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ESR OF $Gd(Al_{1-x}M_x)_2$; M = Ge, Sb LAVES PHASE COMPOUNDS

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ESR measurements for $Gd(Al_{1-x}Ge_x)$ and $Gd(Al_{1-x}Sb_x)$ pseudobinary systems with $x \leq 0.15$ are presented. In all investigated compounds a marked change in thermal broadening of the line width was observed in temperature lower than 300 K. Using obtained results the bottleneck parameter was calculated as a function of concentration x.

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1. Introduction

In this paper the results of an ESR investigation of intermetallic compounds of type $Gd(Al_{1-x}M_x)_2$, where M = Sb, Ge, are presented. Pseudobinary compounds of this type are Laves phases of cubic $C15$ crystal structure.

Introducing a nonmagnetic metal M in the place of Al allows to investigate the effect of varying the conduction electron concentration on the magnetic and ESR properties of these compounds. Results of ESR investigation in case of non-magnetic metals such as Pd, Cu, Ag, Ga, In, Sn, Pb and Bi reported in earlier papers revealed that the bottleneck effect existing in basic $GdAl_2$ compound notably depends on size and concentration of introduced metal M. As the Gd ions are in the S state, the direct relaxation from Gd ion system (i) to the lattice (L) is negligible and the only possibility is the indirect relaxation through the conduction electron system (e).

The bottleneck effect depends on the ratio of the relaxation rate δ_{eL} to the relaxation rate δ_{ei}. Introducing nonmagnetic Ge or Sb atoms in place of Al could change the δ_{ei} relaxation rate as a result of changing the density of states at the Fermi level, but could not create any additional path of relaxation from Gd system to the lattice. Increasing concentration x of metal M introduces imperfections to the crystal lattice, which could scatter conduction electrons. This process should lead to a slight increase in relaxation rate δ_{eL} and contribute in breaking the bottleneck.

2. Experimental

The polycrystalline samples of the $Gd(Al_{1-x}Ge_x)_2$ and $Gd(Al_{1-x}Sb_x)_2$ were obtained by arc-melting under pure argon atmosphere. The X-ray diffraction showed that the samples are single phase for x up to 0.15.

The ESR investigation was performed within the X band in the temperatures higher than paramagnetic Curie temperature of the investigated compounds.

3. Results

According to the expectations the dependences of the spectroscopic splitting factor g on temperature measured for $Gd(Al_{1-x}Ge_x)_2$ and $Gd(Al_{1-x}Sb_x)_2$ compounds exhibit behaviour similar to that observed earlier for compounds with other nonmagnetic metals. The changes of the g factor against concentration x were within the limit of the experimental error.

The dependences of line width DII on temperature, however, exhibits unexpectedly noticeable change in slope at temperatures near 280 K. This change was observed for all investigated compounds with Ge as well as with Sb (Fig. 1).

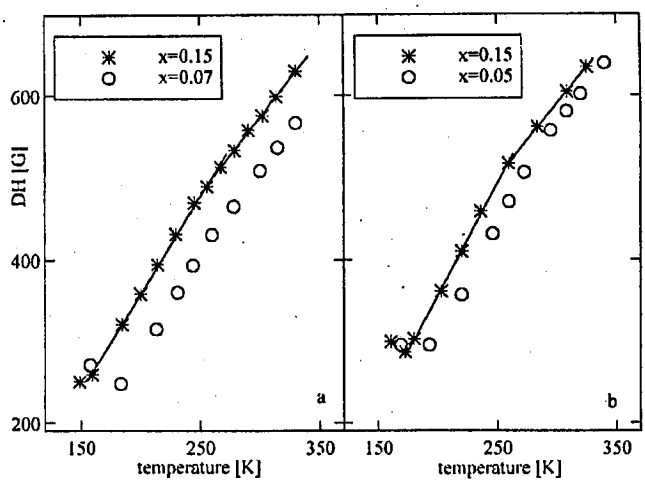

Fig. 1. An example of the dependences of the resonance line width DH in compounds: (a) $Gd(Al_{1-x}Ge_x)_2$; (b) $Gd(Al_{1-x}Sb_x)_2$.

The changes in the slope $\partial DII/\partial T$ as a function of concentration x reflecting changes in the bottleneck were estimated using dependences $DII(T)$ both in lower and higher regions of temperature.

The bottleneck parameter δ_{eL}/δ_{ei} was calculated, using the formula

$$\frac{\partial DII}{\partial T} = \frac{X}{X+1}\left(\frac{\partial DII}{\partial T}\right)_0, \tag{1}$$

where $X = \delta_{eL}/\delta_{ei}$, $(\partial DII/\partial T)_0$ is the Korringa value for fully unbottlenecked system and was assumed to be equal to 70 G/K [1].

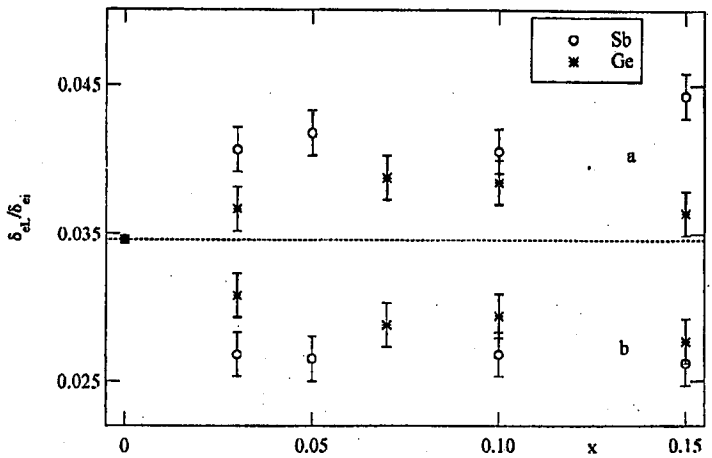

Fig. 2. Dependence of the bottleneck parameter $X = \delta_{eL}/\delta_{ei}$ on concentration x of Ge and Sb calculated using $\partial DH/\partial T$ in temperatures: (a) below 280 K and (b) above 280 K.

The dependences of parameter X on concentration of the Ge and Sb atoms in the investigated compounds are shown in Fig. 2.

There are not any considerable changes of δ_{eL}/δ_{ei} parameter as a function of Ge or Sb atoms content. Such a behaviour indicates that neither δ_{ei} nor δ_{eL} relaxation rates do not change markedly in the investigated x range. This fact suggests in turn that the density of states at the Fermi level does not depend markedly on the concentration of Ge or Sb atoms. It could be also assumed that imperfections introduced with substituting Al by Ge or Sb atoms do not play essential role in relaxation processes from conduction electrons system to the lattice.

The observed in all samples noticeable change of the thermal broadening in temperature near 280 K (Fig. 1) means that in this temperature bottleneck is rapidly reinforced. This change could be created by rapid increase in δ_{ei} or reducing δ_{eL} relaxation rate value. This effect is probably related to the small clusters of Gd atoms existing in these compounds in temperatures below 280 K. In this temperature range scattering of conduction electrons to the lattice due to this Gd clusters increases δ_{eL} relaxation rate and causes breaking of the bottleneck. Presence of such clusters was reported [2] in $Gd(Al_{1-x}Bi_x)_2$ compounds, where authors observed, as well as for the $Gd(Al_{1-x}Sb_x)_2$ compounds, small deviation from the linearity in the plot of the inverse susceptibility versus temperature. The presence of these clusters, however, was not observed in the X-ray diffraction pattern.

References

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