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Increasing the ductility of single crystalline silicon treated by hydrogen plasma

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This study aims to investigate the effect of hydrogen and defect on ductility of single crystalline silicon. Silicon MEMS with mechanical structure was susceptible to fatigue fracture. Fatigue lifetime of silicon in hydrogen was extremely shorter than that in air. Recently, silicon fatigue failure was found to cause mechanically accumulate damage by cyclic loads because striation-like pattern and dislocation on fatigue fracture origin was observed by transmission electron microscopy. These results suggested that dislocations in silicon moves easily under hydrogen environment even at room temperature. Meanwhile, reactive ion etching (RIE) has used as standard microfabrication technique of MEMS structure. However, ion bombardment during RIE process induces damage on silicon surface. The presence between hydrogen and defect on silicon surface were closely related to plastic deformation and fatigue behavior. Different four types of specimens, which are made of p-type single crystal silicon with polished (100) surface, were prepared to evaluate the relationship between defects, hydrogen and combination of defects and hydrogen by nanoindentation test. Specimen were exposed to SF_6 plasma for 10 sec to induce defect into silicon surface. Hydrogen was diffused into silicon by CVD plasma which is excited by 400 W microwave for 1 hour. Hydrogen depth distribution and trapping state on each specimens were measured by Time of Flight Secondary Ion Mass Spectrometry (TOF-SIMS) and Thermal Desorption Spectroscopy (TDS), respectively. Either defect or hydrogen does not have effect on indentation depth under same load level. Surface defect and hydrogen had significantly deeper indents than the other cases. In case of shallow indentation depth, change rate of plastic deformation become relatively larger than deep indentation depth. These results showed that silicon surface in the presence of defect and hydrogen was softer than silicon bulk even at room, and suggested correlation with defect accumulation of silicon fatigue fracture.

Keywords
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