半導体材料におけるイオンビーム誘起ナノ構造体

Nanostructure Formation Induced by Ion Beam Irradiation on Semiconductor Materials

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Introduction

It is possible to fabricate nanostructures on semiconductor materials, such as Ge and Si, via ion beam irradiation. These technologies may be required for some device application which should be constructed with the nano-order processing and control of irradiation damages.

Nanostructuring on Ge mainly stems from the self-organization of point defects, and results in a formation of abundant porosity within a certain region which is almost as deep as ion range[1]. On the other hand, nanostructuring on Si stems from the sputtering effect and atomic diffusion[2]. In this research, nanostructuring on both of Ge and Si were investigated, via Ga monoatomic ion and C_{60} cluster ion beam irradiation, respectively. Especially morphological changes of nanostructures which depend on experimental parameters were focused.

Experimental procedure

Substrates used as samples were single-crystalline Ge and Si. All the substrates were mirror polished and irradiated at (001) plane. To fabricate nanostructures on Ge, Ga ion beam was utilized with a FIB (Focused ion beam, FEI, QUANTA 3D200i). The fluence and beam flux were $5\times10^{19} – 1\times10^{21}$ ions/m^2 and $1.3\times10^{18} – 8.9\times10^{20}$ ions/m^{2}s, respectively. The incidence energy was 30 keV, and the incidence angle was 0°.

To fabricated nanostructures on Si, C_{60} cluster ion beam was utilized with an ion-implanter (NECAM 9SDH-2) and a tandem accelerator (NISSIN ELECTRIC NH40SR). The incidence energy was 50–540 keV or 1–9MeV, respectively. The fluence was $1\times10^{16} – 1\times10^{19}$ ions/m^2 and the incidence angle was 0° or 60°. All the irradiated regions were captured by a SEM (Scanning Electron Microscope, HITACHI SU8020) with the SE detecting mode, and some of them were captured by a TEM (Transmission Electron Microscope, JEOL JEM-2100F) for cross-sectional observations as well.

Results and discussion

Nanostructures on Ge changed their morphological characters depending on the beam flux. When the fluence was 5×10^{19} ions/m^2, nanoporous structures appeared throughout the beam flux of $1.3\times10^{18} – 1.8\times10^{20}$ ions/m^{2}s. Then abundant porosity and no flux-dependent change were found out at 1×10^{20} ions/m^2. The structure morphology changed at 1×10^{21} ions/m^2, depending on the beam flux throughout $1.4\times10^{18} – 8.9\times10^{20}$ ions/m^{2}s.

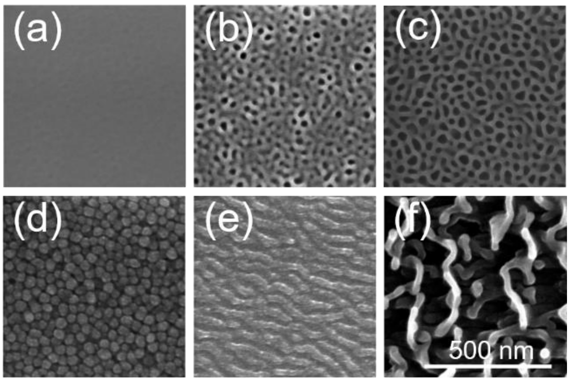

Fig. 1 Various morphological changes of Ge nanostructures (a–c) and Si nanostructures (d–f).

Nanostructures on Si changed their morphological characters depending on the incidence energy, angle and fluence. When the incidence angle was 0°, concave and convex structures formed on almost all the structured region. Structure sizes increased with an increase in the incidence energy. On the other hand, concave and convex-, string like- and ripple structures were found out at the incidence angle of 60°. The structure type varied with the irradiation condition, especially ripple structures formed relatively at a lower incidence energy, while string-like structures formed at a higher energy.

References

1) N.G. Rudawski and K. S. Jones, J. Mater. Res., **28,** 1633-1645(2013).
2) T. K. Chini, M. K. Sanyal, and S. R. Bhattacharyya Phys. Rev. B **66**, 153404 (2002).