

# Modification of morphologies and mechanical properties of Si crystal by low fluence ion beam irradiation in sub-micrometer scale

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その他のタイトル	低照射量のイオンビームによってシリコン結晶表面に生じるナノメートルサイズの形状及び機械的特性の変化
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## 論文内容の要旨

The importance of complicated 3-dimensional (3-D) structure in micro or nano-meter scale is increasing in various fields, such as electric device, micro-electromechanical systems (MEMS), optical devices and biochips. In addition to a geometric shape of the surface, mechanical properties are also important factors to be considered, especially in the field of MEMS. However, it is difficult to fabricate such complicated 3-D structures with enough precision and mechanical properties by means conventional method. Ion beam technologies, used to be applied as a useful and convenient tool to fabricate 2-dimensional structures in nanometer scale, is a hopeful candidate by expanding its ability to 3-dimensional fabrication because of its high resolution along lateral direction and a controllability of its projection range. Recently, It has been confirmed that an expansion effect of crystal material by irradiating relatively low-fluence ion beam cause a surface swelling, and the swelling height could be controlled by change ion beam parameters. If this expansion effect is applied to 3-D micro/nano-structures, it is expected that morphological modification of micro/nano-structure can be achieved without serious deterioration of mechanical properties. In order to improve new fabrication method with ion beams, I intend to investigate lateral deformation of micro/nano-structures and modification of mechanical properties of crystal materials induced by low fluence ion beam irradiation.

In this thesis, it has been found that low fluence ion irradiation can induce a lateral deformation phenomenon on crystal nanostructure. Different size of initial nanostructure fabricate by FIB were irradiated with 240 keV Kr beam with fluence up to  $5 \times 10^{14}$  ion/cm<sup>2</sup> and Raman spectroscopy were used to investigated evolution of amorphous fraction at the same time. TEM measurement and SRIM calculation were utilized to observed inner change of crystal Si and defects distribution in crystal Si, respectively. In this study, elastic deformation of nano-structures on Si crystal along lateral direction has been successfully achieved firstly by irradiating low fluence Kr-ion beam with 240 keV and the observed results indicate that this deformation strongly depends on the fluence of irradiation and structure size of nano-structure. The evolution of heterogeneous amorphous amorphization, which is associated with stress in the

lattice structure, can give consistent explanation to understand the fluence dependence. The combination of anisotropic mechanical properties and suppression effect arising from Si matrix gives probable explanation for the structure sizedependence.

In addition, the mechanical properties of crystal Si sample irradiated with low fluence ion beam were also investigated by nano indentation. Observed results indicate that both modification of hardness and that of Young's modulus show fluence dependence and depth dependence and this results consist with SRIM calculation. Compared with high fluence irradiation effect, change of mechanical properties induced by low fluence ion beam irradiation is relative weaker.

Based on the above results, it is expected that this method of lateral expansion crystal material induced by low fluence ion beam irradiation is applied to fabricate relative complicated nanostructure.