PO1084

Effect of hydrogen on the mobility of surface defects induced in plasma etching process for silicon

Masaru Nakamura, Taehoon Kim, Hayato Izumi, Shoji Kamiya

Nagoya Institute of Technology, Nagoya, Japan

masa0705spring@yahoo.co.jp

Reactive ion plasma etching (RIE) is widely used to fabricate mechanical structures in micro electro-mechanical systems (MEMS). However, RIE inevitably induces defects to the surface. Recent studies have shown that fatigue lifetime of silicon MEMS structures was intimately correlated to the initial surface damage [1], and that the fatigue lifetime was significantly shortened in humid [2] and hydrogen environment [3]. In the meantime, dislocation mobility in silicon crystal within the temperature range of 390 to 480°C was reported to significantly increase while being exposed to hydrogen plasma [4]. Therefore it was investigated in this study if hydrogen enhances surface defect mobility, even at room temperature, possibly leading to shorter fatigue lifetime. To prepare the specimens, mirror polished silicon wafers were exposed to RIE plasma to introduce surface damage. The wafers were further exposed to either boiling water or hydrogen plasma to introduce hydrogen underneath the surface. For the comparison, counter specimens without being exposed to RIE plasma and with or without further hydrogen introduction were also prepared. Mechanical properties were then characterized with nano-indentation technique. Consequently, wafers with both RIE damage and further introduced hydrogen had significantly deeper indents than those with the other conditions.

The results means that hydrogen strongly interacts with crystal defects to enhance their mobility even at room temperature leading to easier plastic deformation, while the interaction with defect-free crystal was hardly visible within the experiment in this study. This fact could be a key information to understand and control the fatigue behavior of micro-scale structures fabricated by plasma etching process.

[1] S. Kamiya et al., IEEE 24th International Conference on MEMS (2011), pp 404-407.
[2] T. Tanemura et al., J. Micromech. Microeng. 23 (2013), 035032.
[3] H. Izumi et al., Materials Letters 142 (2015), pp 130-132.
[4] Y. Yamashita et al., Physica Status Solidi (A) 171 (1999), pp 27-34.

Keywords
silicon, plasma etching, hydrogen,
defect, nano-indentation