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

Title of Project: Essence of Size Effects on Strength of Metallic Nano-Films

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Research Project Number : 26220901 Researcher Number : 50174107
Research Area : Mechanical Engineering, Engineering Materials/Mechanics of Materials
Keyword : Nano/Micro Material Mechanics, Strength of Materials, Fracture, Fatigue, Creep, Metallic Thin Films

【Purpose and Background of the Research】

Mechanical properties and strength of polycrystalline metallic thin films in the thickness range of 10 nm – 1,000 nm (or metallic nano-films) strongly depend on film thickness. This is due to the enhanced constraint of dislocation motion by finer grain sizes in thinner films, starvation of dislocation sources in small volumes, and the difference in surface effects on deformation and fracture. In addition to these structural effects, film surface is subject to oxidization by the ambient air. However, the effects of oxidization, or oxide layer, on the strength of nano-films have been scarcely studied, and hence the essential size effects on the strength have not been clarified.

The purpose of this research is to clarify the essential size effects on the mechanical properties and strength of metallic nano-films (Cu, Al, and Au). To accomplish this, we investigate the effects of native oxide layer and oxidization during deformation and fracture, and thereby extract the intrinsic surface effect by using metallic nano-films with controlled microstructures such as grain sizes.

【Research Methods】

We develop an integrated experimental system for *in situ* strength evaluation that enables high-resolution observation of damage and fracture mechanisms under controlled environments (oxy-gen partial pressure), removal and control of oxide layer on film surface, and *in situ* experiments dedicated for tensile properties, fracture toughness, creep, and fatigue strength. These are based on the original experimental techniques such as fabrication of large area freestanding metallic nano-film specimen (Fig.1) and strength testing of a variety of fracture phenomena (Fig.2). By using the system, we conduct systematic experiments and elucidate the essence of size effects on deformation and fracture in nano-films.

【Expected Research Achievements and Scientific Significance】

Although micro-mechanical systems comprising of thin films are fabricated by state-of-the-art technologies, no reasonable mechanical criteria are applied in the strength/reliability designs. This is because the size and environmental effects on the strength of nano-films are unclear, and hence the dominant mechanics remains an open question.

This study offers reasonable mechanical criteria in strength design of micro- and nano-devices in service environments by clarifying the essential size effects on the strength of nano-films: the study contributes to the reliability enhancement of devices by improving the strength of nano-films by controlling the oxide layer, or surface modification.

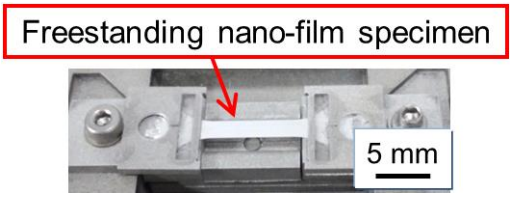

Fig.1 Large area freestanding Al nano-film specimen

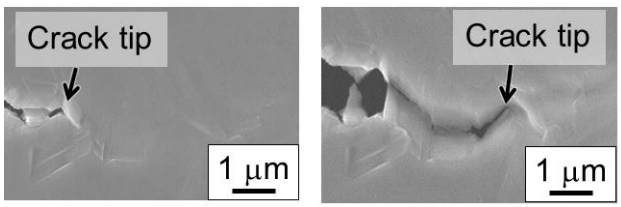

Fig.2 *In situ* fracture toughness experiment of Cu nano-film

【Publications Relevant to the Project】

(1) H. Hirakata, N. Fukuhara, S. Ajioka, A. Yonezu, M. Sakihara, and K. Minoshima, The Effect of Thickness on The Steady-State Creep Properties of Freestanding Aluminum Nano-Films, Acta Materialia, Vol.60, 2012, pp. 4438 – 4447.
(2) T. Kondo, T. Imaoka, H. Hirakata, M. Sakihara, and K. Minoshima, Effects of Stress Ratio on Fatigue Crack Propagation Properties of Submicron-Thick Freestanding Copper Films, Acta Materialia, Vol.61, 2013, pp.6310-6327.

【Term of Project】 FY2014-2018

【Budget Allocation】 149,900 Thousand Yen

【Homepage Address and Other Contact Information】

http://www-micro.mech.eng.osaka-u.ac.jp/home.html