NEW DATA ON THE SPIN SHUBNIKOV - DE-HAAS EFFECT IN InSb

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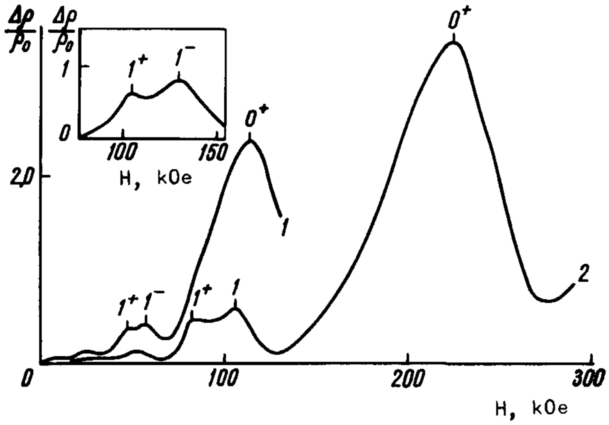
Submitted 2 March 1965

The influence of the spin splitting of the zero Landau level on the Shubnikov - de-Haas effect was first observed experimentally in InSb and InAs at 20°K in pulsed magnetic fields[1, 2]. This phenomenon was observed and investigated at 4.2°K in [3, 4]. However, spin splitting of Landau levels with N = 1 (N is the Landau level number) have been observed by no one to date. By increasing the sensitivity of the measurement procedure and by using homogeneous single-crystal InSb samples, we succeeded in observing spin splitting of the first Landau level. Measurements of the transverse magnetoresistance were made at 4.2°K in pulsed fields up to 300 kOe.



Transverse magnetoresistance of InSb samples at 4.2°K. 1 - sample No. 5, 2 - sample No. 6. Upper left - sample No. 7

We photographed the changes in the voltage of potential probes in the magnetic field. The figure shows plots of the magnetoresistance in a transverse magnetic field for InSb samples 5 - 7. The curves have several maxima. The maximum 0^+ corresponds to the splitting of the level with N = 0^+. The maxima 1^- and 1^+ are the results of spin splitting of the Landau level with N = 1 in the magnetic field; they are located at 105 and 82 kOe or at 130 and 109 kOe for InSb samples 6 and 7, respectively. The splitting of the first level is much less pronounced in InSb sample No. 5.

Samples 3 and 4 show zero maxima, i.e., maxima corresponding to the 0^+ level. The first maxima of samples 3 and 4 are at lower field values, so that no splitting of the first level is observed here. The resonant values of the magnetic fields H_0^+, H_1^-, and H_1^+ corresponding to the split levels with $N = 0$ and 1 are listed in the table (at ($T = 4.2^oK$).

Sample No	n, cm^{-3}	m^*/m	H_0^+, kOe	H_1^-, kOe	H_1^+, kOe	$\|g\|_0^+$	$\|g\|_1^-$	$\|g\|_1^+$	$\|g\|_{pot}$
1	$2.0\cdot10^{15}$	0.0130	7,90	-	-	60	-	-	53
2	$6.7\cdot10^{15}$	0.0135	17.0	-	-	55	-	-	51
3	$3.7\cdot10^{16}$	0.015	57	-	-	45	-	-	44
4	$7.5\cdot10^{16}$	0.019	94	-	-	33	-	-	36
5	$9.4\cdot10^{16}$	0.020	113	58	47	29	-	-	33
6	$2.7\cdot10^{17}$	0.022	223	105	82	30	32	32	29
7	$3.8\cdot10^{17}$	0.024	-	130	104	-	23	20	27

The theory of the "spin" Shubnikov - de-Haas effect was developed by L. É. Gurevich and A. L. Éfros[5]. Recently S. T. Pavlov[1)] calculated the positions of the oscillation maxima of the transverse magnetoresistance, with account of the temperature correction of the chemical potential, and obtained for the N^+ levels

$$\left(\frac{1}{H}\right)_N^+ = \frac{e}{2\hbar c}\left(\frac{2}{\pi^2 n}\right)^{2/3}\left[\sum_{k=0}^{N}\left(\sqrt{k}+\sqrt{k+\frac{m^*}{m_{sp}}}\right)+0.53\sqrt{\frac{k_0 T m^* c}{\hbar e H}}\right]^{-2/3} \qquad (1)$$

and for the N^- levels

$$\left(\frac{1}{H}\right)_N^- = \frac{e}{2\hbar c}\left(\frac{2}{\pi^2 n}\right)^{2/3}\left[\sum_{k=1}^{N}\left(\sqrt{k}+\sqrt{k-\frac{m^*}{m_{sp}}}\right)+0.53\sqrt{\frac{k_0 T m^* c}{\hbar e H}}\right]^{2/3} \qquad (2)$$

Here $|g| = 2m/m_{sp}$, n is the electron concentration, $\hbar = h/2\pi$, h = Planck's constant, k_0 Boltzmann's constant, H the magnetic field, m^* the effective mass, m_{sp} the spin mass, m the mass of the free electron, and e the electron charge.

The table lists the g-values calculated from (1) and (2) for the experimental values of H_0^+, H_1^-, and H_1^+. It also gives the values of g_{pot} calculated by the Roth formula:

$$g_{pot} = 2[1 - (\frac{m}{m^*} - 1)(\frac{\Delta}{3\epsilon_g + 2\Delta})] \qquad (3)$$

For InSb, ϵ_g = 0.23 eV and Δ = 0.9 eV. The effective masses used in the calculations were taken from [6]. As expected, the temperature correction is appreciable in weak magnetic fields. This is why too high values were obtained for $|g|$ in [4], where the calculations were made with formulas that took no account of the temperature correction.

The table (samples 1 and 2) lists also the g-values calculated from the results of [4] with account of the temperature correction. The error in the determination of the resonant values of the magnetic field is 7 - 10%, so that the g-values calculated from (3) and from our experimental data are in satisfactory agreement.

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1) The authors thank S. T. Pavlov for graciously supplying formulas (1) and (2).