The fact that allowance for six coordination spheres with the aid of "effective" coefficient gives a good interpretation of the experimental results suggests that the effective radius of the excitation of the spin density around the Mn atom is close to the radius of the sixth sphere and amounts to not less than 6 Å.

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LAW OF SPIN-ECHO DAMPING OF CONDUCTION ELECTRON IN METALS

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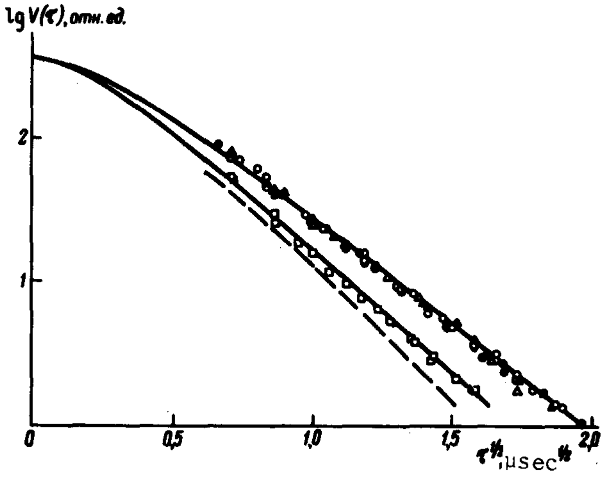
The damping of spin-echo signals on conduction electrons in lithium was found to obey a square-root law. The concept of spatially-inhomogeneous spin relaxation on impurities (in the interior of the metal) is introduced and may explain the observed law.

We have previously reported [1, 2] observation of conduction-electron spin echo (CESE) from spheroidal particles of metallic lithium suspended in an LiF dielectric matrix. In those investigations, the maximum time interval τ between the sounding pulses (the interval was limited by the intensity of the echo signal from the investigated samples) was ∿ 0.8 - 1 μsec. The observed damping of the main and stimulated CESE signals was close to exponential within the limits of experimental error.

We report here preliminary results of an investigation of CESE for analogous samples, but with a larger amount of metal. Improvement of the measurement technique and an increase in the signal intensity have made it possible to increase appreciably the interval τ (to 5 μsec). It turned out, unexpectedly, that the empirical law for the CESE damping is

$$V(2\tau) = V_0 \exp(-\sqrt{2\tau/T_{\text{eff}}}). \qquad (1)$$



Amplitude of the signal of the main CESE, in relative units, vs. the variable interval between the sounding pulses, τ: o and Δ – experimental points at 300 and 390°K respectively without a gradient, ● and ▲ – the same but with a gradient, □ – experimental points at 77°K without a gradient, dashed line – qualitative character of the echo-signal fall-off with a gradient.

The measurements were made at 390, 300, and 77°K using a two-pulse technique both in a homogeneous constant magnetic field and with application of a linear field gradient G up to 30 Oe/cm. The results are shown in the figure. As seen from the figure, at 300 and 390°K the experimental points fit the relation (1) with a parameter $T_{eff} = 8.3\times10^{-8}$ sec, and the linear gradient has no effect on the decrease of the CESE. At 77°K and G = 0, the measurement results agree with (1), but at a value $T_{eff} = 7.4\times10^{-8}$ sec. Application of the gradient at nitrogen temperature increases the damping rate of the signal. With increasing G, the CESE damping variation changes from that of a square root (1) to exponential.

Damping of the transients in accordance with (1) was observed earlier on localized spins in solid dielectric paramagnets. This damping law is the consequence of the stochastic character of the variation of the local magnetic fields produced by the impurities that are randomly disposed in the sample. It is important here that the interaction with the impurities are of the long-range type and depend on the distance like τ^{-3} [3].

In our samples, the relaxation of the conduction-electron spin system is determined mainly by the spin-orbit interaction with the impurities. Although this interaction is indeed short-range, it can also lead to echo damping in accordance with (1) if the observation time is comparable with the average time of the spin scattering of the conduction electron. We recognize that owing to the random disposition of the impurities in the metal the real spin relaxation of the conduction electrons is spatially inhomogeneous, and the stochastic parameter is the number of impurities on the conduction-electron trajectory. Then the time t_{coll} between the collisions that lead to the relaxation is distributed with a density $g(t_{col}) = \tau^{-1}\exp(-t_{col}/\tau_0)$, where τ_0 is the time between successive acts of relaxation of the conduction electrons on the impurities. Instead of taking into account the variation of the time t_{col} along the trajectories of the conduction electrons, we assume that t_{col} is constant on the trajectory, and the number of trajectories with given t_{col} is distributed with a density $g(t_{col})$. Then the time of transverse spin relaxation of the conduction electrons for a given trajectory of T_2 - t_{col}, and the averaging of the solutions of the Bloch equations over the trajectories with distribution g(T) yields for the CESE damping the final expression

$$V(2\tau)\quad V_0\exp\{-2\tau/T_S\}(4\tau/\tau_0)K_1^2(\sqrt{4\tau/\tau_0}), \tag{2}$$

where T_S is the surface relaxation time, $K_1(x)$ is a modified Bessel function of the second kind, $\tau_0^{-1} = \sigma_S N_0 v_F$, σ_S is the effective cross section of the spin scattering by the impurity, v_F is the Fermi velocity, and N_0 is the number of impurities per unit volume. The solid lines in the figure correspond to expression (2) at the following parameter values $N_0\sigma_S = 10^{-2}$ cm^{-1} and $T_S^{-1} \simeq 10^{-5}$ μsec at 77°K (at 300 and 390°K the contribution of the surface relaxation is negligibly small).

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