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COMMENTS AND ADDENDA

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Néel Temperature of EuTe †

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A Green's-function procedure for calculation of the Néel temperature of a type-II face-centered-cubic antiferromagnet is applied to EuTe. Exchange constants resulting from a fit to low-temperature heat-capacity measurements are used. The resulting Néel temperature T_N is (9.76 ± 0.41) °K, compared to the experimental 9.81 °K.

In a recently published paper,[1] spin-wave theory was used to calculate the magnon contribution to the specific heat of EuTe, a rocksalt-structure antiferromagnetic insulator, whose spin magnetic moments are confined to (111) planes. Starting with a Hamiltonian including Heisenberg exchange, with first- and second-neighbor interactions only, plus anisotropy terms, we obtained the two branches of the spin-wave spectrum and their resulting contribution to the specific heat. The anisotropy constants D_1 and D_2 refer to the "out-of-plane" and "in-plane" anisotropies, respectively. We sought values of the first- and second-neighbor exchange constants J_1 and J_2 which would reproduce the experimental specific-heat curve at low temperatures [$T < \frac{1}{3}$ (Néel temperature)]. We required that J_1, J_2, D_1, and D_2 be consistent with the magnon energies at the center of the zone as given by the antiferromagnetic resonance measurements of Battles and Everett.[2] The values of J_1 and J_2 needed to do this turned out to be $J_1 = (0.07 \pm 0.02)$ °K and $J_2 = -(0.21 \pm 0.02)$ °K. These values are somewhat larger than those predicted by molecular-field theory.[3]

As a further check on our J_1 and J_2 values, we attempted to calculate the Néel temperature of EuTe, using a Green's-function method developed by Lines.[4] Lines considers the case of one direction of alignment of spins, and breaks the lattice into a and b sublattices, such that the spins on the a sublattice point in the opposite direction from those on the b sublattice. This is consistent with the spin configuration in EuTe. A Heisenberg Hamiltonian

$$H = \sum_{ij} 2J_{ij} \vec{S}_i \cdot \vec{S}_j ,$$

where the sum includes all the spin pairs, is assumed. The following expression for the Néel temperature T_N is obtained:

$$S(S+1)/3kT_N = \langle \mu / (\mu^2 - \lambda^2) \rangle_K \quad ,$$

where $\langle\ \rangle_K$ is an average over wave vectors in the first Brillouin zone of the magnetic lattice. The quantities μ and λ are given by

$$\mu = \sum_{j-g}^{s} 2J_{jg} [e^{i\vec{k} \cdot (\vec{j} - \vec{g})} - 1] + \sum_{j-g}^{d} 2J_{jg} \quad ,$$

$$\lambda = \sum_{j-g}^{d} 2J_{jg} e^{i\vec{k} \cdot (\vec{j} - \vec{g})} \quad ,$$

where $\vec{j} - \vec{g}$ locates the nearest neighbor of a particular spin with respect to that spin. The s (d) on the summation indicates that $\vec{j}$ and $\vec{g}$ are on the same sublattice (different sublattices). For the special case of antiferromagnetic ordering of the second kind in a face-centered cube, these become

$$\mu = 4J_1 \{\cos[\tfrac{1}{2}a(k_x - k_y)] + \cos[\tfrac{1}{2}a(k_y - k_z)] + \cos[\tfrac{1}{2}a(k_z - k_x)]\} + 12J_2 \quad ,$$

$$\lambda = 4J_1 \{\cos[\tfrac{1}{2}a(k_x + k_y)] + \cos[\tfrac{1}{2}a(k_y + k_z)]$$

$$+\cos\left[\tfrac{1}{2}a(k_x+k_z)\right]\}$$

$$+4J_2\{\cos(ak_x)+\cos(ak_y)+\cos(ak_z)\}\ ,$$

where a is the lattice constant. It is to be noted that if one computes the quantities $\mu+\lambda$ and $\mu-\lambda$ from these expressions, making proper use of trigonometric identities, the results will differ from those quoted in Lines's paper by negative signs, and factors of $\frac{1}{2}$ in the arguments of the trigonometric functions. We substituted the values of J_1 and J_2 from our specific-heat calculation into the expression for T_N. The average was done numerically over the paramagnetic Brillouin zone rather than the antiferromagnetic Brillouin zone, with proper account taken of the fact that the integral was over twice the volume in k space as was needed. We sought values of the exchange constants J_1 and J_2 in the range given above, obtained from the specific-heat calculation, which would yield a Néel temperature within 0.5 °K on either side of the experimental value 9.81 °K. It was found that T_N is rather more sensitive to changes in J_2 than in J_1. For $J_1=(0.07\pm0.02)$ °K and $J_2=-(0.215\pm0.005)$ °K, we obtained $T_N=(9.76\pm0.41)$ °K, in quite good agreement with the above experimental value.

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Influence of Normal-State Electrical Resistance on the Superconducting Transition Temperature of Ultrathin Films*

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Recent data showing decreases in the T_c of ultrathin films are reconsidered in the light of results from work on fluctuations in films, which indicate the possibility of a large "pair-breaker" in high-resistance films.

Recently, we have made a study of the decrease in transition temperature T_c in ultrathin films.[1] In this present paper we wish to amplify some of the conclusions in Ref. 1 by taking into account recent work on fluctuations in films, and in particular we wish to make a speculative estimate of the T_{c0} of films in the absence of the "pair-breaker" which appears to be associated with the large $R_\square$ of the films. We briefly review some of the results. With the theoretical work of McMillan,[2] it became evident how the increases in the T_c of soft-metal films could be related to "softening" of the phonon spectrum, either by disorder or by soft phonons caused by surfaces.[3,4] Unfortunately, the maximum T_c observed in either disordered[4,5] or ultrathin films[1,3] never approached the limits predicted by the theories. In fact, it was found that in the very thinnest films the T_c actually decreased again. In Fig. 1 we show data on Al films, previously reported,[1] showing that T_c rises as the thickness is decreased and finally decreases again in the thinnest films. In the case of Pb, where the enhancement is expected to be small, it was found that T_c decreased as the films were made thinner,[1,6,7] and the depression (of T_c) correlated with the sheet resistance $R_\square$. The question of why the T_c decreased was discussed, but was never convincingly explained on the basis of any existing theoretical ideas, and this is still the case at present. It is the purpose of this note to estimate how the effect of the high $R_\square$ in the films can affect the transition temperature of Al films. The clue to how to treat this problem is provided by Kajimura and Mikoshiba (KM),[8] although we emphasize that this phenomenological approach certainly does not imply that there is an understanding of why large $R_\square$ reduces T_c as rapidly as it does.

In recent work on fluctuation phenomena in Al films,[9] large deviations have been found from the mean-field theory of Aslamazov and Larkin (AL).[10] Thompson[11] has modified the AL theory by including a term originally proposed by Maki. This addition-