Formation kinetics of thermal double donor in Ge

K. Inoue, T. Taishi, Y. Murao, Y. Tokumoto, K. Kutsukake, Y. Ohno, I. Yonenaga

Institute for Material Research, Tohoku University, Sendai 980-8577, Japan
a Faculty of Engineering, Shinshu University, Nagano 380-8553, Japan

kaihei-inoue@imr.tohoku.ac.jp

Thermal double donors (TDDs) are generated upon annealing in the temperature range 350-450°C in oxygen-rich Si and Ge crystals. As a long-term topic in defects in semiconductors, the formation mechanism and properties of TDDs are discussed mainly in Si as an electrically-active oxygen cluster. Up to now, the atomic structure of TDDs is understood to be a pair of two long chains of oxygen atoms. In contrast, Ge is far less known about TDDs due to experimental limitations that the concentration of oxygen is generally low in Ge. Here, we report the kinetics of TDDs formation based on reduction of oxygen by using oxygen-enriched Ge [1, 2].

Specimens, prepared from a Ge crystal containing dissolved oxygen (O\textsubscript{i}) with the concentration of 4-5×10\textsuperscript{17} cm\textsuperscript{-3} grown by a new CZ method, were annealed in a temperature range 300-500°C. Shrinkage of an absorption peak related to the O\textsubscript{i} at 855 cm\textsuperscript{-1} and development of a peak related to the TDD at 780 cm\textsuperscript{-1} were observed simultaneously by infrared absorption spectroscopy at room temperature. The formation of TDDs was also confirmed by the Hall-effect measurement.

Reduction of O\textsubscript{i} concentration upon the annealing was kinetically analyzed with Smoluchowski-approach. The activation energy of the reduction of the O\textsubscript{i} concentration was evaluated to be 1.7 and 2.0 eV in the early and prolonged stages of the annealing, respectively. These values are close to that of the diffusion O\textsubscript{i} in Ge crystal. Thus, the formation of TDD is supposed to be two reactions: In the early stage of annealing, the merge reaction of two O\textsubscript{i}s is dominant to form an oxygen dimer. In the prolonged stage, development of such an oxygen dimer to a TDD by absorbing an O\textsubscript{i} is dominant in accordance with the O\textsubscript{n}-2NN model [3].