ANTIFERROMAGNETIC RESONANCE IN $CoCO_3$

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Antiferromagnetic resonance in cobalt carbonate was investigated in the frequency range 10—35 kMc and in the temperature range 4.2—1.5°K. The frequency dependence of the resonance field was obtained. No line shift with variation of temperature was observed.

IN the antiferromagnetic state (T_N = 18.1°K), cobalt carbonate ($CoCO_3$) has a weak ferromagnetic moment.[1] The magnetization vectors of the sublattices M_1 and M_2 and the ferromagnetic moment σ lie in the basal plane. The spin-wave spectrum of such a magnetic structure consists of two branches:[2,3]

$$\varepsilon_1 = \hbar\omega_1 = \sqrt{\mu^2 H(H + H_D) + \Theta^2 a^2 k^2}, \quad (1)$$

$$\varepsilon_2 = \hbar\omega_2 = \sqrt{2\mu^2 H_A H_E + \mu^2 H_D H + \Theta^2 a^2 k^2}, \quad (2)$$

where H is an external magnetic field applied in the basal plane, H_D is the Dzyaloshinskiĭ field responsible for weak ferromagnetism, H_E and H_A are the effective exchange and anisotropy fields, a is the lattice constant, and Θ is the exchange constant.

Equation (1) shows that in the first branch of the spin waves there is no gap at H = 0. This makes it possible to observe antiferromagnetic resonance in fields of the order of several kOe at frequencies in the centimeter region.[4] At k = 0, the vectors M_1 and M_2 oscillate in the basal plane, the angle between them remaining constant. The second branch of the spin waves—as in normal antiferromagnets—has a comparatively large gap.

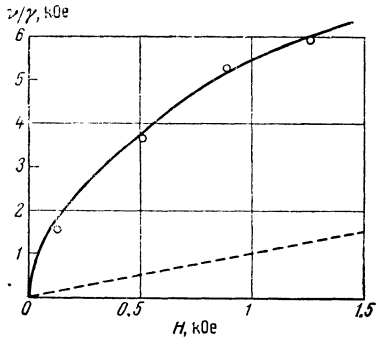
Static measurements, carried out earlier by Borovik-Romanov and Ozhogin, made it possible to determine the quantity $H_D = \sigma_0/\chi_\perp$, which is 27×10^3 Oe for $CoCO_3$.

The purpose of the present work was to carry out experiments which would allow a quantitative check of Eq. (1) by observing antiferromagnetic resonance in $CoCO_3$ in the uniform precession case (k = 0).

Antiferromagnetic resonance was studied using single crystals of cobalt carbonate obtained by the hydrothermal method of Ikornikova.[5] [1)] The $CoCO_3$ crystals were in the form of quite transparent red plates, 0.5—1 mm in size and 0.1—0.5 mm thick. The single-crystal state and orientation of the samples were checked by x-ray diffraction. Resonance was observed using a magnetic spectrometer similar to that used by Borovik-Romanov et al.[4], and microwave power was obtained from klystron oscillators covering the frequency range from 10 to 35 kMc.

Antiferromagnetic resonance was observed in the temperature range from 4.2 to 1.5°K. The samples were placed in cylindrical resonators in which H_{011} oscillations were excited. The static magnetic field and the microwave field were always mutually perpendicular (which is the condition for the excitation of the low-frequency branch of the spin waves[6]). The static magnetic field was in the horizontal plane. The measurements were carried out for two orientations of a crystal: 1) the microwave field in the basal plane of the sample; 2) the microwave field along the threefold axis, perpendicular to the basal plane.

In the former case, the value of the resonance field obeyed the formula $R_{res} = H_0/\cos\varphi$, where H_0 is the resonance field in the basal plane, and φ is the angle between the basal plane and the direction of the external magnetic field. In the second case, the orientation of the crystal allowed us to observe the crystal anisotropy in the basal plane. No such anisotropy was found.



[1)] The author is grateful to N. Yu. Ikornikova, of the Crystallography Institute, U.S.S.R. Academy of Sciences, for kindly supplying the single crystals.

The results obtained for the frequency dependence of the resonance field are given in the figure (the dashed line represents the paramagnetic frequency $\nu = \gamma H$). These results are described satisfactorily by the formula

$$(\nu/\gamma)^2 = H(H + H_D),$$

where the value $H_D = 27 \times 10^3$ Oe was taken from static measurements.[1] The curve plotted using this formula deviates by not more than 2% from the experimental points if the value of γ is selected to correspond to $g = 4.0$. This deviation is due to the error in the determination of the position of the resonance line maximum.

It was found that the line width varied strongly with the frequency (≈ 100 Oe at 10 kMc and ≈ 500 Oe at 35 kMc) but not greatly from sample to sample, although the shape of the line was different in different samples. As in the work of Borovik-Romanov,[4] the observed lines consisted of many components which were less clear than in the case of $MnCO_3$.[4] At intermediate frequencies, the line structure became complicated and this was the reason for the uncertainty in the determination of the line position. The line structure may have been due to the same factors as in the case of $MnCO_3$.[4] The line width and shape are being studied at present.

In contrast to the results for $MnCO_3$, the line position did not vary with temperature between 4.2 and 1.5°K. A calculation, similar to that carried out by Borovik-Romanov et al,[4] shows that, because of the smallness of the hfs interaction constant of $CoCO_3$ (specific heat measurements give $A/k = 0.004$°K for $CoCO_3$ and $A/k = 0.013$°K for $MnCO_3$ [7]), the shift of the line position on varying the temperature between 4.2 and 1.5°K, i.e., during the magnetization of nuclear spins, should not exceed 10—15 Oe.

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[1] A. S. Borovik-Romanov and V. I. Ozhogin, JETP **39**, 27 (1960), Soviet Phys. JETP **12**, 18 (1961).

[2] A. S. Borovik-Romanov, JETP **36**, 75 (1959), Soviet Phys. JETP **9**, 54 (1959).

[3] E. A. Turov, JETP **36**, 1254 (1959), Soviet Phys. JETP **9**, 890 (1959).

[4] Borovik-Romanov, Kreĭnes, and Prozorova, JETP **45**, 64 (1963), Soviet Phys. JETP **18**, 46 (1964).

[5] N. Yu. Ikornikova, Kristallografiya **6**, 745 (1961), Soviet Phys. Crystallography **6**, 594 (1962).

[6] E. A. Turov and N. G. Gusseĭnov, JETP **38**, 1326 (1960), Soviet Phys. JETP **11**, 955 (1960).

[7] I. N. Kalinkina, Dissertation (IFP AN SSSR, 1963).

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