

High sensitivity infrared absorption spectroscopy and infrared defect dynamics of silicon crystal (16) Nitrogen in as-grown silicon crystals

シリコン結晶の高感度赤外吸収と赤外欠陥動力学 (16) as-grown結晶中の窒素

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Introduction Nitrogen in silicon usually forms interstitial pair (N_iN_i) and its concentration is measured by the infrared absorption by the pair complexes (NNO_n , $n = 0-2$). Also it is known that N in CZ silicon at low concentrations forms shallow thermal donor (STD) of NO pair complexes (NO_n , $n = 1-3$). We found the infrared absorption for the local vibration modes of STD [1, 2] and identified the origin [3, 4]. Furthermore, we found that the absorption line at 551 cm^{-1} decreased after the electron-beam irradiation [5] and the 688 cm^{-1} line appeared by the post annealing at $400\text{ }^\circ\text{C}$ in FZ silicon, and assigned the latter as VVNN [6] which was predicted theoretically [7]. Here we examined them in the as-grown crystals.

Experimental The samples were N doped CZ and FZ crystals at various contents. Some of them were irradiated with electron beams and then annealed. The differential IR absorption was measured at a resolution of 2 cm^{-1} for the 2 mm thick polished samples at room temperature, using the non-doped or non-irradiated sample as the reference. The relatively weak signals on the strong background absorption by the NN and NO pair and oxygen were obtained by using the Lorentz function fitting to the latter.

Results and discussion The absorption line at 551 cm^{-1} was observed in the as-grown CZ and FZ crystals. An example of its relation to NN absorption in as-grown FZ silicon is shown in the figure. It was proportional and about 1/3 of the NN absorption. The 551 cm^{-1} absorption line has been observed previously in the ion implanted, laser annealed and quenched sample and later suggested to be the absorption by the Si next to N_i by theoretical prediction [7]. We follow this. The 689 cm^{-1} absorption line was observed in as-grown FZ silicon. It was suggested that VN_s and VVNN composed of facing pair of VN_s have the absorption at nearly the equal wavenumber. Therefore we assigned the 689 cm^{-1} absorption line is due to VN_s . Its relation to the NN absorption in the same FZ silicon was shown in the figure. It was about 1/5 of the 551 cm^{-1} absorption line. It has not been clearly observed in the CZ silicon yet.

Summary It was found that the N_i and VN_s are included in the as-grown silicon crystals. The intrinsic point defect was directly observed for the first time in the as-grown silicon. It will help understanding the N-V&I interaction and defect formation during crystal growth. It was shown that the N is present in various forms in the silicon crystal. It is necessary to identify, measure and observe their behavior separately. Determining their dipole moment by theoretical work rather than the measurement is expected for that.

[1] Inoue, SSP(2005). [2] Inoue, Physica(2006). [3] Inoue, Mat.Sci.Eng.B (2006). [4] Inoue, Kawamata, Okuda, ECS Trans. 86-10, 87(2018). [5] Inoue, PSS (2016). [6] Inoue, JAP(2018). [7] Goss, Phys. Rev. B(2003).

