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Hetero-3D 地上対照実験としての静電浮遊実験を用いた Ti6Al4V 中のヘテロ凝固核 TiC による結晶粒微細化

Ground reference experiments for *Hetero-3D* on grain refinement of Ti6Al4V by TiC using the electrostatic levitation furnace

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1. Introduction

In additive manufacturing, adding TiC as heterogeneous nucleation site particles to Ti6Al4V has been proposed to promote nucleation of fine microstructures[1)]. In order to reveal the mechanism of this phenomenon, our research group is planning space mission *Hetero-3D* to conduct experiments with Electrostatic Levitation Furnace on the International Space Station (ISS-ELF) which can eliminate factors other than TiC that cause nucleation. However, the opportunities for ISS-ELF experiments are limited. In this study, Ti6Al4V samples without and with TiC were melted and solidified in the Electrostatic Levitation Furnace (ESL) as the ground reference experiments for the ISS-ELF experiments and the grain distributions on the cross sections were analyzed to clarify the effect of TiC addition on prior-β grain refinement.

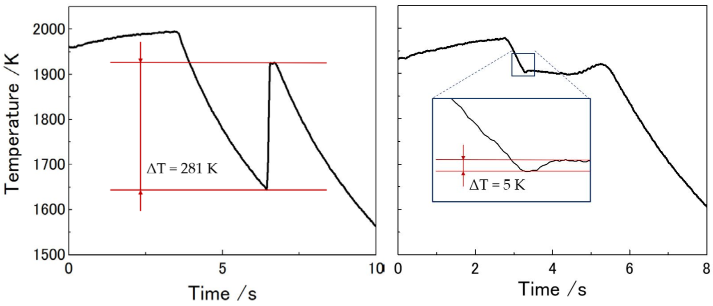
2. Experimental Procedure

First, Ti6Al4V powder without and with TiC particles (particle size < 20 μm) was sintered by Spark Plasma Sintering (SPS) method at 1273 K. The sintered pieces were cut into 30 mg blocks and formed into spheres by using surface tension in the arc furnace. Each sample was heated in the ESL under a high vacuum. After the sample was melted completely, heating lasers were turned off. The value at the plateau region in the cooling curve obtained with the radiation thermometer was adjusted to fit the melting point of Ti6Al4V, 1923 K, and the undercooling ΔT was calculated. The experimental samples were then polished. The Inverse Pole Figure (IPF) maps of crystal orientation of α phase at room temperature on the cross sections were obtained by

Electron Backscatter Diffraction (EBSD) analysis. After they were reconstructed into the orientation of β phase based on the relationship of crystal orientation during isotropic transformation, the number of grains on the prior-β grain map was counted.

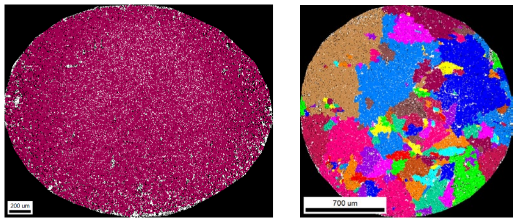
3. Results

Figure 1 shows the cooling curves. The undercooling of the sample without TiC was 281 K, and the one with TiC was 5 K. **Figure 2** shows the prior-β grain maps. As shown in **Fig. 2(a)** which became an ellipse because of the incomplete parallel setting, the entire cross section of the sample without TiC consisted of one prior-β grain. On the other hand, the one with TiC shown in **Fig. 2(b)** consisted of about 150 prior-β grains.



(a) (b)

Figure 1. Cooling curves and undercoolings ΔT: (a) Ti6Al4V without TiC; (b) Ti6Al4V with TiC.



(a) (b)

Figure 2. Prior-β grain map: (a) Ti6Al4V without TiC; (b) Ti6Al4V with TiC.

4. Discussion

The cause of the results that adding TiC made the undercooling ΔT smaller than the one without TiC by 276 K and the number of prior-β grain increase can be attributed to the following mechanism. At the time when prior-β grains were produced, TiC decreased the energy barrier. Following that, undercooling ΔT, the driving force for nucleation, became smaller, and TiC worked for prior-β grain refinement as the heterogeneous nucleation particles properly.

5. Conclusion

In the melting and solidification experiments of the Ti6Al4V sample with TiC (particle size < 20 μm) of 5 vol.% in the ESL, the undercooling ΔT became smaller than the ΔT of the sample without TiC by 276 K and the number of prior-β grain increased from one to about 150. These results were thought to be caused because TiC decreased energy barrier and promoted nucleation.

References

1) Y. Watanabe, M. Sato, T. Chiba, H. Sato, N. Sato, S. Nakano, S. Suzuki: Effect of Heterogeneous Nucleation Site Particles on Microstructure of Additively Manufactured Ti-6Al-4V Alloy. Journal of Japan Laser Processing Society, **26** (2019) 46.