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7.14 Hyperfine Interactions of Spin Polarized β-Emitter ^{12}N in V Crystal

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Light ion implantation has a particular characteristics; the ions are found mainly in crystallographic interstitial locations, the sites which are very rare with heavier impurities. Therefore, the NMR detection of these ions provides us with knowledges on the electronic structure of the interstitial impurities as well as on that of the host materials, i.e. hyperfine interactions that may be needed as the basic grounds to develop new metals.

The main purpose of the present study was to investigate hyperfine interactions of ^{12}N ($I^{\pi}=1^{+}$, $T_{1/2}$=11 ms) in bcc V crystal by use of the NMR detection and asymmetric β decay. Also, from these experiments we determined the impurity sites in bcc metal following ion implantation, and we might be able to guess the impurity sites and surrounding renormalization in bcc Fe in which it was very difficult to determine these effects due to the impurity from its NMR spectra alone[1,2].

The experimental procedures were essentially similar to that of the previous hyperfine interaction studies of short-lived β emitters[1,2]. The β-emitting ^{12}N was produced through $^{10}B(^{3}He,n)^{12}N$ reaction initiated with ^{3}He beam of 3.0 MeV. The ^{12}N nuclei ejected to the recoil angle of 15-20 degrees were implanted in a disk of V crystal by use of the kinetic energy obtained in the reaction. The β-rays emitted from ^{12}N in V were detected by two sets of counter telescopes placed above and below the V sample relative to the polarization. A static magnetic field was applied parallel to the polarization direction in order to maintain the polarization of ^{12}N in the sample and also to perform NMR detection. By observing asymmetries in the up-down β-ray counting rate ratios, nuclear polarization was deduced. Also, the change in nuclear polarization of ^{12}N, as a result the asymmetry change in the β rays, was observed as a function of rf frequency with its oscillating magnetic field being applied perpendicular to the static field.

It was disclosed from the nuclear quadrupole spectra (for example see Fig. 1) obtained as a function of crystal orientation relative to the external magnetic field that all ^{12}N nuclei which maintained nuclear polarization were located in interstitial sites which were crystallographically equivalent. For instance, two orientations for the field gradient q, i.e. parallel to the symmetry axis of the surrounding V distribution, at an equivalent site are allowed if c-axis is parallel to H_0, i.e. one of them is parallel to H_0, and the other is perpendicular to H_0. The quadrupole coupling constant $\omega_Q/2\pi = 3eqQ/4h = -(415.9\pm1.2)$ kHz, with its asymmetry $|\eta| < 0.024$ was determined. The present result from the quadrupole spectra that the single and equivalent interstitial site is allowed for ^{12}N in V is the same as that for ^{12}N in other fcc metals. On the contrary, it is noted that majority (~80%) of ^{12}B nuclei is located in interstitial site in bcc and fcc metals while the remaining 20% is in a substitutional site[1,2].

Sharp NMR spectra of double quantum transitions at Larmor frequency ν_L(DQ) which is induced between magnetic substate m = +1 and m = -1, were observed as a function of crystal orientation and rf strength. The DQ line of I = 1 system at high field is free from small broadenings in the resonance due to the radiation damages. A typical spectrum is shown in Fig. 2 for the H_0 direction oriented from <100>, <010>, and <001> axes 48.5, 41.8, and 86.0 degrees, respectively. It is found that the line composed of three components in consistent with the quadrupole spectra. Dipolar broadenings for the three lines were extracted and were compared with the van Vleck values for respective orientations of the symmetry axes of the surrounding V distribution. Relative change of the observed widths as a function of crystal orientation is in good agreement with that of the theoretical van Vleck values, and the location is concluded to be tetrahedral site. From these strong narrowing found in the widths, it is disclosed that ^{12}N nuclei at the tetrahedral site of V, and the nearest

V atoms are displaced from the regular position due to the ^{12}N impurity, since the narrowing effects in the widths due to the motion of ions at high temperature and the nuclear quadrupole interaction of the surrounding host V atoms caused by the impurity itself are negligible compared with the nuclear dipolar widths observed. The lattice expansion of relatively large size of $\Delta a/a = 0.5$ is concluded to explain the observed sharp nuclear dipolar widths.

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References

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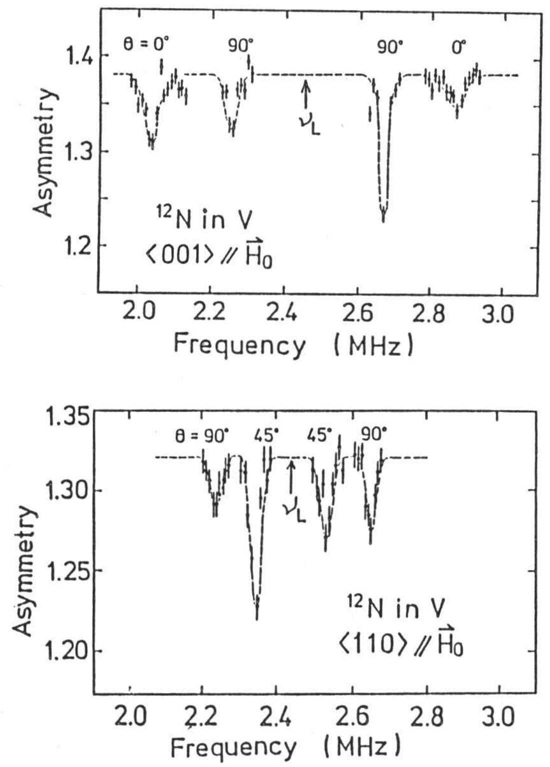

Fig. 1. Typical nuclear quadrupole spectra of ^{12}N in V.

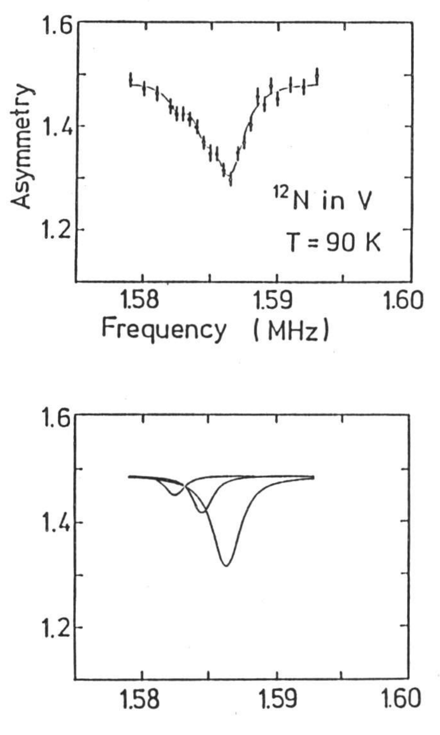

Fig. 2. Typical double quantum transition.