Electric field gradient of ZnO crystal measured by β-NQR of ^{23}Ne

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This report presents the results of the experimental program NP1612-RRC47, which is a part of a project to measure the ground-state magnetic dipole (μ) and electric quadrupole (Q) moments of neutron-rich Ne isotopes.

The structures of neutron-rich Ne have attracted much attention because of their exotic structures in the ground states, such as large deformation and p-wave halo, as suggested by some of the experiments.[1)] In order to investigate such structures, measurements of μ and Q moments are one of the most effective ways; however, up to now, there exist no moment data for neutron-rich Ne isotopes. In our project, we approach the ground-state moments of neutron-rich Ne isotopes by means of β-detected nuclear magnetic resonance (β-NMR). As the first step of this project, we performed an experiment to determine an appropriate single crystal with an electric field gradient at the Ne stopping site for β-NMR measurement of the Ne isotopes. In the present experiment, we applied a β-NQR method[2)] to the spin-polarized ^{23}Ne, whose ground-state moments and spin were well known.[3)]

The experiment was performed by using RIKEN projectile fragment separator (RIPS). A radioactive ^{23}Ne was produced by the one-neutron pickup reaction of ^{22}Ne (70 MeV/nucleon) with a 0.25-mm-thick Be target. The ^{23}Ne spin polarization was obtained by injecting the primary beam with a tilt angle of 2° with respect to the Be target at the focal plane F0 and selecting the momentum of ^{23}Ne at the dispersive focal plane F1. The obtained spin polarization of ^{23}Ne was approximately 8%.

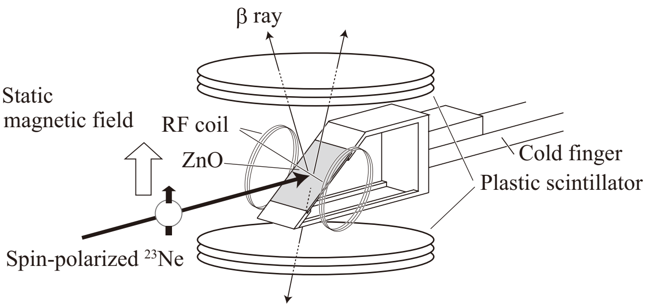

Fig. 1. Experimental setup.

Table 1. Comparison between the experimental $|q|$ and the calculated ones.

Exp.	Calc.	
	Zn site	O site
31(3) $\times 10^{19}$ [V/m^2]	30 $\times 10^{19}$ [V/m^2]	45 $\times 10^{19}$ [V/m^2]

Figure 1 shows a layout of the experimental setup. In the figure, the spin-polarized ^{23}Ne beam comes from left to right side and stops in a ZnO single crystal in vacuum. The crystal was cooled down to ∼47 K to achieve a long spin-lattice relaxation time. A static magnetic field of 0.5 T was applied to the crystal. An oscillating magnetic field was applied by a pair of coils perpendicular to the static magnetic field through a vacuum chamber wall, made of fiber-reinforced plastics. The β rays from the β decay of ^{23}Ne were detected by two telescopes, which consist of three 1.0-mm-thick plastic scintillators, placed at 0° and 180° along the polarization direction.

The obtained NQR spectrum for the ZnO crystal has been already shown in the previous report.[4)] The observation of the resonance indicated that the ZnO single crystal is available for the Ne NMR measurement and ensures sufficient spin-lattice relaxation time. From the obtained ν_Q $(= eqQ/h) = 1.08(5) \times 10^3$ kHz and the literature Q moment value of ^{23}Ne, $Q = 145(13)$ emb,[3)] the electric field gradient q was obtained as $|q| = 31(3) \times 10^{19}$ V/m^2.

For a deeper insight, the obtained electric field gradient was compared with those calculated by using the gauge including projector augmented waves (GIPAW) approach.[5)] Table 1 compares the experimental electric field gradient with those calculated for substitutional sites of Zn and O. As seen in the table, the experimental value is very close to that for the O site. It may suggest that the implanted ^{23}Ne tends to stop at the substitutional Zn site.

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