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SEEBECK-COEFFICIENT CONTROL OF ULTRATHIN SOI LAYERS AND ITS NOVEL CHARACTERIZATION TECHNIQUE

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In recent years, thermoelectric devices have been attracted considerable attention due to their ability to produce electric power from waste heat. However, thermoelectric conversion efficiency is still not enough for practical use. Nanostructure has been introduced to overcome this problem since the quantum confinement effect can enhance the thermoelectric efficiency. However, there are some problems for the introduction of nanostructures. One is the difficulty in the fabrication of thermocouple consisting of n- and p-type nanowires due to their nanometer-scale dimensions since the thermoelectric materials are usually used in a structure of thermocouple for practical applications.

As a solution for the fabrication of nanowire thermocouples, we propose a method in which Ga ions are implanted by a focused ion beam (FIB) into an array of P-doped Si nanowires patterned in a Si-on-insulator (SOI) layer. Firstly, in order to confirm the formation of p-type Si by Ga-ion implantation, we have investigated the variation of Seebeck coefficient of a P-doped SOI layer by implanting Ga ions. The Seebeck coefficient of Ga-implanted SOI layer was found to have an opposite sign as compared with that of the original P-doped SOI layer. Moreover, the Seebeck coefficient of Ga implanted SOI layers increased with decreasing the implanted Ga concentration. These results indicate that p-type Si was produced by the Ga-implantation and the Seebeck coefficient can be controlled by the dose of Ga ions. It is predicted from the theoretical Seebeck coefficient that in the co-doped Si with the Ga concentration comparable to the original P concentration, the carrier transport is significantly influenced by the coexistence of both ions through the ionized impurity scattering.

Another problem for the usage of nanostructures is the lack of the thermoelectric characterization technique for nanostructured materials. With the aim of measuring the Seebeck coefficient of nanometer-scale materials, we have developed a novel technique using Kelvin-probe force microscopy (KFM) that gives us the information about local Fermi energy of the sample. By this technique, the Seebeck coefficient of a thin n-type SOI layer was evaluated to be -0.78 ~ -1.06 mV/K, which is close to the value obtained using the conventional measurement method. Therefore, the KFM technique is revealed to be a powerful tool for evaluating the Seebeck coefficient of thermoelectric nanostructures.

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