Study of ESR spectra at low temperatures and high pressures

A A Galkin, A Yu Kozhukhar', S N Lukin, G A Tsintsadze
Donetsk Physico-Technical Institute, Academy of Sciences of the Ukr.SSR, Donetsk, USSR

Systematic investigations by Lukin and Tsintsadze (1975a, 1975b), Kozhukhar' *et al.* (1975), and Galkin *et al.* (1975) of the influence of high hydrostatic pressures on the ESR spectra of iron group ions in zinc fluorosilicate revealed that the impurity paramagnetic ion contributes substantially to the formation of crystal field components. The trigonal component of the crystal field of nickel, cobalt, and manganese ions decreases monotonically with increasing pressure. At the pressures of 1·6 kbar (T = 4·2 K), 21 kbar, and 30 kbar (T = 4·2 K), crystal field symmetry of the aforementioned ion complexes becomes cubic, and with further rise of pressure the nearest neighbourhood distortion changes sign. In the case of the divalent vanadium ion the magnitude of the trigonal component of the crystal field increases monotonically when external pressure is applied.

Studies of the effect of pressure on zero-field splittings of nickel and manganese ions at different temperatures have made it possible to evaluate the contribution of thermal lattice vibrations to the magnitude of these splittings (Kozhukhar' *et al.*, 1975).

The effect of hydrostatic pressure on the exchange and magnetic dipole–dipole interactions of nickel ions has been studied with the aid of spectroscopy, by determining the exchange integrals of nickel ion pairs in a lattice of zinc fluorosilicate with an impurity content of 1 to 5% Ni^{2+} (Al'tshuler and Valishev, 1965), and investigating the contributions of spin–spin interactions to the absorption line width of isomorphous nickel fluorosilicate.

Measurements of the effect of pressure on the spectrum of $Ni^{2+}:ZnSiF_6.6H_2O$ exchange pairs yielded the increase in the exchange integrals of three types of pairs in the first three coordination spheres (Kozhukhar' and Tsintsadze, 1975). The exchange integral of the nearest neighbour Ni^{2+} ions increases exponentially with pressure: $\partial \ln I_1/\partial \ln V = -12 \pm 2$.

The narrowing of ESR lines at high pressures through exchange has been studied on $NiSiF_6.6H_2O$ for the case of zero trigonal component of the crystal field. It was found that isotropic exchange and magnetic dipole–dipole interactions predominate in the spin system, and the contribution of these interactions to the line width may be separated experimentally.

From the temperature dependence of the absorption line width of $NiSiF_6.6H_2O$ in the paramagnetic state we have found the increase of the Curie temperature T_C to be $\partial \ln T_c/\partial \ln V = -14 \pm 3$, which agrees well with the increase of the exchange integral I_1 under pressure.

References

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In all the samples a ferromagnetic phase (FM) was found. This phase appeared at pressures above P_c and was stable over a definite temperature range. The temperature dependence of the magnetisation of $Mn_{0.94}Fe_{0.06}As$, shown in figure 1, is typical of the entire system. The two magnetic transitions, namely the high-temperature transition at T' and the low-temperature one at T'', which have some special features (Gribanov, 1975) are easily distinguished. The values of P_c, T', and T'' are strongly dependent on x. P–T phase diagrams for two compositions are given in figure 2. The sign of dT'/dP and dT''/dP is seen to change with x. Thus for $x = 0{\cdot}06$ and $P = 7{\cdot}5$ kbar, $dT'/dP = 11$ K kbar^{-1} and $dT''/dP = -10$ K kbar^{-1}. For $x = 0{\cdot}15$ and $P = 5$ kbar, $dT'/dP = -9$ K kbar^{-1} and $dT''/dP = 45$ K kbar^{-1}.

Since the effect of alloying on a magnetic transition is similar to that of pressure, it may be expected that the sign of dT'/dP and dT''/dP for $Mn_{0.94}Fe_{0.06}As$ will also change with increasing pressure. This means that the ferromagnetic phase stability region of the investigated system in the P–T coordinates is a closed one. By varying x we may study, one by one, individual parts of this region, as illustrated in figure 3.

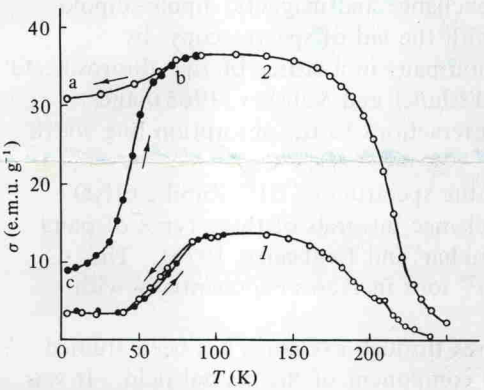

Figure 1. Temperature dependence of the magnetisation of $Mn_{0.94}Fe_{0.06}$ As in different magnetic fields at 7·5 kbar: *1* 1·24 k0e, *2* 9·4 k0e.

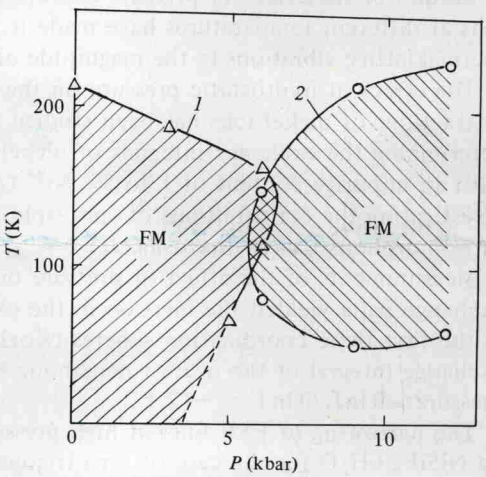

Figure 2. P–T phase diagrams for two compositions of $Mn_{1-x}Fe_xAs$: *1* $x = 0{\cdot}15$, *2* $x = 0{\cdot}06$.

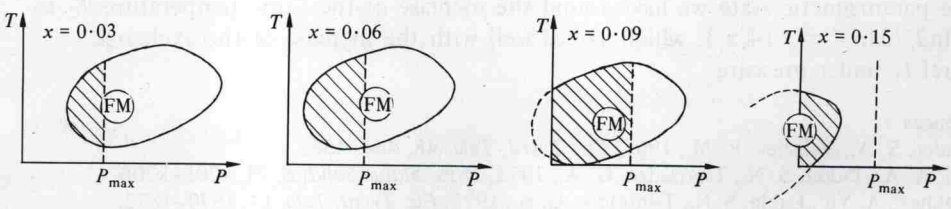

Figure 3. Shift of the ferromagnetic phase stability region (FM) in $Mn_{1-x}Fe_xAs$ system with increasing value of x. The dashed area is the ferromagnetic phase stability region which was observed experimentally.

References

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