GROWTH TEMPERATURE DEPENDENCE OF Ge QUANTUM DOTS GROWN ON CARBON-IMPLANTED SI SUBSTRATES

Masaaki Ogawa, Hyung-jun Kim, Joo-young Lee, Dong-ho Cha, and Kang L. Wang
Device Research Laborator, Department of Electrical Engineering, University of California, Los Angeles
Los Angeles, California 90095-1594, USA
masa@ee.ucla.eduT

Due to the low-dimensional confinement effect, self-assembled Ge quantum dots (QDs) grown on Si are expected to demonstrate novel optoelectronic properties, which can be applied to Si-based technology competitive with traditional optoelectronic III-V and other materials. However, this self-assembled method has not achieved the dot diameter and density comparable to those grown with the III-V semiconductor materials such as InGaAs/AlGaAs, InP/InGaP, AlInAs/AlGaAs, and GaSb/GaAs [1]. Recently, a new approach to scale down Ge dot sizes to less than 15nm in diameter has been reported [2-4]. Pre-deposition of a submonolayer carbon atom on Si substrate results in very small and high density Ge dots because carbon atoms induce a strain field at the interface [2-7].

We used ion implantation instead of in situ carbon evaporation to induce a strain field at the interface. First, we deposited 380Å-thick SiO_2 on Si(111) substrate to achieve the carbon concentration peak near the Si surface. Then, we implanted carbon atoms at different dosage, 9.0×10^{14}, 4.5×10^{15}, and 9.0×10^{15}[Ions/cm^2], using the same energy, 20[keV]. After the implantation, we did rapid thermal annealing to remove the surface damage caused by the implantation at 1050°C for 10sec. Finally, we grow 6ML amounts of Ge on the substrate at different growth temperatures ranging 400 to 550°C using solid source molecular beam epitaxy.

The surface morphology is investigated by atomic force microscopy (AFM). The smallest Ge quantum dots with a 150Å mean lateral diameter, a 20Å mean height, and an areal density of 8.0×10^{10} cm^{-2} are obtained using the highest dosage substrate. Growth temperature dependence for the Ge dot growth reveals that the dot density and size can be controlled very well by optimizing the growth conditions. For our experiments, the highest dosage substrate achieves the smallest and highest density Ge dots at all of the growth temperatures, 400-550°C.

It is thus suggested that carbon-implanted substrate can be used to achieve very small dimension and high density of Ge dot.

References:

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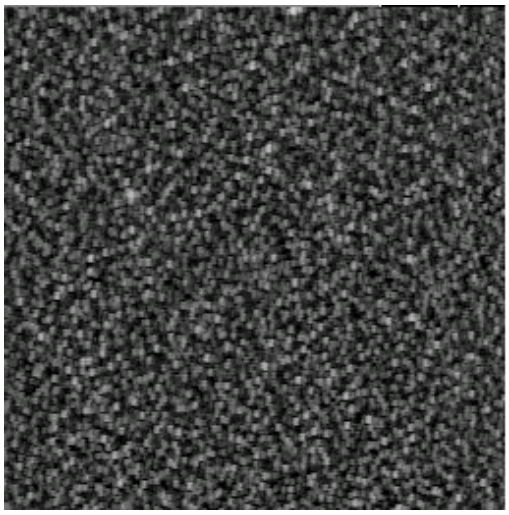
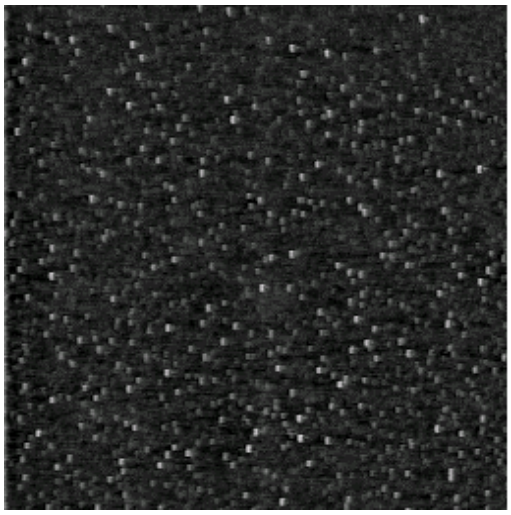
Figures:

AFM images (1μm×1μm) for the highest dosage substrate (9.0×10^{15}[Ions/cm^2])



(a) T_G = 500°C



(b) T_G = 550°C