Tensile Testing of Polysilicon Thin Films using Electrostatic Force Grip

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Polysilicon thin films were tensile tested by a thin film tensile tester developed for reliability evaluation of microelectromechanical (MEMS) devices. This tensile tester has a new specimen chucking system using electrostatic force. This method enables us to handle thin (few micrometer thick) specimens easily without damage. The tensile strength of polysilicon specimens is evaluated and some fracture properties are investigated. To study variation of the reported tensile strength of polysilicon films and to check accuracy of the tensile tester, we have participated the cross comparison of tensile testing techniques.

Our tensile tester is characterized by the specimen chucking methods\(^1\). A cantilever beam shaped specimen having the large free end for electrostatic chucking is used as a specimen. One end of the specimen is chucked to the tester by fixing the substrate and the other end is chucked by electrostatic force. For conductive polysilicon films, the electrostatic force is generated when the voltage is applied between a probe and the specimen. Silicon wafer covered with insulating film is used as the probe. This system has many advantages; 1) small damage to the specimen because electrostatic force is relatively weak force but enough to fix the thin specimens, 2) easy handling of specimen because the specimen itself need not to be touched while preparing tensile test, and 3) a number of specimens are tested simultaneously.

Tensile testing of LPCVD polysilicon thin film that is most often used material for MEMS devices was carried out. The specimens were 2 μm thick and 10-1000 μm long and 2-20 μm wide. The polysilicon film showed brittle fracture. The tensile strength ranged 2 to 4 GPa depending specimen size and process conditions. From the statistical analysis of the size effect on strength we estimated the fracture origin locations, which is agreed with the fracture surface observation\(^1\). The relationship to process conditions was discussed with the microstructures of the polysilicon films\(^2\). The smaller-grained and higher temperature annealed films had higher strength.

Recently, some tensile testing methods for thin film have been developed, and their measured tensile strength ranged between 1 to 5 GPa. These result causes uncertainty of the thin film tensile testing methods. To study this differences in tensile test results, five institutes were tested the same polysilicon thin films\(^3\). Johns Hopkins Univ. and we used electrostatic grip, Caltech used adhesive glue and Sandia National Lab. and NIST uses indenter for hocking the specimen with ring shape on its free end. The tensile strength measured at each institute is compared.

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