Study of ion-implanted-nitrogen related defects in diamond by transient photocapacitance spectroscopy

Junjie Guo1,2, Toshiharu Makino1,2, Satoshi Yamasaki1,2, Masahiko Ogura2, Aboulaye Traore1, Muhammad Hafiz Bin Abu Bakar1,2 and Takeaki Sakurai1

E-mail: s1930098@s.tsukuba.ac.jp

Nitrogen-vacancy (NV) centers in diamond are intensively investigated for the implementation of quantum devices because of the optical addressing and microwave control of their spin state even at room temperature. Nowadays, nitrogen ion implantation in diamond followed high-temperature annealing is widely used to produce NV centers, control their distribution by changing energy and dose of ions. In this work, defects induced by nitrogen ions implantation in diamond are investigated by transient photocapacitance (TPC) spectroscopy and photoluminescence (PL) spectroscopy. The sample is Schottky diodes fabricated on CVD boron-doped diamond layer which is divided into two parts, half of the diamond film was treated with nitrogen ion implantation and annealing treatment and the other without.

Room temperature TPC spectrums of diamond Schottky diode are measured for photon energy ranging from 0.78 to 3.1 eV. Figure 1(a) shows the TPC signals normalized by the photon flux (STPC) as a function of the photon energy. The red and black curves are TPC signals of Schottky diodes fabricated in the areas with and without ion implantation. The obvious increase from around 1.2 eV of photocapacitance in both spectrums should be due to a hole emission process from hole trap states in the depletion layer of the Schottky diode. The thresholds of 1.3 eV appear in both signals, where the intensity of signal in implantation area is higher, so that means 1.3 eV is probably caused by the presence of excited impurity energy levels related to a common impurity like nitrogen, an intrinsic defect like a vacancy or a carbon interstitial, or even NV center. The 2.2 eV defect only exists in the implantation area, which probably is attributed to the nitrogen-vacancy center. It is known that the carrier state of NV center changes with different biases because of the variation of the Fermi level. The PL spectrums have been measured under different bias conditions to identify the charge state. The variation of PL spectra with different applied voltages showed in figure 1(b) suggests that the charge state of NV centers is controlled by bias voltages since their effect on the Fermi level. NV centers are actively switched from the negative state and natural state. It may be due to the band bending in the depletion region of Schottky contact, in such a way that the Fermi level shifts around defects levels, which varied the charge state of NV center and its electrical and optical properties. The further work is voltage-dependent TPC to identify NV center by comparing the variation of spectrum shape.

Figure 1 (a) Transient photocapacitance spectroscopy signal; (b) PL with different applied voltages using 532 nm green laser

References