Evaluation of Size Effect on Mechanical Properties of Nano- and Micro-scale Materials Using AFM-Based Technique

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The objectives of this thesis are establishments of 1) fabrication method for nano-scale structures and 2) testing techniques for nano/micro-scale materials, and 3) the evaluation of specimen size effect on mechanical properties of MEMS/NEMS materials. This thesis consists of total 7 chapters including introduction and conclusions.

The 1st chapter is the introduction of this thesis. Importance of material testing for micro/nanometer-sized materials was described. In 2nd chapter, material testing techniques and fabrication procedure of micro/nanometer-sized specimens were described. In this research, two types of testing techniques were developed: nano-scale bending test using an atomic force microscope (AFM) and micro-scale tensile test in the AFM. In 3rd chapter, evaluation of specimen size effect on mechanical properties of Si was performed by AFM bending tests. Young's modulus of Si had no specimen size effect, whereas fracture strength was influenced by the size. In 4th chapter, the AFM bending tests were carried out to reveal the specimen size and temperature effects on plasticity of nano-scale Si beams at intermediate temperatures. The nano-scale Si deformed plastically at 373K～573K, and smaller-sized beam showed larger plastic deformation behavior. Edge dislocation model proposed here could rationalize that the size effect on the plastic deformation behavior was determined by the correlation between the specimen size and thermal activation energy. In chapter 5, the AFM bending test was performed to clarify the size effect on SiO_2-beam's mechanical properties. The SiO_2 beam prepared by a thermal oxidation of Si beam fractured in a brittle manner at 373K～573K. Maximum peak-to-valley distance of the SiO_2 beam surface determined the fracture strength of the beam. In chapter 6, AFM tensile test was performed to estimate the mechanical properties of DLC films. Young's modulus, Poisson's ratio and fracture strength of the films were evaluated. The final chapter is the conclusion of this thesis.