## 【Grant-in-Aid for Scientific Research (S)】
## Clarification of innovative deformation mechanism in harmonic structure materials and creation of design principle for structure materials for next generation

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For many years, ultra-fine grained (UFG) metals have proven to be attractive structural materials due to their superior strength, especially when compared to their coarse-grained (CG) counterparts. However, the disadvantage of homogeneous UFG materials is typically low elongation due to plastic instability in the early stages of deformation. Therefore, producing materials with superior combinations of high strength and high elongation remains a hot topic in materials engineering. Harmonic Structure (HS) design can be a candidate material design that combines high strength with high ductility at the same time. Figure 1 shows a concept of HS design. In contrast to a "Homogeneous UFG" material, the "HS" material has a unique heterogeneous "Three-dimensional (3D) Gradient Microstructure" in which the UFG regions form an interconnected three-dimensional network surrounding the CG regions, and the CG and UFG regions are periodically arranged in all directions. The HS materials exhibit various anomalous deformation behaviors, such as "preferential recrystallization", "preferential stress-induced transformation", and so on. Therefore, the purpose of the present research project is to reveal these unique deformation behaviors and create an innovative structural metallic materials design concept.

The first step of the research is to develop an efficient process to produce the HS materials via multiple severe plastic deformation powder metallurgy processes. The HS materials will be subjected to deformation behavior analysis not only by an in-situ SEM deformation analysis facilities, but also the Spring-8 synchrotron facility. Simulation techniques such as MD and FEM modeling will also be applied to clarify the deformation mechanism from the atomic scale.

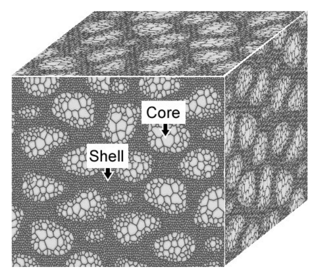

Figure 1
Concept of the HS design

This research project is expected to resolve the strength-ductility paradox. Understanding the micro- and macro-scale deformation mechanisms will guide the development of innovative structural materials. From the engineering point of view, the HS materials can be produced by combining the classical industrial methods based on the powder metallurgy processes. It is worth noting that this research project will be very useful in practical applications.

Publications related to the project: ~ 50 publications

1) Kei Ameyama, Fabien Cazes, Hervé Couque, Guy Dirras, Shoichi Kikuchi, Jia Li, Frédéric Mompiou, K. Mondal, Dmytro Orlov, Bhupendra Sharma, David Tingaud, Sanjay K. Vajpai: *Materials Research Letters*, Vol.10(2022), 440-471.
2) Yoshikazu Nakai, Shoichi Kikuchi, Daiki Shiozawa, Takumi Hase, Issei Nakazawa, Keisuke Fujita, Mie O. Kawabata, Kei Ameyama: *ADVANCED ENGINEERING MATERIALS*, (2023), 201836.
3) Tomotsugu Shimokawa, Tatsuya Hasegawa, Keito Kiyota, Tomoaki Niiyama, Kei Ameyama: *Acta Materiala*, Vol.226(2022), 17679
4) Shoichi Kikuchi, Yuhei Nukui, Yuta Nakatsuka, Yoshikazu Nakai, Masashi Nakatani, Mie O Kawabata, Kei Ameyama: *International Journal of Fatigue*, Vol.127(2019), 222-228.
*And so on.*