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LT 21

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Part S4 - LT Properties of Solids 1: Magnetism (experiment)

Magnetic non-linearity at strong Hall drift

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Steady current non-linear phenomena connected with a dependence of conductivity tensor components on self magnetic field of Hall drift have been investigated in aluminum. Strong Hall drift has been arranged by applying of cylinder conductor geometry, transport current being made to flow between inner and outer concentric contacts. Self magnetic field and resistivity are studied as a function of external field and transport current. The role of dispersion law anisotropy and elongated electron orbits are analysed by the method of orientation averaging of conductivity tensor.

РЕПОЗИТОРИЙ БГУ

1. INTRODUCTION

A cylindrical geometry of conductor having a radial current flow is benefit for investigation of magnetoconductivity of uncompensated metals because this geometry gives a possibility to use a regime of current supply. An absence of Hall field is suitable for study of peculiarities of electron scattering. On the other hand a presence of Hall current stimulates an appearance of self magnetic field which may be parallel or antiparallel to an external field. As a result a medium becomes inhomogeneous on magnetosusceptible parameters because a self magnetic field decreases from sample center to its outer diameter [1,2].

Here we represent a results of investigation of some aspects of magnetic non-linearity connected with self magnetic field in aluminum cylindrical conductors having a radial current flow and placed in coaxial an external magnetic field. Voltage drop along sample radius and a self magnetic field dependence on external magnetic field and radial current magnitude are represented. An anisotropy of dispersion law and electron scattering are discussed by means of effective relaxation time. A comparison of magnetoresistance with free electron approximation is made.

2. EXPERIMENTAL AND ANALYTICAL APPROACH

Samples for investigation were disk shaped conductors taking inner and outer concentric contacts of diameter 3 and 36 mm respectively. Sample thickness was 2 - 4 mm. Polycrystalline aluminum was chosen for sample fabrication to exclude crystal anisotropy being a disturbing factor in such experimental geometry. A maximal density of radial current near inner contact achieved of 600 A/cm^2, an external magnetic field was up to 8 T. Hall sensors and potential probes were mounted on sample surface along its radius. Samples were mounted in low temperature inset situated in liquid helium cavity. Registration methods were a measurement of voltage current characteristics, a measurement of voltage signals on potential probes and Hall sensors. Self magnetic field magnitude was determined as a difference between total magnetic field on sample surface and a magnetic field of superconducting solenoid in helium cryostat.

3. RESULTS AND ANALYSIS

An influence of strong Hall drift on magnetoresistive properties of sample is studied by means of voltage drop on sample surface in magnetic field. A dependence of voltage signal is represented in Fig.1 where experimental data having been received at different magnitudes of current flowing through sample. Voltage difference presents a total magnetoresistance. Here a magnetic field is inhomogeneous parameter and as a result a magnetoconductivity is non-local characteristic because it depends both on external magnetic field and current magnitude not only in this point but in sample volume. High level of resistivity of cylindrical conductors accompanies by respective self magnetic field. There is an interaction between

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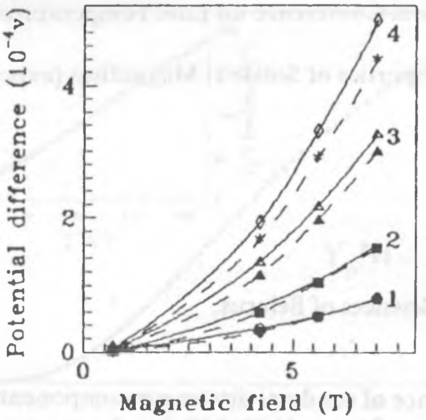

Fig.1. Potential difference on sample surface as a function of an external magnetic field at different currents I, A: 40 (1), 80 (2), 160 (3), 240 (4); solid lines - collinear geometry, dashed lines - anticollinear geometry.

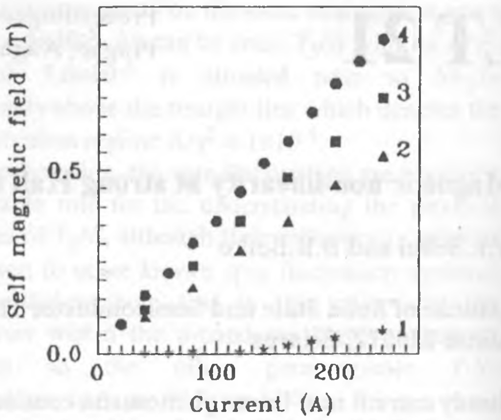

Fig.2. Self magnetic field dependence on radial current in external magnetic field B, T: 0.7 (1), 4.2 (2), 5.5 (3), 7.0 (4).

self and an external magnetic field. In Fig.1 a voltage drop differs for collinear and anticollinear geometry of current flow. For collinear geometry an effective total magnetic field is greater of an external field because directions of self and external field coincide. As a result a magnetoresistive effect is more large. An interaction between self and an external magnetic fields would be more effective for sample having more high thickness. For long cylindrical conductors a self magnetic field that is its coaxial component is greater of short cylindrical sample. A magnitude of self magnetic field is represented in Fig.2 where self field is expressed as a function of current through a sample. It is seen that quasi-linear dependence takes place. A self magnetic field on sample surface on axis may be represented as

$$B = -\frac{I\omega\tau}{c}\frac{1}{h}\ln\left(\frac{r_1}{r_2}\frac{h+\sqrt{h^2+r_2^2}}{h+\sqrt{h^2+r_1^2}}\right)$$

here I is a radial current, ω is a cyclotron frequency, τ is an effective relaxation time, h is sample thickness, r_1 and r_2 are inner and outer sample radii. It should be mentioned that τ is smaller in magnitude than a relaxation time τ_0 calculated from zero magnetic field resistance corresponding to free electron approximation. Decrease of τ is connected with anisotropy of electron scattering and appearance of elongated orbits. Respectively both $\omega\tau$ and an azimuthal Hall current decrease and are about a third of free electron parameter. A decrease of relaxation time may be represented as a result of geometrical averaging of intracrystalline conductivity in polycrystal conductor. Such averaging allows to present diagonal components σ_{xx} and σ_{yy} of conductivity tensor as

$$\sigma_{xx} = \sigma_{yy} = \sigma_0\left(\frac{1}{(\omega\tau_0)^2} + \frac{\alpha}{\omega\tau_0}\right)$$

here σ_0 is a zero magnetic field conductivity, α is small parameter describing a width of layer of elongated orbits. An additional term $\alpha/\omega\tau_0$ is smaller of basic term. A presence of this additional term increases conductivity components. An effective relaxation time may be represented as a smaller term in comparison with τ_0.

4.CONCLUSION

Notice that analogous phenomena in other conducting materials (semimetals, semiconductors) are small in magnitude despite a high carrier mobility on a reason of low carrier concentration. In this conditions a parameter $\omega\tau$ is very high but both an initial resistance and its growth in magnetic field will lead to boiling crisis at very small magnitude of current. Comparison shows that metallic media in this geometry are more preferable for realisation of different current phenomena where must exist a small level of energy dissipation.

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