PAC Spectroscopy of Gd-Tb Alloy between 18K and RT

I. 10. PAC Spectroscopy of Gd-Tb Alloy between 18K and RT

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Introduction

As have been described in several reports in this volume, heavy rare earth elements have peculiar magnetic properties as helix- or ferrocone-magnetism. These are interpreted as a result of a RKKY type interaction of conduction electrons[1].

Adding to the basic research for the magnetism, alloy magnets for practical uses have been developed with a rare earth element as one of the constituent. Such examples are Sm-Co or Nd-Fe-B magnet.

The motive of the present work is rather simple and intuitive. Namely, if two rare earth elements with the different easy axis of the magnetization are mixed together, which direction the axis will be directed ? Although many alloys were studied, a result on a Gd-Tb alloy will be described in the following. As has been described in previous reports, Tb has the easy axis in the basal plane. On the other hand that of Gd is almost parallel to the c-axis below 50K

Experimental

Known amounts of Tb and Gd were melted in Ar atmosphere together with ^{111}In-chloride solution to prepare a PAC source. Tb and Gd form a complete solid solution and hence both atoms should be distributed randomly in the alloy.

The specimen was set in a cryostat of which temperature is regulated by 0.01K and the PAC spectroscopy was performed at temperatures between 18K and RT.

Result and Discussion

Fig. 1. shows the PAC spectrum for Gd-Tb alloy (Tb: 53.3 at.%) and the corresponding Fourier spectrum in Fig. 2. As in the cases of Gd or Tb, a precession signal with a trend of beating is observed between 18K and 50K although the amplitude is much more reduced. Although several components are resolved in the Fourier spectrum, the amplitudes are comparable with the noise level. Nevertheless, with assuming the hyperfine field in the alloy is comparable with those of the constituents, we can resolve four components near 400Mrad/s as in the cases of Gd or Tb marked by arrows in Fig. 2.

This gives 28T as the magnitude of the hyperfine field in the alloy at 18K, which is comparble with that for Tb at 77K, 27T.

At the temperature of 52.5K, a broad bulge develops at about 60ns as shown in Fig. 1, of which component is resolved as 100Mrad/s component in Fig. 2. This component develops with the increasing temperature and become the main component above 55K corresponding to the precession signal with the 60ns period in Fig. 1. Since the magnitude of the frequency is almost temperature independent up to 300K, the origin must be of an electric type. This shows that the alloy transforms to the paramagnetic phase as low as at 53K despite of that the Curie temperature of Gd or Tb is near RT. Namely, by alloying, Curie temperature of Gd or Tb is shifted to the lower temperature of 50K-55K from RT. This shifting of the Curie temperature upon alloying has been found in most of rare earth binary alloys or the alloys with 3d transition metals and seems to be a quite common phenomenon. Intuitively, the long range interaction to give rise to the magnetic ordering in pure rare earth metals seems to be destroyed upon alloying to give such a shift. The cause of the shifting should be examined based on the solid state theory of the rare earth magnetism.

Next let us discuss the EFG in the alloy. Comparing with those in pure Gd or Tb, the period of the precession in the alloy is considerably reduced by a factor of four. Namely, the magnitude of the EFG is about 4 times larger in the alloy than those in Tb or Gd. Different from pure Gd or Tb to give a symmetric EFG (η=0) because of the hcp structure, the alloy should, in principle, give an asymmetric EFG. This is because that the local hcp symmetry is destroyed by the alloying element even when the alloy has kept the hcp structure. These as well as the cause of the increased EFG also should be treated theoretically.

The site of ^{111}In in the alloy is somewhat uncertain in the present. However, it is speculated that it will occupy equally both Gd and Tb site in the alloy, since the chemical properties are almost the same for these two elements. Nevertheless, we observe only one EFG frequency. This indicates that the magnitude of the EFG for ^{111}In at Gd site is almost the same with that at Tb site. This is reasonable for the present 50:50 alloy, since the local environment is almost the same for each site for such a high concentration alloy.

Finally we discussed the direction of the magnetization axis in the alloy in the ferromagnetic state at 18K. With assuming the faint four lines marked by arrows in Fig. 2 are due to the quadrupole splitting, the same analysis as in pure Tb or Gd was done to give β=90. Although tentatively at present because of the faint signal, the magnetization direction of the alloy is concluded to lie in the basal plane just as the case of pure Tb.

Summarizing these results on the Tb-Gd alloy;

(1) The magnitude of the hyperfine field is almost the same with those in pure Tb.
(2) The Curie temperature is considerably reduced upon alloying.
(3) The magnitude of the EFG is increased about 4 times upon alloying.

The application of the melting method for the source preparation and the subsequent PAC spectroscopy will provide a useful mean for the development of new magnetic materials. Namely, once one finds a very high hyperfine field in the PAC spectrum, the material is likely to have a high macroscopic magnetization for the practical use. This is so for the case of 3d transition metals as Fe or Ni although the sign of the field is reversed. The relation between the microscopic hyperfine field and that of the macroscopic should be established both empirically and theoretically

Acknowledgement

This work is supported by Grant in aid for Scientific Research in Priority Area from the Ministry of Education, Science and Culture of Japan.

References

1) Fukunaga H., "Magnetism in Rare Earth Elements" in *Science of Rare Earth Elements*, ed. by Adachi G., pub. by Kagaku-Donin (1999) (in Japanese).

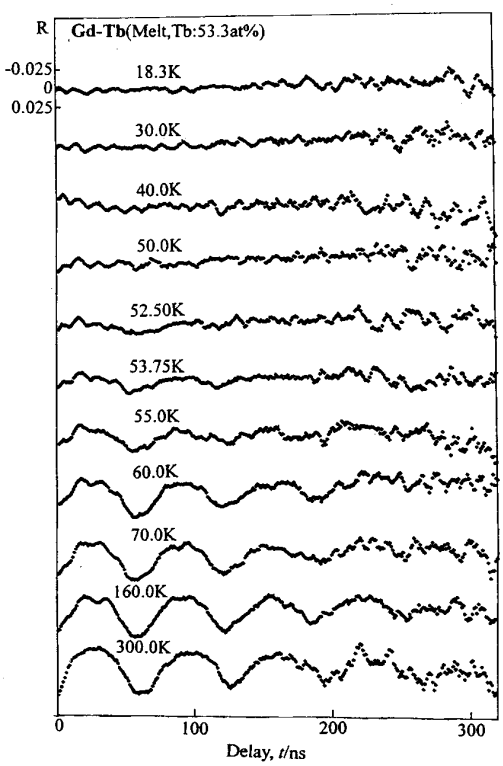

Fig. 1. PAC spectrum for Gd-Tb alloy between 18K and RT.

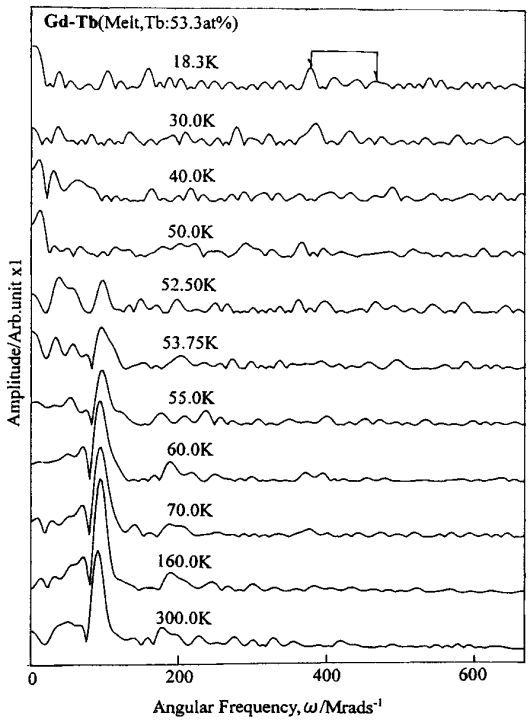

Fig. 2. Fourier spectrum for Fig. 1.