【Grant-in-Aid for Scientific Research (S)】
Science and Engineering (Engineering II)

Title of Project : A New Concept Breakthrough in Materials Development: Reverse 4D Materials Engineering

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Research Area : Structural, Functional materials
Keywords : Strength, Toughness, Fracture, Fatigue, Creep

【Purpose and Background of the Research】
Recent developments in 3D/4D imaging techniques provide direct observation of complex and dynamic phenomena of materials. In the present study, a new technology for materials development, 'Reverse 4D Materials Engineering' (hereinafter RFME), is achieved through the utilization of advanced imaging techniques.
The conventional materials development process involves design, evaluation and production, in that order, as shown in Fig. 1. RFME is a reverse chronological process (also shown in Fig. 1) that enables rapid development of high-performance materials. In RFME, microstructures are virtually optimized by means of an accurate image-based simulation (IBS) in which multi-scale 3D structures of existing materials, which are difficult even to quantify, let alone treat theoretically, according to the present science, are accurately reproduced. To render RFME a practical technique for microstructural control, usable in manufacturing, the representation of a given complex 3D microstructure is 'coarsened' (i.e., unnecessary information is eliminated and the remaining important information is expressed with simplified parameters) to make it suitable to conventional materials design techniques.

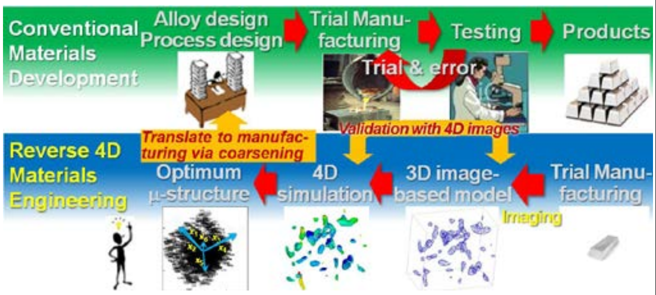

Figure 1 Reverse 4D Materials Engineering

【Research Methods】
IBS is performed by modeling the microstructures of practical materials accurately in 3D/4D. After the selection of an extremely limited number of kinds, morphologies and locations of microstructural features strongly affecting materials characteristics of interest, from an enormous array of microstructural features, the coarsening process thoroughly filters out a staggering amount of microstructural information. IBS and coarsening are investigated in this project, and then an engineering methodology is established by combining the essential techniques. In addition, we perform the microstructural optimization of practical materials, as a demonstrator study, to prove the feasibility of RFME.

【Expected Research Achievements and Scientific Significance】
Allowing conventional manufacturing technology to take into account the complex morphologies of existing materials is expected to result in a paradigm shift in materials development for all structural/functional materials. The proposed technology is based on imaging and analysis techniques that have been especially advanced in Japan, and should make a strong and long-lasting contribution to a variety of industries in our country. For example, as a new approach to materials development, it is applicable to a wide range of materials, such as metals, ceramics, polymers, and their composites, and to other fields, such as those involving various micro/nano structures and the degradation of infra-structures.

【Publications Relevant to the Project】
・H. Toda, S. Masuda, et al., Statistical assessment of fatigue crack initiation from sub-surface hydrogen micropores in high-quality die-cast aluminum, Acta Mater., Vol. 59, 4990–4998, 2011
・L. Qian, H. Toda, et al., Direct observation and image-based simulation of three-dimensional tortuous crack evolution inside opaque materials, Phys. Rev. Lett., Vol. 100, 115505-115508, 2008

【Term of Project】 FY2012-2016

【Budget Allocation】 125,700 Thousand Yen

【Homepage Address and Other Contact Information】
http://four-d.me.tut.ac.jp/index.html