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ヘテロ凝固核による金属凝固挙動への影響解明を目的とした ISS-ELF 利用実験 Hetero-3D

ISS-ELF utilization experiment Hetero-3D for investigation of the effects of heterogeneous nucleation site particles on solidification behavior of metals

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1. Introduction

The JAXA's science experimental theme “Heterogeneous solidification behavior of powder metals for 3D printer” (Abbreviation: Hetero-3D, PI: S.Suzuki, Waseda University) was verified as an orbital experiment theme with Electrostatic Levitation Furnace on International Space Station (ISS-ELF). Preparations are underway for the launch of samples in the fall of 2022 and the orbital experiment in the spring of 2023.

In a 3D printer for metals using powder bed fusion, there is a problem that crystals grow in the building direction, which causes the strength anisotropy with decreased strength vertical to the building direction. Therefore, a method of forming equiaxed grains is strongly desired. To solve this problem, the research group including the PI and CIs has been developing metal powder for 3D printer that realizes high formability and high strength by a heterogeneous nucleation. The method is to add heterogeneous nuclei to metallic powder for 3D printer to promote nucleation during solidification. At present, detailed thermodynamic elucidation of the nucleation mechanism is required. The objective of this study is to investigate the effects of heterogeneous nucleation site particles on solidification behavior of metals by microgravity space experiments, which are ideal methods without nucleation from the container and convection.

2. Research Plans

2.1. Experiments

A spherical sample of each material (Ti, Ti6Al4V alloy, with and without heterogeneous nucleation site particles TiC) is heated above the melting point by laser in ISS-ELF. After several seconds of heating, the sample is cooled down and solidified. The temperature history is recorded using a pyrometer.

2.2. Post-flight Analyses

After recovery of the samples, they are embedded in resin and polished. Crystal grains in the solidified sample are evaluated using optical microscope, Scanning Electron Microscope, and Electron Backscatter Diffraction. From the maximum supercooling degree and crystal nucleation frequency obtained from these experiments, the critical nucleation radius and critical free energy in solidification nucleation are discussed.

3. Current Status

3.1. Reference ground experiments and numerical simulations

Reference ground experiments were performed in the Electrostatic Levitation Furnace (ESL) under a high vacuum. Following unexpected problems were found and solved. 1) TiC particles melted away[1)], which was suppressed by limiting the heating time and temperature. 2) Bubbles generated in the sample melt, which was solved by improvement of powder preparation with reducing gaps between powder particles. From the results of the reference ground experiments, the effect of crystal refinement by adding TiC was confirmed[2)].

Reference ground experiments and numerical simulation[3)] with aerodynamic levitation[4)] and electromagnetic levitation showed results that the convection in the sample melt in these levitation methods is much stronger than in ESL and microgravity conditions.

3.2. Sample preparation and preparation for launch

The flight samples were prepared through Spark Plasma Sintering method and formed into spheres in the arc furnace. The absence of large pores inside the spherical samples was confirmed using X-ray Computed Tomography. The prepared samples were packed in a sample holder of ELF and processed for the launch.

References

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