【Grant-in-Aid for Scientific Research (S)】
Science and Engineering (Engineering)

Title of Project : Electron Spin Control of Diamond by Surface Carrier and its Application to Nuclear Spin Detection of Biomolecules

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【Purpose and Background of the Research】

An NV center composed of nitrogen (N) atom and vacancy (V) site in diamond crystal has electron spins, which interact with other electron spins or nuclear spins. Local nuclear magnetic resonance (NMR) of surface adsorbed molecules has been studied based on spin-spin interaction of NV center in world wide. As shown in Fig.1, an energy of two spins (S=1) in a negatively charged NV (NV^-), splits into two levels (M_S=0 and M_S=±1), i.e. spin-polarization without magnetic field. The superposition of M_S=0 and M_S=-1 is detected accurately by spin resonance and red fluorescence (638nm) of NV^-. With the entanglement formed by the superposition, a single nuclear spin can be measured. ^{13}C in diamond (1st publication) and ^{1}H of oil or PMMA on diamond surface have been measured by German and USA groups recently. Now, the local NMR of single nuclear spin becomes very urgent research subject. However, the sensitivity is not enough for biomolecule detection. Local NMR based on single NV^- is going to be applied for biomolecule sensing in this study.

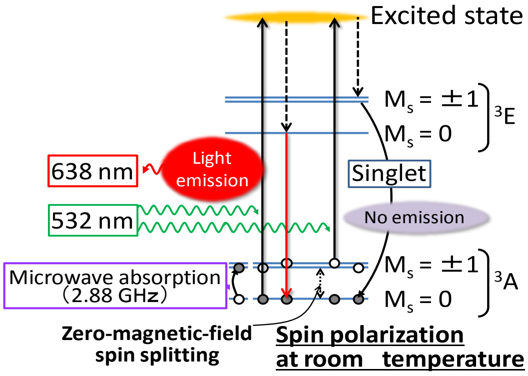

Fig.1 Zero-magnetic-field spin splitting at M_S=0 and M_S=±1 of NV^- center in diamond.

【Research Methods】

1. NV center with long coherence time near surface: a NV^- with a long coherence time (1msec) is formed near surface to interact external nuclear spin. For that purpose, ultra pure and 99.99% ^{12}C enriched diamond is prepared and the surface is terminated by fluorine (F) atoms (Fig.2). The reason for the F-termination is the high electron affinity to keep NV^- center negatively charged. The termination is also effective in increasing the coherence time.

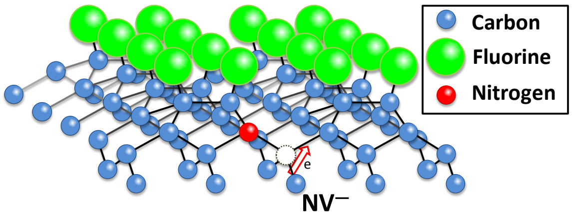

Fig.2 Diamond (001) F-terminated 2×1 surface where NV^- centers are preserved.

2. Biomolecule detection by electron spin of NV^- :
In the NMR observation of biomolecules, 180° shifted pulse waves are alternatively irradiated with the NMR frequency of a biomolecule to the superposition between M_S=0 and M_S=-1. The entanglement between the electron spins and a nuclear spin is formed. Generally, from the nuclear spin, the direction of electron spin is frequently changed by the pulse wave oscillation, the magnetic field from electron spin is averaged to be zero. In an entanglement, however, the magnetic field from electron spin is not cancelled and is affected by nuclear spin of biomolecule. Thus, NMR signal of biomolecule can be detected.

【Expected Research Achievements and Scientific Significance】

In recent years, short DNA or RNA molecules having 10-20 bases are highlighted because they are used for RNA interference in medicine and for DNA/RNA based biosensors (2nd publication). Observation of secondary structure of these molecules during biochemical interaction is one of the significant subjects of biomolecular research. Local NMR of one particular biomolecule will greatly contribute to biotechnology.

【Publications Relevant to the Project】

1. H. Fedder, J. Isoya (Research collaborator) et al. Nature Nanotech. **7,** 657 (2012).
2. A. Ruslinda, H.Kawarada (Project leader) et al. Biosensors & Bioelectronics. **40,** 277 (2013).

【Term of Project】 FY2014-2018

【Budget Allocation】 146,300 Thousand Yen

【Homepage Address and Other Contact Information】
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