Unconventional ESR spectrometer for investigating materials with wide ESR lines as well as Hall conductivity on microwave frequency

V.A. Ryzhov[1], I.A. Kiselev[1], and A.V. Lazuta*[1]

[1] Petersburg Nuclear Physics Institute RAS, Orlova Roscha 1, Gatchina, Leningrad district, 188350, Russia
*Corresp. author: A.V. Lazuta, e-mail: alexandr@VL9467.spb.ru, Phone: +7 812 348 9590, Fax: +7 81271 31963

Recently a problem of ESR-signal unobservability has taken on a particular interest in connection with investigation of cuprates (high temperature superconductors) and related materials (CuO), where a signal of Cu^{2+} is unobserved [1]. The reason for this is not completely clear [2].

We present here ESR spectrometer, which allows one to study wide ESR transitions. The main its peculiarities can be summarized as follows: 1) A cylindrical two-mode balanced cavity is used with TE_{111} oscillations. A steady magnetic field H is oriented along the cylinder axis (z axis). A sample is placed at the base of the cavity in linearly polarized *ac*-field $h(t)$ (x axis). The plane of detection (y axis) is perpendicular to the excitation one and the detected signal is proportional to off-diagonal component of magnetic susceptibility tensor χ_{yx}, $M_y=\chi_{yx}(\omega, H, T)h(t)$. Therefore, a rotation of plane of polarization of the *ac*-field is detected. If the frequency of eigen oscillations of TE_{111} cavity does not depend on an angle position of their polarization plane, it is possible to achieve a high degree of frequency-independent decoupling (40-60 dB) between excitation ($h(t)||x$-axis) and detection modes and signal $M_y(H)$ can be registered on zero background [3]. Besides, such decoupling allows one to employ a generator with a high oscillation power (klystron with output power $P\sim1$W) without appearing its frequency and amplitude noise at a detector. Thus, the sensitivity of spectrometer ($\chi_{min}\sim 1/P^{1/2}$) is higher than in traditional one, where only 50mW-generator should be employed to avoid its noise appearance on a detector.

2) A periodic sweep of the H and a synchronous accumulation of a signal are employed. A range of H-sweep is established to scan the entire signal or maximal sweep-range is used for wide ESR lines. Therefore, there is no loss of signal amplitude. While in traditional ESR spectrometers, where a modulation of H is used and derivative of a signal is registered, such a loss exists for wide ESR lines since it is impossible to provide an optimal amplitude of modulation. The last should be near half-width of the ESR line.

3) The geometry of the field inside the our cylindrical cavity is such that microwave currents of plane of excitation flow on the internal surface of the cavity base (with a sample on it) and inside a sample and their direction is perpendicular to steady field H. Therefore, due to Hall effect the currents appear in direction perpendicular to both the currents of excitation plane and H. They excite the oscillations in the detection plane. Thus, the Hall signals, exhibiting a linear dependence on H, should exist from material of cavity (Cu) and a sample. Indeed, the Hall signal from material of cavity was registered and its amplitude was in reasonable agreement with estimations [3].

This spectrometer was used for studying spin dynamics of quasi-1D CuO, $Cu_{1-x}Zn_xO$ and $Cu_{1-x}Li_xO$ single crystals [4]. In CuO a large relaxation rate Γ (~5 kOe), depending on an orientation of the crystal, was found. An analysis of spin dynamics of this quasi-1D-system, taking into account a spin diffusion, spinon excitations and chains's interaction, gave a value of Γ that was in a reasonable agreement with the experimental value. It was found that "spin"-doping (by Zn) weakly affects the spectra. While "charge"-doping (by Li) considerably broadens the spectra (Γ ~13-15 kOe). It was explained by formation of exchange-coupled complexes of Li and copper spins. Hall signals were also observed in these crystals.

According to our preliminary data, ESR signal from Nd^{3+} ion was found in 0.03 mol% Nd^{3+}:$LaAlO_3$ at 300K. It also demonstrates a possible application of this nontraditional ESR spectrometer.

References

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