteristics	values
Laser power density	$4x10^4$ W/cm^2
Focus diameter	200 μm
Ti particle size	200 μm
Energy of X ray	30 keV
X ray area	2 x 4 mm^2
Flame rate of high speed video camera	1000 fps
Baseplate	SUS 304

3. Results and discussion

Fig.2 shows the high speed video camera images by the synchrotron radiation. The contact angle was measured in order to evaluate the wettability of the molten Ti particle. The contact angle on the SUS304 plate was 148 degrees. The contact angle of molten Ti decreased with increase the baseplate temperature. At the baseplate temperature of 500 degree Celsius, the contact angle with molten Ti became small to 32 degrees. In our previous study, sputtering was evaluated in the SLM method by heating to 150℃. It is considered that wettability improves as the temperature rises and the effect of suppressing sputtering appears.

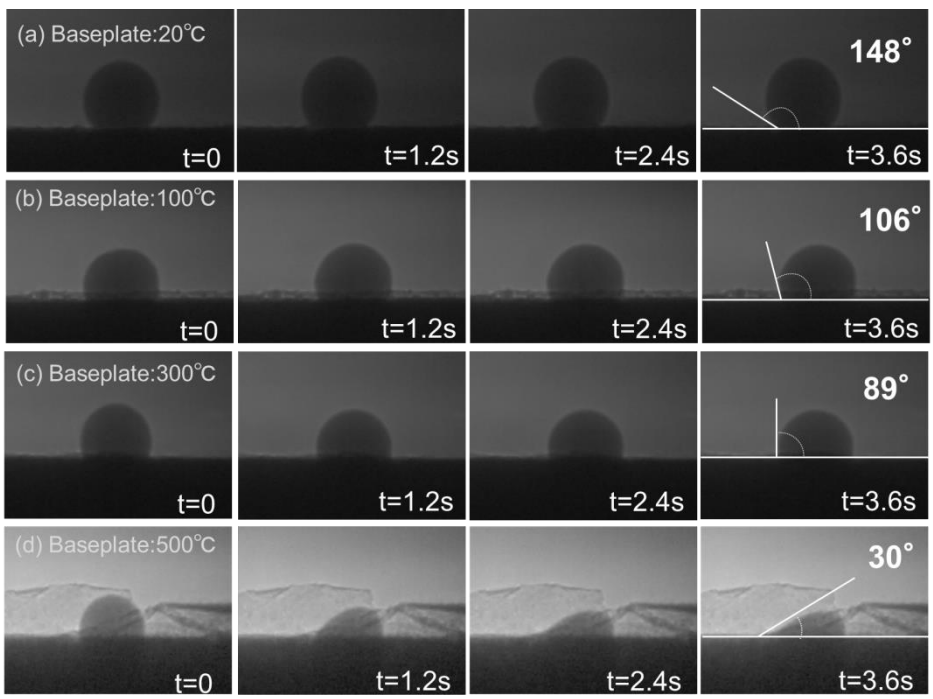

Fig. 2. High speed video camera images by synchrotron radiation while the laser irradiation. The baseplate temperature was varied at (a) room temperature, (b) 100℃, (c) 300℃ and (d) 500℃

4. Summary

It was demonstrated that dynamics of molten titanium irradiated with laser was investigated experimentally by a synchrotron radiation analysis. Melting and solidification process were captured with high speed video camera via a scintillator. From the results, It was revealed that the contact angle of molten Ti particle on the SUS304 plate was depended on the baseplate temperature. At the 500 ℃, the contact angle of molten Ti particle became minimum to 30 degrees from 148 degrees .

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