論文 / 著書情報
Article / Book Information

題目(和文)	ダイヤモンド量子センサの集積化に向けたデバイス技術に関する研究
Title(English)	A Study on Device Technologies for Integration of Diamond Quantum Sensors
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第11976号, 授与年月日:2021年3月26日, 学位の種別:課程博士, 審査員:岩﨑 孝之,宮本 恭幸,山田 明,波多野 睦子,小寺 哲夫,川原田 洋
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第11976号, Conferred date:2021/3/26, Degree Type:Course doctor, Examiner:,,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	要約
Type(English)	Outline

Abstract of dissertation

A Study on Device Technologies for Integration of Diamond Quantum Sensors
(ダイヤモンド量子センサの集積化に向けたデバイス技術に関する研究)

Takuya Murooka

Magnetometry is one of the key metrological techniques in contemporary society. It is widely applied in many fields such as life science, medicine, and mechatronics, among others; therefore, the spatial resolution, sensitivity, and dynamic range requirements differ from each other, no sensor can satisfy all fields. A nitrogen-vacancy (NV) center in diamond, which is the topic of this study, is one of the promising solid-state systems for quantum sensors due to its superior properties. Therefore, the NV center is being studied as a magnetometer with high sensitivity for a wide range of applications.

Research on magnetometers based on the NV center is advancing, and a lot of effort has been devoted toward realizing highly sensitive magnetometers with the NV center. However, the measurement setup of magnetometers often includes an optical table with a size of more than 1 m, producing a large sensor system volume. This has become a bottleneck in the practical application of sensors. Therefore, it is of great importance to miniaturize and integrate sensor systems, as well as improve the sensitivity for practical applications of magnetometers with the NV center. Moreover, miniaturization of the sensor system will contribute to further expansion of the application field of high-sensitivity magnetometers with the NV center.

This study focused on device technologies as the basis for integrated sensor systems. Specifically, photoelectrical detection of the NV center was conducted. For this purpose, p–n junction devices were developed, and the NV centers were formed inside the diamond electronic devices to efficiently detect spin-dependent photocurrents from the NV centers. In the photoelectrical detection, devices with low leakage currents are required because leakage currents become one of the noise sources. Investigation by means of the electron-beam-induced current technique and conductive atomic force microscopy revealed the defects that are responsible for leakage currents. Then, devices exhibiting low leakage currents were fabricated, and photoelectrical detection of the NV centers incorporated in the fabricated devices was performed.

In addition, Schottky barrier diodes were fabricated on heteroepitaxial diamond substrates for large-area processing of integrated sensor systems. In this study, 3C-SiC/Si was selected as the substrate material because it enables production of large-size substrates with low cost and has high affinity to the conventional silicon processes. 3C-SiC/Si substrates can be expected to realize an integrated on-chip sensor device via the elemental technologies investigated. For the fabricated diodes on the heteroepitaxial film, the electrical characterization was investigated and defects causing leakage

currents were revealed.

The topics studied in this study are important elemental technologies to realize the integration of highly sensitive diamond quantum sensors for practical use in the future.