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Negative Magnetoresistivity in Liquid with Dark Electric Current

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Abstract: *The action of a magnetic field on an ordinary substance is accompanied by a decrease in the electrical conductivity of the substance. It turns out that even in an electrical system consisting of two asymmetric aluminum electrodes immersed in a pure liquid, when exposed to a magnetic field, the conductivity increases. The change in current strength in such a system is proportional to the square of the strength of the external magnetic field. As the distance between the field source and the system increases, the relative change in current sharply decreases. Temperature variations cannot explain the observed phenomenon.*
***Key Word**: Magnetoresistance, Magnetic Field, Voltage, Electric Current, Aluminum, Water*

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I. Introduction

Magnetoresistivity is an effect that reduces the electrical conductivity of a material when it is placed in a magnetic field. This phenomenon in ordinary metals has been known for many years and is explained by the fact that conduction electrons in a magnetic field should move along spiral paths. The effect becomes noticeable only in sufficiently strong fields, in which the electron trajectory is significantly curved along the length free run. The mean free path is the average distance over which an electron in a metal is displaced by electric field between two collisions with lattice atoms, defects or impurity atoms. The resistance of the material is caused by the scattering of electrons in such collisions, since their direction of movement after the collision changes.

Among the effects that lead to magnetoresistivity, weak localization can be distinguished, as the most well-known effect leading to negative magnetoresistivity [1], that is, an increase in conductivity is observed when a magnetic field is applied. This is a one-electron quantum interference effect, leading to additional scattering of carriers, which reduces the conductivity [2]. It is believed that negative magnetoresistivity is observed only in very strong fields at low temperatures [3]. On the other hand, the features of the dark electric current in a liquid [4] force us to consider this current as the result of quantum processes. Therefore, to some extent, magnetoresistivity must occur in a liquid at weak fields and ordinary temperatures. Below are the results of measurements of the dark current flowing in pure water with two asymmetric aluminum electrodes.

II. Magnetization and Temperature of Liquid

The goal is not only to register a change in conductivity under the influence of a magnetic field, but also to find out at what parameters of the magnetic field this occurs. Therefore, the source of the magnetic field must be an electromagnet. This will allow us to study the influence of the magnitude of the magnetic field induction on the strength of the current flowing in the electrical circuit. The quantitative characteristic of such a dependence is the induction of the magnetic field B_0 created by the electromagnetic one.

The second task is to find out how the distance from the source of the magnetic field to the aluminum electrodes affects the magnitude of the current. The ring shape of an electromagnet allows you to see how the voltage drop increases or decreases when exposed to a powerful magnetic field. On the other hand, the electromagnet has a significant drawback. This is the heating of the liquid causing the current in the liquid to increase. Therefore, it is necessary to simultaneously measure not only the voltage drop across the load resistor, but also the temperature of the liquid. The neglect of such measurements seems doubtful [5]. The distance between the field source and the cell V with the liquid under study should be as large as possible, where the magnetic field induction is weak. It is known that the properties of a temperature sensor depend on an external magnetic field. To eliminate this contradiction, a remote temperature recorder should be used, consisting of a probe P, a heat transmitter T and a temperature sensor D (Fig. 1). It should be possible to compare the results obtained with what was expected or expected. Therefore, all installation parameters must be described.

The diameter c of the outer aluminum electrode C was 30 mm and that of the inner electrode E is 8 mm. The depth h of immersion was 15 mm. Voltage u on the load resistance R=100 kΩ is registered each 10 seconds using a memory oscilloscope. The second channel of the electronic oscilloscope is used for measurements of the temperature *t*. Geometric parameters of the electromagnet are: *H*=16 mm, *r*=80 mm, *p*=42 mm.

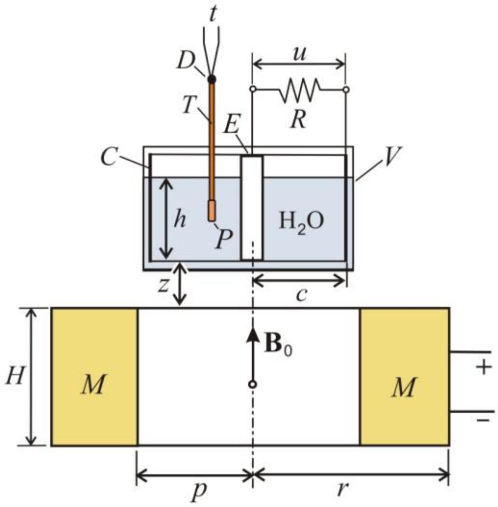

Fig. 1. Two immersed aluminum electrodes in magnetic field of electromagnet *M*.

The magnetic field is created by an electromagnet connected to a direct current source for short periods of time. This makes it possible to carry out measurements in a periodic mode, which in turn increases the accuracy and repeatability of measurements. The number of turns of the electromagnet is large. An example of the influence of the magnetic field on dark electric current is shown in Fig. 2.

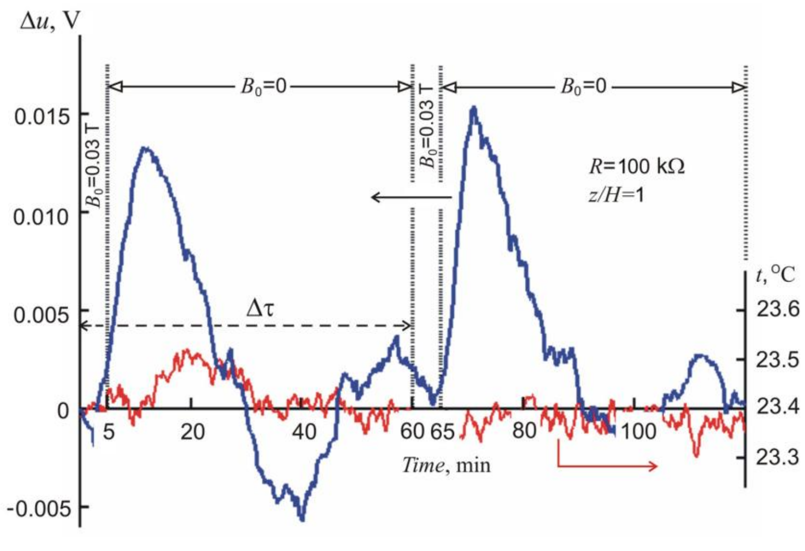

Fig. 2. Changing the voltage and temperature with turning the magnetic field on and off.

The result of the action of such a rather weak magnetic field on a dark electric current flowing in pure water with two aluminum electrodes is obvious, although it is unexpected. Under the action of the field, the current in the circuit increases, and does not decrease, which is characteristic of the positive magnetoresistivity. The change in voltage Δu compared to the average voltage value u~0.2V is small, but cannot be explained by statistical errors or fluctuations in the dark current. It is impossible to explain the detected effect by the influence of liquid heating or aluminum electrodes. Strong voltage changes do not repeat relatively weak voltage changes. Moreover, the position of the maximum voltage change differs significantly from the position of the temperature maximum. This is true even if such a temperature maximum appears in some measurements. Attention should also be paid to changes in the temperature at which this occurs. They are too small to provide such an increase in voltage caused by the action of a magnetic field. In any case, the details of such a magnetoresistivity must be studied.

III. Negative magnetoresistivity

The effect needs to be quantified. Let this be the magnitude of the change in current, averaged over a time interval of $\Delta\tau$=60 min (Fig. 2):

$$\Delta I = \frac{1}{R\Delta\tau}\int_{\Delta\tau} \Delta u(\tau)d\tau$$

An aim here is to confirm that negative magnetoresistivity is a real physical phenomenon caused by the action of a magnetic field on the surfaces of aluminum electrodes and possibly on the liquid in which they are placed. Magnetoresistivity is a secondary phenomenon. Therefore, the dependence of the relative change in current $\Delta I/I$ on the induction of the magnetic field B_0 created by the electromagnet must be quadratic. It turned out that this is indeed the case and can be approximately described by the dependence $\Delta I/I=\beta B_0^2$ with β=19.8 T^{-2}.

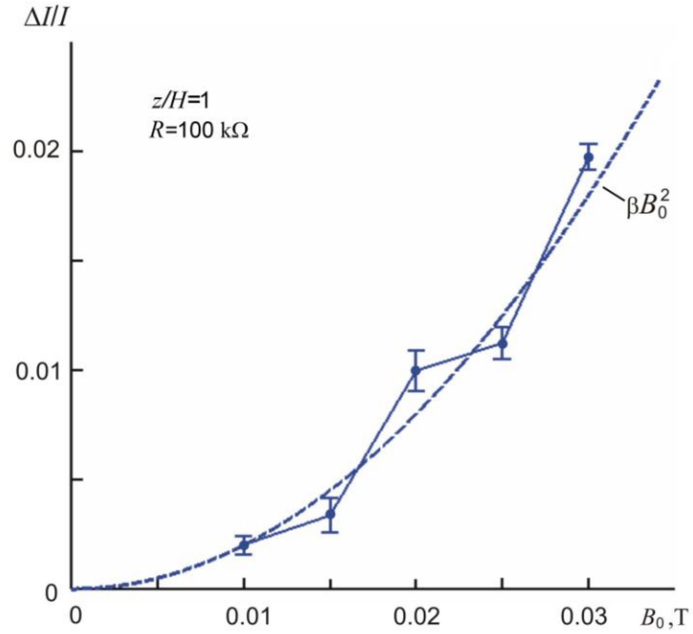

Fig. 3. Relative change in current as a function of magnetic field induction.

It should not be forgotten, however, that the heat transferred to the system from magnetic induction must obey a similar law [6]. This is the only alternative phenomenon that claims to explain the observed increase in conductivity. Nothing else can be found. That is why the distance z between the source of the magnetic field and the aluminum electrodes is large. Increasing the distance z will inevitably lead to a decrease in the thermal component of the effect. Therefore, special attention should be paid to the dependence of the effect on distance. The experimental results that can be obtained with negative n cannot be considered unambiguous. The dependence of the relative change in the current caused by the action of a magnetic field on the distance z is shown in Fig. 4.

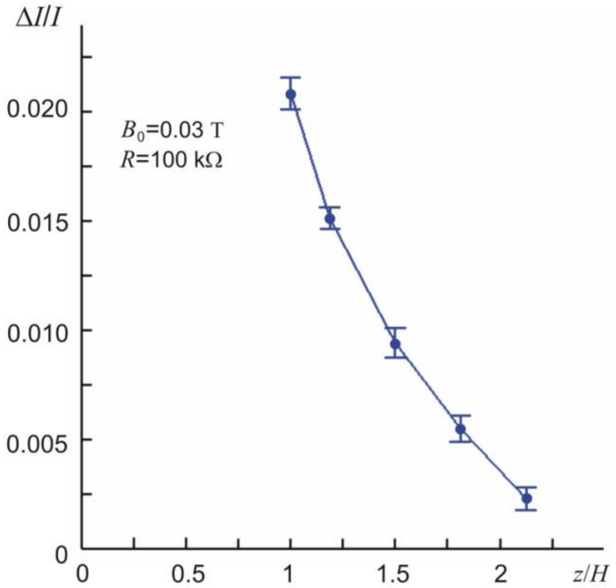

Fig. 4. The distance dependence of changing the current.

Relative change with increasing distance z decreases too quickly. It is practically impossible to associate such a change with a decrease in temperature. First, the change in temperature at large z is very small. Secondly, heat dissipation with increasing distance from the heat source to the receiver occurs relatively weakly, much weaker in comparison with a change in the magnetic field induction.

IV. Conclusion

The observed effect of negative magnetoresistivity is quite important. It turns out that the effect of a magnetic field increases the efficiency of extracting dark electrical energy. The magnetic field does not change the energy, but reduces its losses during the interaction of ions with the aluminum surface. The quadratic nature of the dependence of the relative change in current on the magnetic field induction can significantly affect the efficiency of dark sources of electrical energy. It also turned out that negative magnetoresistivity is characteristic not only of some exotic materials [7], and occurs not only in strong magnetic fields and not only at relatively low temperatures.

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