【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Engineering)

Title of Project : Novel Material Design Based on Unified Understanding on Unique Mechanical Behaviors in Bulk Nanostructured Metals

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Research Project Number : 15H05767 Researcher Number : 30263213
Research Area : Structural and Functional Materials
Keyword : Structural Metallic Materials; Ultrafine Grain; Strength; Ductility; Grain Boundary

【Purpose and Background of the Research】

The aim of the present study is to fundamentally acquire an unified understanding on various unique mechanical behaviors in Bulk Nanostructured Metals. Bulk Nanostructured Metals are the polycrystalline bulky metallic materials composed of grains or/and phases having average sizes smaller than 1 μm. The minimum grain size in conventional bulky metallic materials has been about 10 μm. When the grain size is reduced to nano-meter scale, the metallic materials become full of grain boundaries, as shown in Fig.1. Such Bulk Nanostructured Metals show various kinds of unique properties that have never seen in conventional materials. The unique mechanical properties we have found by now are as follows: (1) yield-drop phenomena universally appearing in all bulk nanostructured metals, (2) extra-hardening in Hall-Petch relationship, (3) hardening by annealing and softening by deformation, (4) strain-rate dependent deformation at ambient temperature, (5) huge Bauschinger effect, (6) activation of impotent slip systems in HCP crystals, and (7) significant change in deformation twinning and deformation induced martensitic transformation. All these could not be understood by conventional theories of materials science and physical metallurgy.

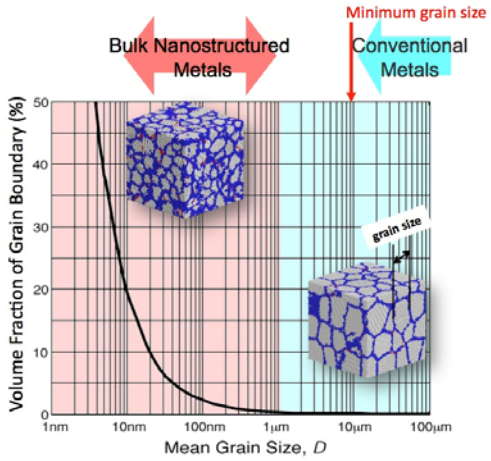

Fig.1 Volume fraction of grain boundaries as a function of mean grain size. BNMs are full of grain boundaries, while conventional metals are rare of grain boundaries.

【Research Methods】

Bulk Nanostructured Metals with various mean grain sizes are systematically fabricated in selected alloy systems by the thermo-mechanical processes developed by the principle investigator. As it has been clarified that the plastic deformation of the Bulk Nanostructured Metals having grain sizes larger than 100 nm is borne by dislocation slips, special focus is put on the interaction between dislocation and grain boundaries. State-of-the-art techniques like digital image correlation (DIC) and in-situ deformation analysis using Neutron (at J-PARC) or synchrotron (at SPring-8) are used in addition to advanced nanostructure analyses for clarifying the mechanisms of the unique mechanical behaviors.

【Expected Research Achievements and Scientific Significance】

Since Bulk Nanostructured Metals perform excellent mechanical properties, such as the strength 4 times higher than the conventional metals. Thus, the knowledge obtained in the present study can contribute to designing Bulk Nanostructured Metals having desirable properties, that would be used as novel structural materials guaranteeing safe and stable society.

【Publications Relevant to the Project】

"Hardening by Annealing and Softening by Deformation in Nanostructured Metals", X.Huang, N.Hansen and N.Tsuji: Science, Vol.312, No.5771 (2006), pp.249-251.
N.Tsuji: Chapters 2 and 22 in “Nanostructured Metals and Alloy”, edited by S.H.Whang, Woodhead Publishing Ltd. (2011)

【Term of Project】 FY2015-2019

【Budget Allocation】 154,700 Thousand Yen

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