Three-Dimensional Analysis of Phosphorus-Doped Si Nanocrystals Embedded in SiO_2 Matrix by Atom Probe Tomography

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Si nanocrystals (Si NCs) embedded in SiO_2 matrix have attracted much attention for application to optical and electronic devices [1]. The properties of these devices are strongly dependent on Si NCs structural characteristics. In our previous report, the shape, size and areal density of Si NCs as a function of SiO thickness were investigated by atom probe tomography (APT) [2]. As a further step, an establishment of efficient doping method into Si NCs is a challenging issue, and extensively studied recently [3,4]. In this work, we studied phosphorous (P) doping into Si NCs embedded in SiO_2 by using APT, and explored efficient incorporation into Si NCs.

A SiO_2/SiO/SiO_2 stack was deposited on Si(100) substrate by electron beam deposition in high vacuum regime [1]. Then, to form Si NCs, the sample was annealed at 1050 °C for 30 min in N_2 flux. Subsequently, P-delta layer and SiO_2 cap were formed. For P diffusion into the Si NCs (already-formed) layer, the sample was annealed at 1100 °C for 4 h [See Fig. 1(a)]. Needle specimens for APT analysis were prepared by Ga focused ion beam from a cross-sectional direction. Laser-assisted atom probe was used for APT analysis.

Figure 1(b) shows the plan-view APT map of Si and P atoms around Si NCs layer. It is demonstrated that the diffused P atoms were efficiently trapped inside of Si NCs [Fig. 1(c)], which is consistent with the XPS analysis. In this presentation, the detail of APT and XPS data will be shown.

The authors thank Mr. N. Ebisawa (IMR Tohoku Univ.) for the technical support. This work was supported in part by JSPS Kakenhi (Grant No. 15H05413).

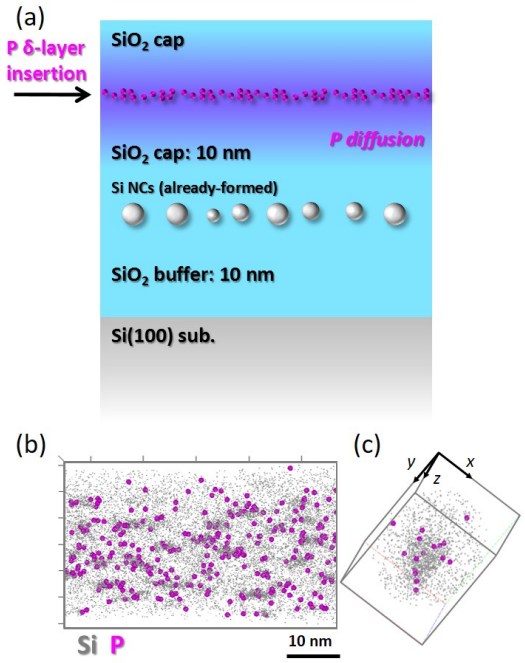

Fig. 1: (a) Schematic illustration of sample structure. (b) Plan-view atom map of P (100%) and Si (15%). (c) One Si NC is extracted (Selected volume: 7.8 × 9.8 × 7.8 nm^3).

References

[1] G. Seguini *et al.*, Appl. Phys. Lett. 103, 023103 (2013).

[2] B. Han *et al.*, JSAP Spring Meeting, 12p-A20-9 (2015); RSC Adv. 6, 3617 (2016).

[3] M. Perego *et al.*, Nanoscale 7, 14469 (2015).

[4] M. Mastromatteo *et al.*, J. Mater. Chem. C, 4, 3531 (2016).