JASMAC
Conference of the Japan Society of Microgravity Application

P24

Hetero-3D での ISS-ELF の高速度カメラを用いた Ti6Al4V の結晶成長速度の解析

Elucidation of Crystal Growth Rate of Ti6Al4V Using the High-Speed Camera in the ISS-ELF in *Hetero-3D*

櫛舎祐太 [1], 馬渕勇司 [1], 花田知優 [1], 上田雄翔 [1], 門井洸衛 [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], 小山千尋 [3], 織田裕久 [3], 石川毅彦 [3], 渡邊勇基 [4], 鈴木進補 [1]
Yuta KUSHIYA[1], Yuji MABUCHI[1], Chihiro HANADA[1], Yuto UEDA[1], Koei KADOI[1], Hirokazu AOKI[1], Ryosei SAGUCHI[2], Motoko YAMADA[2], Hisashi SATO[2], Yoshimi WATANABE[2], Chihiro KOYAMA[3], Hirohisa ODA[3], Takehiko ISHIKAWA[3], Yuki WATANABE[4], and Shinsuke SUZUKI[1]
[1] 早稲田大学，Waseda University,
[2] 名古屋工業大学，Nagoya Institute of Technology,
[3] 宇宙航空研究開発機構，Japan Aerospace Exploration Agency (JAXA),
[4] 株式会社エイ・イー・エス，Advanced Engineering Services (AES)

1. Introduction

In the space mission, *Hetero-3D*, a crystal growth process of a droplet of Ti6Al4V alloy was recorded using the high-speed camera (HSC) in the electrostatic levitation furnace in the International Space Station (ISS-ELF). Though it is known that crystals in undercooled liquid metal grow in rectangular shapes during recalescence and tend to grow their corners[1)], the time variation of crystal growth rate is still uncertain. Thus, the objective of this study was to establish and verify the calculating method of the local crystal growth rate to discuss the kinetics of crystal growth during recalescence by analyzing the displacement of the solid-liquid interface (SLI).

2. Experimental Procedures

Ti6Al4V powder was mixed with 2 mass% TiC particles, sintered by spark plasma sintering method, and cut into cubes of approximately 20 mg. After that, the cube was shaped into a sphere by arc melting. The specimen was levitated, melted, and solidified in the ISS-ELF. The crystal growth process and the temperature history during recalescence were recorded by the HSC at 10,000 fps and a pyrometer at 100 Hz, respectively.

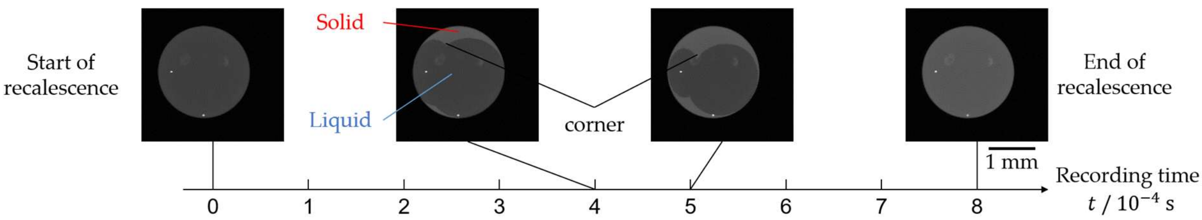

Figure 1. Solidification images during recalescence captured using the high-speed camera.

3. Results

The crystal growth process resulted in 53 K of the degree of undercooling in 9 frames at 10,000 fps. Representative frames of the specimen are shown in **Fig. 1**. It may be back side that the observed crystal growth began. The two rounded SLI integrated and covered the surface of the droplet. The corners of the SLI were observed in 5 frames.

4. Discussion

The three-dimensional coordinate of the SLI apex can be obtained by Hough transform and the following calculations. The radius of the droplet in the image r_{2D}, is the same as that of the actual droplet sphere, r_{3D}. If the center of the actual droplet is the origin, (x_{3D}, y_{3D}, z_{3D}): the 3D coordinate of the SLI apex is expressed below as shown in **Fig. 2 (c)**, and **Eq. (1)**.

$$(x_{3D}, y_{3D}, z_{3D}) = \left(x_{2D}, y_{2D}, \sqrt{r_{3D}^2 - x_{2D}^2 - y_{2D}^2}\right), \tag{1}$$

where x_{2D} *and* y_{2D} are the vector components from the center of the apparent droplet. The included angles θ of two vectors of SLI apex on the specimen were calculated in the equation below as shown in **Fig. 2 (d)**.

$$\theta = arccos\left(\frac{x_1x_2 + y_1y_2 + z_1z_2}{r_{3D}^2}\right), \tag{2}$$

Where (x_1, y_1, z_1) and (x_2, y_2, z_2) are coordinates of the corners of SLI in former and later images. Furthermore, the displacement on the droplet surface *l*, is calculated by multiplying θ and r_{3D}. Finally, the frame rate *f*, was multiplied by *l* to obtain the local crystal growth rate *v*. The tendency is that the crystal growth rate becomes faster as the crystal grows as shown in **Fig. 2 (e)**. The error of calculation is also shown.

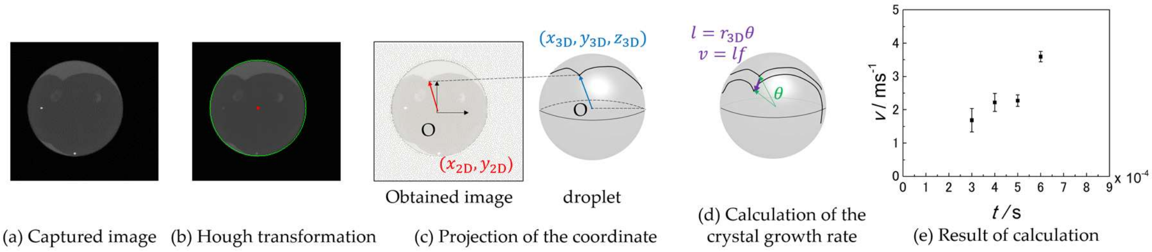

Figure 2. Schematic of calculation. Four plots in **(e)** come from five frames with corners in view field.

5. Conclusions

The images of solidification during recalescence were recorded by the HSC in the ISS-ELF. The coordinates of the SLI were projected from 2D to 3D and the crystal growth rates of undercooled droplet were calculated. As a result, it was revealed that the local crystal growth rate increases during recalescence.

Reference

1) D. M. Stefanescu: Morphology of Primary Phases. In Science and Engineering of Casting Solidification, 3rd ed., Springer (2015).