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Hetero-3D の ISS-ELF 実験における Ti-6Al-4V の 3 次元結晶粒解析

Three-Dimensional Grain Analysis of Ti-6Al-4V in the ISS-ELF Experiment for *Hetero-3D*

門井洸衛 [1], 上田雄翔 [1], 櫛舎祐太 [1], 上野遥か [1], 馬渕勇司 [1], 花田知優 [1], 青木祐和 [1], 左口凌成 [2], 山田素子 [2], 佐藤尚 [2], 渡辺義見 [2], 小澤俊平 [3], 中野禅 [4], 小山千尋 [5], 織田裕久 [5], 石川毅彦 [5], 渡邊勇基 [6], 鈴木進補 [1]
Koei KADOI[1], Yuto UEDA[1], Yuta KUSHIYA[1], Haruka UENO[1], Yuji MABUCHI[1], Chihiro HANADA[1], Hirokazu AOKI[1], Ryosei SAGUCHI[2], Motoko YAMADA[2], Hisashi SATO[2], Yoshimi WATANABE[2], Shumpei OZAWA[3], Shizuka NAKANO[4], Chihiro KOYAMA[5], Hirohisa ODA[5], Takehiko ISHIKAWA[5], Yuki WATANABE[6], and Shinsuke SUZUKI[1]
[1] 早稲田大学，Waseda University,
[2] 名古屋工業大学，Nagoya Institute of Technology (NITech),
[3] 千葉工業大学，Chiba Institute of Technology (CIT),
[4] 株式会社 Henry Monitor，Henry Monitor Inc.,
[5] 宇宙航空研究開発機構，Japan Aerospace Exploration Agency (JAXA),
[6] 株式会社エイ・イー・エス，Advanced Engineering Services (AES)

1. Introduction

To elucidate the amount of TiC acting as heterogeneous nucleation site particles for grain refinement in Ti-6Al-4V, *Hetero-3D* mission was conducted by melting and solidifying samples in the electrostatic levitation furnace in the International Space Station (ISS-ELF). Due to the limited number of the space experimental samples, the method to estimate grain counts in the entire sample, N_{3D}, with minimal sample loss was required. This study aims to propose the method of obtaining N_{3D} from a cross section of the ISS-ELF sample.

2. Experimental Procedures

Ti-6Al-4V powder with 5 mass% TiC particles was melted and solidified in the ISS-ELF. A spherical sample with a diameter of 2.26 mm was obtained. A cross section of the sample was obtained by a diamond wire saw and a polishing machine. Furthermore, a prior-β grain map of the cross section was obtained by an electron backscatter diffraction (EBSD) analysis with a step size of 2 μm.

The Voronoi tessellation (VT), which divides the regions by perpendicular bisectors as grain boundaries between preset sites, was conducted to simulate three-dimensional grain distribution using visualization software, OVITO. Eleven models were generated by VT with various grain counts per volume, N_V, from 7 to 333. From each model, cross sections at the same depth as the prior-β grain maps were extracted. Subsequently, the average grain areas on the cross section, $\bar{A}_{\mathrm{voro}}$, were calculated with dividing grain counts by the cross-sectional area.

3. Results

The dimensionless distance from a spherical center to a cross-sectional center, d, was 73 % of spherical radius. The prior-β grain map is shown in **Fig. 1(a)**. Grains on the sample surface, *surface-grain,* had 0.12 mm² of an average area, $\bar{A}_{\text{surface}}$. It was six times as large as that of grains not on the surface, *inside-grain*, with 0.02 mm² of an average area, $\bar{A}_{\text{inside}}$. The relationship between N_V and $\bar{A}_{\text{voro}}$ is shown in **Fig. 1(b)**. The value of N_V decreased exponentially with increasing $\bar{A}_{\text{voro}}$. Applying $\bar{A}_{\text{surface}}$ and $\bar{A}_{\text{inside}}$ to **Fig. 1(b)**, N_V of *surface-grain*, $N_{V\text{-surface}}$, and *inside-grain*, $N_{V\text{-inside}}$, were obtained as 10 mm^{-3} and 285 mm^{-3} respectively.

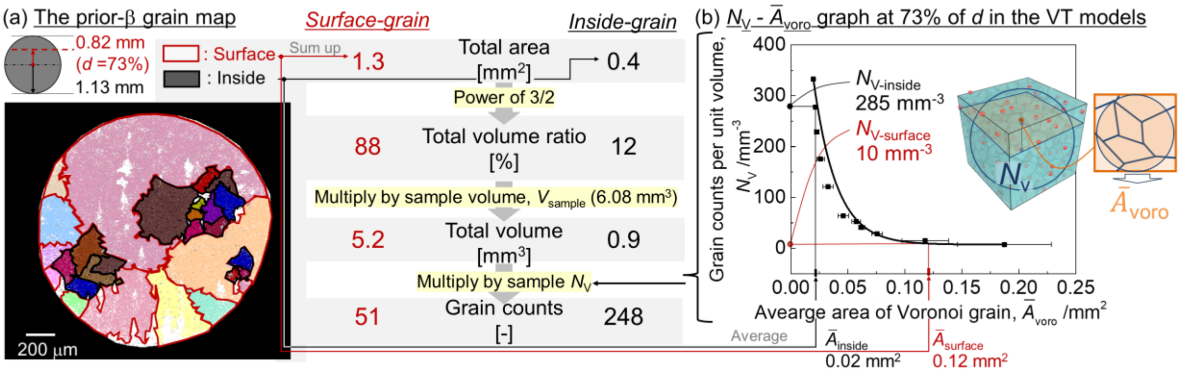

Figure 1. Analytical results with the cross sections at 73% of d in the sample and VT models. The highlighted grains with white and black in (a) indicate *surface-grain* and *inside-grain*, respectively. The graph in (b) shows N_V, assuming uniform grain size with the average grain area.

4. Discussion

Because the sizes between areas of *surface-grain* and *inside-grain* were extremely different, the value averaged for all grains in the cross section should not be uniformly applied to **Fig. 1(b)**. By applying $\bar{A}_{\text{surface}}$ and $\bar{A}_{\text{inside}}$ separately to **Fig. 1(b)**, N_V was obtained for *surface-grain* and *inside-grain* respectively. The equation summarizing obtaining the grain counts was as follows.

$$N_{3\text{D}} = V_{\text{sample}} \left\{ \frac{A_{surface}^{3/2}}{A_{surface}^{3/2} + A_{inside}^{3/2}} N_{v-surface} + \frac{A_{inside}^{3/2}}{A_{surface}^{3/2} + A_{inside}^{3/2}} N_{v-inside} \right\} \tag{1}$$

where A_{surface} and A_{inside} were total area of *surface-grain* and *inside-grain* respectively. **Eq.1** showed 299 of N_{3D}.

5. Conclusion

To propose a method for estimating N_{3D} from a cross section of ISS-ELF sample, EBSD analysis and VT were conducted. By applying A_{surface} and A_{inside} from the prior-β grain map and $N_{V\text{-surface}}$ and $N_{V\text{-inside}}$ from N_V-$\bar{A}_{\text{voro}}$ graph to **Eq. (1)**, N_{3D} was estimated to be 299.