EFFECT OF HYDROSTATIC COMPRESSION ON THE CURIE TEMPERATURE OF EuO ALLOYED WITH GADOLINIUM

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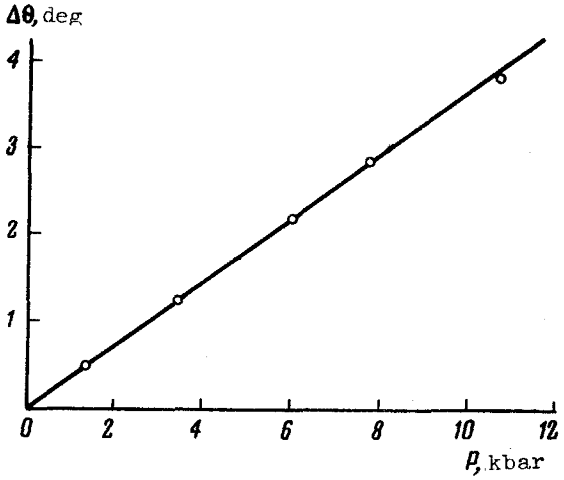
The oxide EuO of divalent europium is a ferromagnet with Curie temperature ~70°K. The nature of the ferromagnetic interaction between the localized 4f electrons in the ion lattice of the chalcogenides of europium has not yet been established. Since the 4f shells of the neighboring Eu^{2+} ions do not overlap, attempts are made at present to demonstrate theoretically that the unfilled 5d states of Eu^{2+} [1] or the 2p states of the anions [2] must take part in this exchange. The appreciable rise of the Curie temperature of EuO following hydrostatic compression [3, 4] is evidence of a strong (exponential) dependence of the exchange-interaction energy on the interatomic distance in this compound.

Alloying of EuS, EuSe, and EuTe with gadolinium and with other trivalent rare-earth elements produced, besides an increased electric conductivity, a strong change in the magnetic properties [5]. It was proposed that the trivalent lanthanide ions give up the excess electrons to the unfilled 5d band of the Eu^{2+} ions, as a result of which the localized 4f spins can interact via the conduction electrons by an indirect-exchange mechanism of the Ruderman-Kittel type [6]. At carrier dansities not exceeding 0.25 electron per magnetic ion, the Ruderman-Kittel interaction in cubic lattices has a ferromagnetic character. Therefore the experimentally observed [5] rise in the Curie temperature of europium chalcogenides alloyed with trivalent lanthanides can be attributed to the occurrence of positive indirect exchange via the conduction electrons. An interaction of this type apparently exists in the indicated compounds together with the exchange interaction between the localized 4f electrons of the neighboring Eu^{2+} ions, which takes place in europium chalcogenides of stoichiometric compositions, which are insulators. It follows from the theory of the indirect Ruderman-Kittel exchange via the conduction electrons that the energy of an exchange interaction of this type varies with the interatomic distance much more slowly than the energy of the direct exchange or of the indirect exchange via the anion. It is of interest to verify this conclusion on europium chalcogenides alloyed with trivalent lanthanides.

We investigated the dependence of the Curie temperature of EuO alloyed with 4 at. % of gadolinium. The single crystals with chemical composition $Eu_{0.96}Gd_{0.04}O$ were prepared by a modified Bridgman method. Their quality was determined from Laue patterns. An x-ray structure analysis has shown that these single crystals have an NaCl lattice with parameter 5.129 Å (the parameter of the Eu lattice is 5.142 Å). The ferromagnetic Curie temperature is 127.7°K. Such an appreciable increase of the positive exchange interaction in the europium oxide as a result of alloying with gadolinium cannot be attributed to the observed decrease of the lattice parameter, since it follows from the data on the shift of the Curie temperature of EuO under hydrostatic compression [3,4] that when the interatomic distance is reduced by 0.2%, as in this case, the Curie temperature can increase only several degrees. The electric conductivity of the $Eu_{0.96}Gd_{0.04}O$ single crystals is approximately 10^{2} $ohm^{-1}cm^{-1}$, as against about 10^{-9} $ohm^{-1}cm^{-1}$ for the EuO crystals. The temperature dependence of the electric



Shift of Curie temperature of the compound $Eu_{0.96}Gd_{0.04}O$ with change of pressure.

conductivity and of the coefficient of the thermal emf of $Eu_{0.96}Gd_{0.04}O$ corresponds in accordance with our data to metallic conductivity.

The procedure for measuring the ferromagnetic Curie temperature at a quasi-hydrostatic pressure up to 12 kbar was described by us in [3]. The Curie temperature of the compound $Eu_{0.96}Gd_{0.04}O$ increases linearly with the pressure in this pressure range (see the figure), the baric coefficient being $d\theta/dp = (4 \pm 0.5) \times 10^{-4}$ deg/bar. Comparison of this result with our data for EuO of stoichiometric composition [3] shows that although the Curie temperature of the $Eu_{0.96}Gd_{0.04}O$ single crystals is almost double that of EuO crystals, the character of its pressure dependence agrees both qualitatively and quantitatively with that observed for EuO.

If we assume, in accord with the foregoing, that the magnetic state of single-crystal $Eu_{0.96}Gd_{0.04}O$ is determined by the superposition of the ferromagnetic exchange interaction between the localized magnetic moments of the Eu^{2+} ions, which is not connected with the conduction electrons, and the indirect exchange via the conduction electrons, then we can conclude that under hydrostatic compression up to 10 kbar only the energy of the former type of interaction changes appreciably. The indirect exchange interaction via the conduction electrons oviously makes no noticeable contribution to this effect.

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CONDUCTION MECHANISM OF HIGHLY-CONDUCTING ORGANIC COMPLEXES BASED ON TCNQ

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Organic complexes based on tetracyanquinodimethane (TCNQ) are of interest as possible objects permitting realization of Little's idea of a superconductivity of a non-phonon type [1]. Certain complexes of this class have at room temperature a high conductivity (~10^2 $ohm^{-1}cm^{-1}$) along the directions of the stacks of TCNQ molecules [2], and there are grounds for hoping that when a second easily-polarized component is introduced into the complex, an