NMR-ON MEASUREMENTS OF $^{187}\text{WF}_{\text{Fe}}$, $^{182,183,186}\text{ReNi}$, $^{186}\text{ReFe}$ AND $^{203}\text{PbFe}$

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The magnetic hyperfine splitting frequencies of $^{187}\text{WF}_{\text{Fe}}$, $^{182}\text{Re}(j^F = 2^+)\text{Ni}$, $^{183}\text{ReNi}$, $^{186}\text{ReNi}$, $^{186}\text{ReFe}$ and $^{203}\text{PbFe}$ in a zero external magnetic field have been determined by the NMR-ON method at about 7 mK as 225.56(6), 130.9(1), 98.17(4), 136.6(4), 1007.0(3) and 58.43(3) MHz, respectively. With the known $g$-factors of $g(188\text{Re}, 1^-) = 1.739(3)$ and $g(203\text{Pb}, 5/2^-) = 0.27456(20)$, the following hyperfine fields were deduced: $B_{HF}(^{188}\text{ReNi}) = -103.05(35)$ kG; $B_{HF}(^{186}\text{ReFe}) = -759.7(13)$ kG; $B_{HF}(^{203}\text{PbFe}) = +279.18(25)$ kG. Taking hyperfine anomalies into account, the $g$-factor of $^{183}\text{Re}$ was deduced as $|g(183\text{Re}, 5/2^+)| = 1.267(6)$. With the assumption of Knight shift factor $K = 0$, the $g$-factors of $^{183}\text{Re}$ and $^{187}\text{W}$ and the hyperfine field of $^{187}\text{WF}_{\text{Fe}}$ were determined as $|g(183\text{Re}, 2^+)| = 1.63(5)$, $|g(187\text{W}, 3/2^-)| = 0.414(10)$ and $B_{HF}(^{187}\text{WF}_{\text{Fe}}) = -714(18)$ kG. The large hyperfine anomaly was deduced to be $^{183}\text{W} \Delta^{187}\text{W} = -0.124(22)$.

1. Introduction

Since the first successful experiment [1] using the NMR-ON technique, a number of nuclei as very dilute impurities in ferromagnetic host metals have been investigated. This technique provides accurate values of the magnetic hyperfine splittings. In most cases, it has been used for the measurements of the $g$-factors of radioactive nuclei. In order to deduce the values of $g$-factors from the NMR-ON results, we have to know the values of the magnetic hyperfine fields in the ferromagnetic host metals. The results of NMR-ON experiments and the known magnetic hyperfine fields are tabulated in refs. [2] and [3], respectively. The main part of uncertainties of the $g$-factors deduced from the NMR-ON experiments usually comes from those of the magnetic hyperfine fields. Therefore, it is important to determine the hyperfine fields with a high accuracy. In addition, they give information concerning magnetic hyperfine anomalies [4].
The present experiments were carried out to measure the magnetic hyperfine fields of $^{187}$WFe, $^{186}$ReNi, $^{186}$ReFe and $^{203}$PbFe and to determine the accurate values of the $g$-factors of $^{187}$W, $^{182}$Re($2^+$) and $^{183}$Re using the NMR-ON technique.

2. Experimental details

Alloys of WFe, ReFe and ReNi were prepared in the following way: W or Re was sputtered onto the surface of pure (99.997%) Fe foils (thickness of $\sim 10\ \mu$m) or pure (99.99%) Ni foils. They were melted in an electron-beam furnace. To ensure homogeneity, the samples were remelted. The resulting alloys containing about 0.17 at.% of the impurity metal were rolled into $\sim 1.5\ \mu$m foils and annealed in vacuum for 2 h at 800 °C. Disks of 4 mm $\phi$ were cut from the foils and irradiated for 12 h in the reactor at the Japan Atomic Energy Research Institute in a neutron flux of $5.6 \times 10^{13}$ neutrons/cm$^2$ sec. After the irradiation, the samples were annealed in vacuum for 2 h at 850 °C and cooled slowly to room temperature over a period of 3 h.

The sources of $^{182}$Re ($T_{1/2} = 12\ h$) and $^{183}$Re ($T_{1/2} = 71\ d$) were prepared by the EC and $\beta^+$ decay of $^{182}$Os ($T_{1/2} = 22\ h$) and $^{183m}\text{Os} (T_{1/2} = 10, 13\ h$) after the $^{182}$W($\alpha, 4n$) and $^{184}$W($\alpha, 5n$) reactions. The targets of $^{182}$W and $^{184}$W were made by evaporating enriched ($94.5\%$) $^{182}$WO$_3$ and ($94.8\%$) $^{184}$WO$_3$ onto thin Cu foils. Stacks of alternating targets and pure Ni foils ($\sim 1.5\ \mu$m) were irradiated with a 50 and a 65 MeV $\alpha$-beam ($\sim 1.8\ \mu$A) for 20 and 68 h, respectively, from the SF cyclotron at the Institute of Nuclear Study, University of Tokyo. The activities were recoil-implanted into the Ni foils. After the irradiations, the sources of $^{182}$ReNi and $^{183}$ReNi were annealed in vacuum for 2 h at 900 °C and 3 h at 650 °C, respectively, and cooled slowly ($\sim 3\ h$). The source of $^{203}$PbFe was prepared in a similar manner. The target of enriched (95.6%) $^{203}$Ta$_2$O$_3$ was used. The irradiation was performed with a 50 MeV $\alpha$-beam for 20 h. Three days after the irradiation, the source of $^{203}$PbFe was annealed in vacuum for 2 h at 600 °C and cooled slowly ($\sim 3\ h$).

The samples were cooled to about 7 mK using a $^3$He/$^4$He dilution refrigerator. An external magnetic field of $B_0$ was produced by small superconducting split coils in nearly Helmholtz geometry to polarize the ferromagnetic host. The temperature of the samples was monitored using a $^{56}$Co source, which was made simultaneously in the foils. For the $^{187}$W and $^{187}$Re isotopes, no thermometer was used because no value of temperature is necessary in NMR-ON experiments. An r.f. field modulated at a rate of 10 Hz was applied in the foil plane and perpendicular to the external magnetic field of $B_0$. The $\gamma$-rays were measured using two pure Ge detectors (151 and 120 cm$^3$) and two Ge(Li) detectors (80 cm$^2 \times 2$) placed at $\theta = 0, 90, 180$ and 270 degrees with respect to $B_0$. The spectra of $\gamma$-rays were stored on a magnetic tape controlled by a mini-computer. Details of the NMR-ON electronics and the system are described in ref. [5].