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Hetero-3D ミッションにおける TiC を添加した Ti 合金試料の ISS-ELF による溶融凝固実験の飛行後解析

Postflight Analyses of Melting and Solidification Experiments of Ti Alloy Samples with TiC by ISS-ELF in *Hetero-3D* Mission

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1. Introduction

The mission of the JAXA's science experimental theme "Heterogeneous solidification behavior of powder metals for 3D printer" (Abbreviation: *Hetero-3D*, PI: S.Suzuki, Waseda University) is being carried out[1, 2]. The objective of this mission is to clarify the effects of heterogeneous nucleation site particles on solidification behavior of metals for 3D printing. For this objective, melting and solidification experiments with Electrostatic Levitation Furnace in International Space Station (ISS-ELF) are an ideal method to exclude the effects of contamination from the container, evaporation and natural convection. The obtained results will be applied to improve the physical properties of the products built by 3D printer through refinement of crystal grains by heterogeneous nucleation site particles added in metallic powder[3]. The overview of this mission is shown in **Fig.1**. Through preflight experiments and simulations, important results have already been obtained on appropriate sample preparation methods[4], heating conditions[5], recording conditions by high-speed camera[6], and temperature and velocity fields in samples[7].

On-board melting and solidification experiments of Ti and Ti alloys with and without TiC heterogeneous nucleation site particles were performed with ISS-ELF as planned in April and May 2023. The samples were returned to the ground in June 2023. The details of the on-board experiments have already been presented at the previous conference JASMAC-35 [2].

Currently the flight samples and telemetry data are being analyzed. This presentation introduces the results obtained through postflight analyses and applications of the results to clarification of the solidification behavior including nucleation and crystal growth.

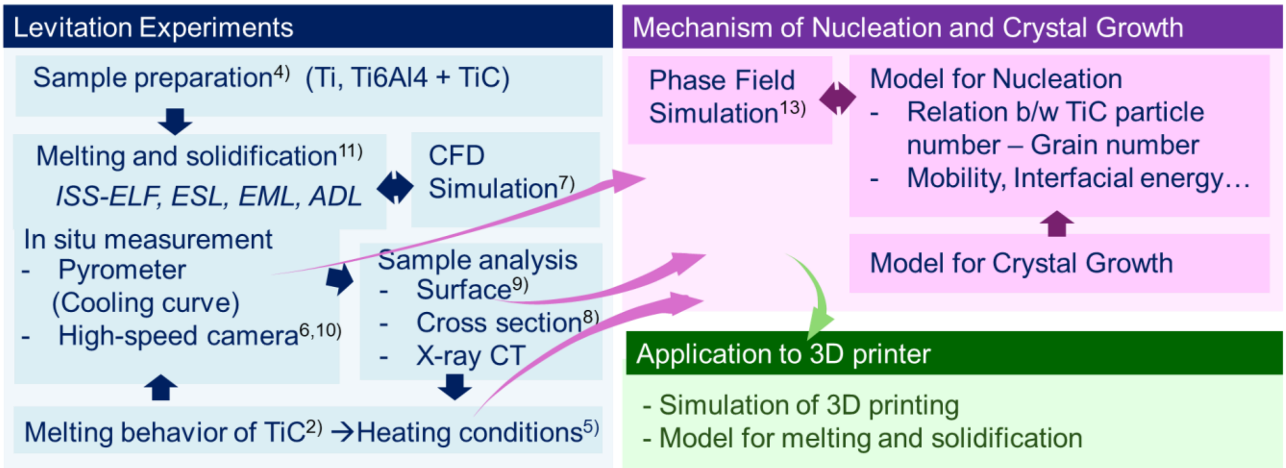

Figure 1 Overview of mission *Hetero-3D*

2. Analyses of Flight Samples and Telemetry Data

A cross section of a flight sample Ti-6Al-4V with 5 mass% TiC was polished and analyzed by electron backscatter diffraction (EBSD). By calculation using Voronoi tessellation the number of prior-β grains was estimated to be 299 [8].

On the surface of the flight sample, streak patterns were observed by scanning electron microscopy (SEM), which were not found on the samples of the electrostatic levitation experiments on the ground. As a result, a streak was found to be a step of height difference lying along the prior-β grain boundary [9].

Telemetry data of movies captured by high-speed camera was analyzed. As a result of a Ti-6Al-4V with 2 mass% TiC, the growth rate of a prior-β grain and its relative error were estimated to be 3 – 5 $mm \cdot s^{-1}$ and 10.2%, respectively [10].

Observation using X-ray computed tomography (X-ray CT) imaging is being prepared to obtain 3D grain mappings of flight samples with the synchrotron radiation facility SPring-8.

From these results, the solidification mechanism will be clarified for the ISS-ELF experiments, as has been done in other levitation experiments [11].

3. Modelling of Solidification Behavior

The dissolution model was established to estimate the number of TiC particles which work as the nucleation sites (Active-TiC) [12]. When the estimated number of Active-TiC particles is input to the Phase-field simulation, the number of the prior-β grain can be calculated. By varying the unknown parameter such as seed (possible nucleation site) density, mobility and so on, the simulated results of degree of undercooling for nucleation onset and number of prior-β grains can be adjusted to the experimental ones. By this procedure, the nucleation and crystal growth are visualized and the physical meanings of the adjusted parameters are discussed [13].

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