NMR study of enriched ^{195}Pt metal

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Abstract

The natural Pt metal has many isotopes. Among them only ^{195}Pt has the nuclear spin, I=1/2. The Pt metal is an ideal system to investigate the concentration dependence of the nuclear spin order without changing the electronic properties. The NMR measurement was performed in the enriched 97% ^{195}Pt metal. The value of T_1T was the same as one in the natural Pt. However T_2 in the enriched Pt was shorter than one in the natural Pt. We also observed the magnetic field dependence of T_2 in the enriched Pt. The nuclear spin order of the enriched ^{195}Pt will be fully discussed.

Key words: nuclear spin order; nuclear spin-lattice relaxation; Spin-spin relaxation time

1. Introduction

From the point of view of NMR experiments, platinum has many advantages over other metals. Some relevant properties are that the ^{195}Pt nucleus is 34% abundant, of spin 1/2 and homonuclear. It is therefore free of quadrupolar effects and a Ruderman-Kittel indirect exchange coupling between nuclear spins produces narrowing of the dipolar linewidth. Moreover the platinum nuclear spins have a short spin-lattice relaxation time. There is a great advantage in performing experiments at low temperatures. It is well known that the Pt NMR thermometer is a common use thermometer at ultr-low temperatures.

On the other hand, platinum metal is a very interesting metal from the point of view of nuclear magnetism. Since the ^{195}Pt nucleus is 34% abundant, of spin 1/2 and other Pt isotopes have no nuclear spin, we can investigate the concentration dependence of the nuclear magnetism by using the enriched ^{195}Pt specimens. Without any change of the electronic state in platinum metal, such as a density of states and also the Ruderman-Kittel indirect exchange interaction, the concentration of the nuclear spins can be controlled by alloying the natural platinum metals with highly enriched ^{195}Pt metals.

In this report, our experimental results of NMR in the 97%-enriched ^{195}Pt metal and also natural metal are shown.

2. Experimental Results and Discussions

The 97.29% enriched-^{195}Pt wire of 0.5 mm diameter was produced in Oak Ridge National Laboratory. The chemical analysis showed the magnetic impurities as following (ppm), Mn:0.11, Fe:2.39, Ni:0.25. The residual resistivity (RRR) of this wire was 20. After annealing the wire at 500 °C for 3 hours, RRR was just improved to be 40. NMR was measured also on the natural Pt wire of the same diameter. The purity of our natural Pt is 3N5(three nine half), but precise amount of impurities are not known. The long wire was cut into 14 pieces of 15 mm length wires. When we put all pieces of

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wire together, the thin PTF tape was used to insulate each other. For the NMR measurements, a home-made pulsed NMR spectrometer was used. The skin depth of our platimum wire can be estimated to be 7.9μm for 10 MHz rf frequency. The Knight shift was obtained to be -4.20% for the enriched Pt sample and -4.17% for the natural Pt sample from the resonant field measrement for 17.17MHz measuring frequency at 4.2K and also 1.5K. In our calculation of the Knight shift we used the frequency of $\gamma/2\pi$=9.153MHz/T for the free ion ^{195}Pt resonance frequency. The Knight shift was same in both natural and eneiched Pt metals.

For the measurement of the spin-lattice relaxation time T_1, spin-echo signals were observed after π pulse rf field with changing the time interval τ between the comb pulses and $\pi/2$ pulse. The echo signals against τ curve was fitted by a single exponential formula. The Korringa constant T_1T was obtained as 30 msecK for both natural and enriched Pt metals. This valu of 30 msecK is nearly the same value as previously reported one[1]. These Knight shift and korringa constant results support that the electronic state does not change with enriching the ^{195}Pt nucleus.

The spin-spin relaxation time T_2 was also measured by using a spin-echo method. The spin echo signal data were collected after $\pi/2$-π pulse sequences. When we plotted the intensity of the spin echo signals against 2τ, the time interval between $\pi/2$ pulse and the spin echo signal, it was found to be the single exponent decay in our measured time range, between 300μsec and 600μsec.The spin-echo method can exclude the effect of the inhomogenity of the applied magnetic field in the measured T_2 values. We measured the field dependence of T_2 between 3 MHz and 25 MHz at 4.2K and 1.7K. The measured spin-spin relaxation time shows the strong frequency dependence, especially in the enriched^{195}Pt specimen. The inverse of T_2 is plotted against the measured rf frequency. It can be well fitted to the following linear equation,

$$T_2^{-1} = T_2^{-1}(0) + 2\pi f \cdot A \qquad (1)$$

where f is the measuring rf frequency and A is the constant value. The value of $T_2(0)$ is 833μsec for natural Pt which value is close to the reported value of T_2=1 msec. However, the value of $T_2(0)$ was 435μsec for enriched Pt. Since the concentration of the nuclear spin is so large in the enriched Pt metal, it is rather reasonable that T_2 due to the dipole-dipole interaction among the nuclear spins becomes short. In the enriched Pt metal the frequency dependence, that is, the coeficient A in the equation (1) is 4 times larger than one in the natural Pt metal. When T_2 and f are expressed as μsec and MHz respectively in the equation (1), the values of A were obtained to be 4.0×10^{-5} for the enriched Pt metal and 1.0×10^{-5} for the natural Pt metal. At present this frequency dependence of T_2 is unknown. In our case, since the rf field is penetrated into only the small skin depth, the nuclear spin difusion in an inhomogeneous magnetic field might take an important roll in the spin-spin decay meachanism. The time dependence of the decay due to the nuclear spin difusion in an inhomogeneous magnetic field is known to have a form exp(-$\alpha\tau^3$). In this case, the decay rate is related to the diffusion constatnt D and the field gradient G by the expression $\alpha = \gamma^2 DG^2/12$, where γ is the gyromagnetic ratio of the nuclear spins.

The decay of the amplitude of the echo signal, however, fitted very well to the single exponential decay, exp(-$2\tau/T_2$). We cannot explain our frequency dependence of the spin-spin relaxation time by the spin diffusion.

3. Conclusion

There was no difference in the knight shift and the Korringa constant in both natural and enriched Pt metals. The spin-spin relaxation time measured in the enriched Pt metal, however, showed much difference from one obtained for the natural Pt metal. $T_2(0)$, the extrapolated value to the zero frequency, that is, no magnetic field effect, in the enriched Pt metal was 435 μsec, naerly half value of one obtained for the natural Pt metal. The magnetic field effect on T_2 was also observed in both enriched Pt and also natural Pt metals. At present we cannot explain this field effect on T_2.

References

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