【Grant-in-Aid for Transformative Research Areas（A)】

Section　II

Title of Project： **Creation of Materials by Super-Thermal Field: Neo-3D printing by Manipulating Atomic Arrangement through Giant Potential Gradient**

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Number of Research Area：21A202　Researcher Number：10322174

【Purpose of the Research Project】

The target of this area is the mechanisms of unique crystal growth under superthermal fields (STF) generated by local heating by electron beams or lasers (Figure 1), which have been found to occur in metal 3D printing (3DP). Studies in this area include advanced *in-situ* observations, numerical simulations matched to the experiments to elucidate the mechanisms. It also includes artificial intelligence to analyze the correlation among the process-structure-property. This area establishes the science for the creation of new materials by STF, which contributes to the creation of new materials, such as 3DP of single-crystals. The outcomes will contribute to a great novelty in materials science.

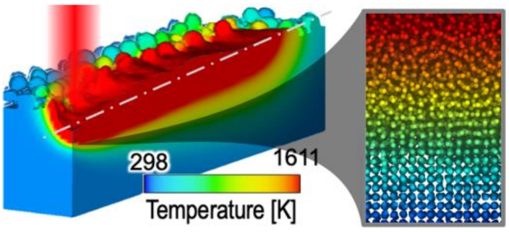

Figure 1 Crystal growth under superthermal field.

【Content of the Research Project】

We aim to elucidate unknown phenomena related to STFs, develop the science of crystal growth in unexplored areas based on the formation of atomic arrangements in STFs, and establish hyperthermal materials science as an academic foundation for the creation of new materials, develop and expand our research in both basic and applied fields by systematically coordinating the research A01 to A03 below.

A01 "Construction of Digital Research Infrastructure"

[Digital twin science for the creation of materials] In-process monitoring of a 3DP and computer simulation to evaluate the dynamic changes of the STF. [Materials informatics for creation of materials] Discovery of the laws, using data science, in the relationships among the process, thermal field, microstructure, and material properties. Derivation of the parameters for the simulation.

A02 "In-situ and Precise Analysis"

【Micro-dynamics of crystal growth】*In-situ* observation by synchrotron X-ray imaging of rapid melting, rapid solidification, and crystal growth in STF. 【Lattice defects analysis of materials created by STF】Analysis of micro-structure, composition, stress, strain, and lattice defects using advanced analytical methods such as electron microscopy, neutron diffraction, and positron annihilation.

A03 "Creation of Transcendental Materials"

[Science for creation of super-titanium] Development of lightweight and heat-resistant super-titanium materials by controlling crystal orientation and microstructure using STFs. [Science for creation of biomaterials] Improvement of metallic implant devices by controlling mechanical biocompatibility through crystal orientation control of biomedical metallic materials (Figure 2) by using STF. [Science for creation of ceramic materials] Establishment of the academic basis for the fabrication of new ceramics materials by applying STF s to melt growth, gas phase growth, and solid particle deposition, direct observation of crystal growth front.

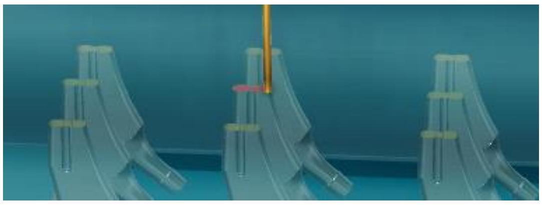

Fig. 2. 3D printing by crystal growth under superthermal field.

【Expected Research Achievements and Scientific Significance】

This Research Area will establish a new category of material science on the crystal growth under the temperature gradient above approximately 10^7 K/s caused by the interaction of quantum beams such as electron beams and lasers with materials. This is expected to be a new guideline for the creation of highly functional materials.

【Key Words】

- superthermal field, additive manufacturing, 3D printing, computer simulation, data science, advanced analysis
- laser, electron beam, rapid heating, segregation, absolute stability, solidification, crystal growth, high-temperature structural materials, biomaterials, ceramics materials

【Term of Project】 FY2021-2025

【Budget Allocation】

853,800 Thousand Yen

【Homepage Address and Other Contact Information】

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