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INSTRUMENTS AND EXPERIMENTAL TECHNIQUES

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Installation for the research of galvanomagnetic effects in manganites of lanthanides

In the problem of increase in volume and information processing rate removed from hard drives of computers, the large role is played by properties of the sensors used for these purposes. The modern magnetoresistive sensors not fully meet qualifying standards that constrains development of the computer equipment. Effects of colossal and gigantic magnetoresistance found rather recently (CMC and HMS) give the chance to create more perfect sensors capable to work in case of indoor temperatures and in the field of feeble magnetic fields. From the point of view of technical applications use of effect of CMC is not just enhancement of already existing computer and semiconductor technologies. It is creation of essentially new elements of operational computer memory which use will lead to essential lowering of energy consumption and increase in non-volatility not only computers, but also such devices as cell phones, electronic organizers, digital cameras and so forth. The task of fundamental physics - to understand the nature of reduction of a resistance under the influence of a magnetic field, that is origins of CMC. In this regard the problem of search and creation of the materials having effects of enormous and huge magnetoresistance, sensors of weak magnetic fields, suitable for creation, is very relevant. The manganites of lanthanides having complex structure can be examples of such materials. Anomalies of physical properties of manganites which can be used for creation of similar sensors are caused by a rich variety of the physical phenomena inherent in manganites of rare-earth elements with a perovskite structure $La_{1-x}(Sr, Ca)_xMnO_3$. However, effective practical application of manganites requires understanding of the physical mechanisms responsible for the observed phenomena. The research of galvano-magnetic effects plays a defining role in search of new materials as they allow to receive data on fundamental properties of semiconductors. These experiments allow to determine those parameters of new materials which are the main criteria of a possibility of their use for creation of these or those sensors and sensors. The description of the experimental installation for a study of magnetic-field dependencies of kinetic coefficients, their measurements, determination of the main characteristics of materials is provided in operation.

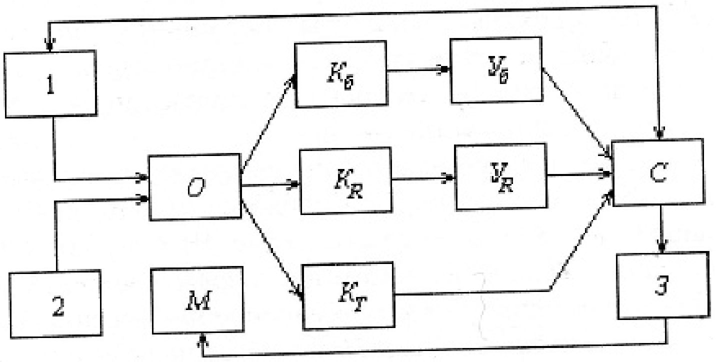
Keywords: installation, magnetic semiconductors, colossal magnetoresistance, galvanomagnetic phenomena, sensors, ferromagnetic structures, electromagnet, power supply, Hall effect, manganite's of lanthanides, register, temperature, photo compensation amplifier, DC potentiometers, control units.

Materials with strong electron correlation and phase separation RE1−xAxMnO3 (RE=La,Pr,Ndetc.) (A=Ca,Ba,Sr, etc.) have drawn attention to themselves after observation of effect of colossal magnetoresistance in 1990 [1-4]. All groups of materials in which spin-dependent scattering and carrier tunneling can be used in the practical purposes are involved in the sphere of the accelerated development of spin electronics [3, 5]. Magnetic Resistive Memory with Random Access (MRAM), perhaps, will form a basis of the next generation of random access memory (DRAM, SRAM, EEPROM). One of candidates for use in the device of Random Resistive Memory are the manganite's and perovskites showing CMC effect [4, 6].

However practical use of CMC effects and other unique properties of manganites require a detailed research of dependence on magnetic field of properties of these materials [7-10]. So, for example, the research of mechanisms of conductivity and magnetoresistance can give additional information for understanding of mechanisms of influence of external magnetic field on properties of manganites.

Importance and need of creation of the installations allowing to investigate the galvano magnetic phenomena for the purpose of search of the materials suitable for creation of sensors of weak magnetic fields follows from the above.

In work the flowchart (Fig. 1) and schemes of separate blocks (Fig. 2-5) of the installation created by authors, allowing to investigate the galvano magnetic phenomena in a solid body in a wide interval of temperatures (from 80 K to 400 K) is submitted.



1 power supply unit sample; 2 — control box in average temperature of a sample; 3 — unitsupply by an electromagnet; $K_б$, K_R, K_T — potentiometers of constant type P 330; $У_б$, $У_R$ — photocompensation amplifiers of the type Ф116/2; M — electromagnet; C — chart recorder type ЭПП-09М or ПДС-021М

Figure 1. The flowchart of the installation intended for a research galvano-magnetic effects. About - the researched sample

The schematic electric circuit of the measuring channel is submitted in the Figure 2. Measurement of the signal arriving from a sample is carried out by a compensation method.

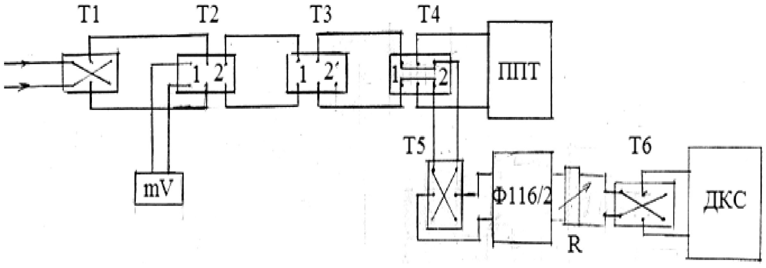


Figure 2. Schematic electric circuit of the measuring channel

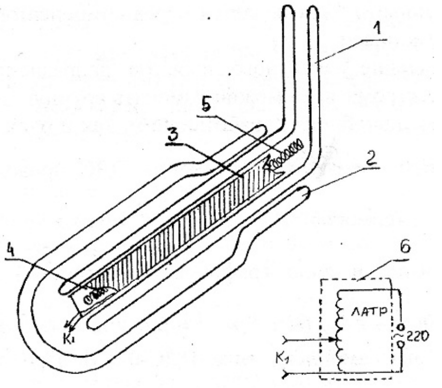
The diagram functions as follows. On the control panel the measured signal from a sample via the switch 1 arrives that allows to polarity of voltage direction. From the switch 1 measured tension moves on average contacts of the switch 2 from which the signal is sent or to the millivolt meter (provision 1), or to contacts of 1 switch 3 (provision 2). Further the measured signal by means of the switch 3 can be sent to a measuring circuit (the provision 1 of the switch 3) or is disconnected from a circuit of measurement (provision 2). In the latter case only the DC potentiometer (DCP) which is working out the calibrated constant voltage that allows calibrating a scale of the two-coordinate register is connected to an input of a circuit of measurement ПДС-021М.

Before starting measurements, calibration of a chain of measurement is without fail carried out.

Change of average temperature of a sample is carried out by means of the cryostat which device is illustrated with the Figure 3.

The cryostat consists of two glass vessels of the Dewar: external – 2 and internal – 1. The external Dewar represents a glass vessel with double walls between which discharge is created. In the external Dewar liquid nitrogen is filled in. The internal Dewar is made in the form of a curved glass tube with double walls between which discharge is also created. The hollow casing from copper is inserted into a wide part of the internal Dewar, on the top and lower parts of which furnaces (spiral) intended for heating and evaporation of nitrogen are fixed. The curved glass tube with a casing and two ovens is inserted in the external Dewar with liquid nitrogen.

The cryostat during measurement rather long time allows to establish and maintain the average temperature of an example of any value in the range from 300 K to 78 K with an accuracy of 0,5 K.

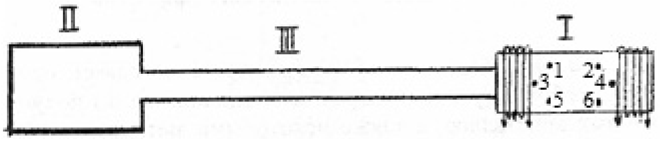


A 1 — internal vessel of the Dewar with a narrow mouth; 2 — external vessel of the Dewar; 3 — casing from a copper foil for transfer of a gradient of temperature; 4 — lower furnace; 5 — top furnace; 6 — laboratory autotransformer

Figure 3. Cryostat device

The control unit of temperature condition of the cryostat includes two power supplies feeding cryostat furnaces. The furnace intended for heating has the forced mode allowing passing quickly from one temperature to another. When giving tension direct to the vaporizing furnace of couple of nitrogen through a narrow top mouth of the internal Dewar and allow to cool the studied sample up to the necessary temperature. Adjustment of temperature of vapors of nitrogen is carried out by giving of tension on the vaporizing furnace.

At measurement of galvano magnetic effects the holder of a sample which scheme is provided on the Figure 4 is used. The sample consists of two heads of I and II, connected by a hollow metal core. The studied sample is attached to a copper plate of a head of the I holder. Then the holder with a sample is located in a curved tube of the internal Dewar of the cryostat located between poles of a constant electromagnet. Average temperature of a sample is taken by means of differential copper константановой thermocouples, one спай by which it is built in in a head of the I holder between a copper plate and a substrate for a sample, and another is in a vessel with ice and the distilled water at a temperature 0 °C.The potential difference on the ends Copper-Constantine differential thermocouple is proportional to the average temperature of the studied sample.



A sample I-head with contacts for the researched samples (1, 2, 3, 4, 5, 6); An II head with the connector providing signal transmission from a sample in a measuring part of installation; The III hollow rod in which bonding wires settle down

Figure 4. Diagram of the holder of a sample

Before operation with an electromagnet the status of windings of an electromagnet, their water cooling, quality of connection of windings are without fail checked. For this purpose execute the following operations:

– pass water from a water supply system through disks of water cooling of an electromagnet, for the purpose of check of a leak of the water leading to closing of windings of an electromagnet;

– check a status of windings for the purpose of detection of breakaways or violation of insulation. In case of detection of those they are removed;

– windings among themselves connect so that magnetic field strength, in case of this value of the current passing through windings had the maximum value;

– value of magnetic field strength decides on the help of Hall Sensor.

In a Figure 5 the diagram of Power Supply of an electromagnet is provided. A supply of an electromagnet is carried out from the rectifier of the constant voltage collected from semiconductor diodes of type *Д232А*according to the bridge scheme. On one diagonal of the bridge alternating adjustable voltage from the autotransformer moves (ЛАТР). From other diagonal the straightened stress which through contacts of magnetic starters is removed $П_1$ и$П_2$ tension moves on electromagnet windings. Ammeter*А*typeМ1108 Т4.1 the size of the current proceeding through an electromagnet winding is measured. Change of the direction of magnetic field is carried out by magnetic actuators$П_1$ и$П_2$. Short circuit of contacts of magnetic starter's $П_1$ и $П_2$ it is carried out by means of the type relay *МКУ*-48.

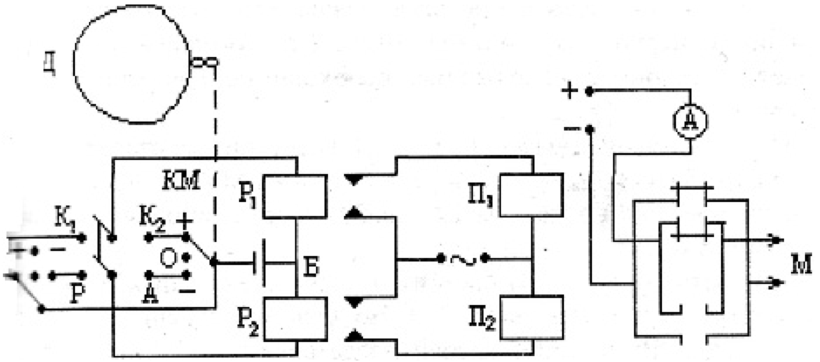


Figure 5. Electromagnet Power Supply (explanations in the text)

The switching unit of an electromagnet figured in a Figure 5 consists of the relay of a direct current P_1 and P_2 (type*МКУ*-48) and magnetic starter's $П_1$ и$П_2$. The relay turns on from the signals arriving from mechanical contacts – *КМ*, operated by a figured disk *Д*, which is built in the chart recorder ЭПП-09Мon one axis with the switch of disks. Starter$П_1$ includes current through a winding of an electromagnet of one direction, $П_2$ - other. By means of mechanical keys K_1иK_2 manual control of the direction of current through an electromagnet winding can be exercised. All contacts of a circuit of switching are supplied with spark extinguishing *RC*-circuits. Current value through an electromagnet winding, i.e. the size of tension of magnetic field necessary for measurement is established manually prior to the experiment.

Necessary operation before carrying out a research of influence of magnetic field on kinetic parameters of the studied sample is graduation of an electromagnet and the choice optimum (perpendicular to the direction of magnetic field in his uniform part) sample arrangements between his poles. To achieve the maximum size of a uniform part of magnetic field uses a wide tip of an electromagnet. Graduation of an electromagnet is carried out by means of Hall Sensor for what he is placed between poles of a magnet and pass electric current via the sensor. The size of the passed current is chosen, proceeding from passport data of the sensor. Rotating Hall Sensor in magnetic field, try to obtain the maximum value of Hall potential difference. In this case Hall Sensor will settle down perpendicular to the direction of magnetic field. Changing the size of the current passing through electromagnet windings register values of the Hall potential difference proportional to tension of magnetic field and build a calibration curve of an electromagnet – a curve of dependence of tension of magnetic field on the current value passing through his windings. In a Figure 6 the diagram of power supply unit of a sample which consists of stabilized is provided current source (from 5 мкАby 100 мА) andrelayP_1 (type РМУГ), operated by mechanical contact *КМ*.

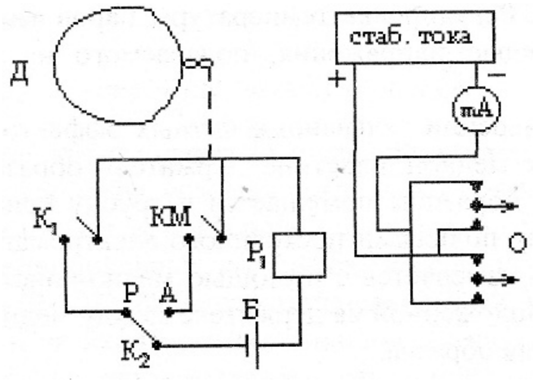


Figure 6. Sample Power Supply

As kinetic parameters are rather sensitive to fluctuations of values of current and tension in network, before carrying out measurements it is necessary to calibrate installation. Calibration of installation is carried out in the following order.

The toggle-switch 3 is set to position 2. Then the constant calibrated tension developed by the DC potentiometer (PDC) will move in a measurement chain entrance through contacts of the toggle-switchT5. Value of the calibrated tension is selected according to value of the measured tension. The selected calibrated tension via the tumblers T4 and T5 moves on an input of the photocompensation amplifier Ф116/2 and amplifiers. The reinforced signal from an output of the amplifier through shop of resistance R300 arrives on an input of the two-coordinate recorder. By means of shop of resistance R300 the maximum value of tension registered by the register is selected equal to the selected calibrated tension. After calibration of installation start measurement of a signal from a sample in the following order. The toggle-switch 3 is turned to position 1 therefore the signal from the studied sample gets on a measurement chain PDC entrance. Part of a signal, is compensated by the calibrated signal which is worked out by PDC direct current potentiometer, and a no compensated part amplifies the photocompensation amplifier Ф116/2 type and the reinforced signal from an output of the amplifier is given on an input of the two-coordinate register ПЛС of 024 M. On the second entrance of ПДС-021М recorder the signal from a copper-constantan thermocouple taking the average temperature of the studied sample is given. Thus, on the tablet of recorder of ПДС 024 M it is drawn, the curve characterizing temperature dependence of a signal which goes from a sample.

Influence kinetic parameters both the size, and the direction of magnetic field. The dependence of kinetic coefficients on the direction of magnetic field is called anisotropy of the corresponding measured parameter. The anisotropy of kinetic parameters can be caused by anisotropy of a power range of carriers of a charge. For example, the dependence of magnetoresistance on orientation of magnetic field is caused by anisotropy of a power range of carriers of a charge. It means that, investigating dependence of some kinetic coefficients on the direction of magnetic field, it is possible to receive data on a power range of carriers of a charge in the studied solid body.

Therefore existence of a possibility of a research of kinetic parameters from size and the direction of tension of magnetic field is rather important. To investigate dependence of kinetic coefficients on the size of tension of magnetic field on one entrance of ПДС-021М recorder the signal corresponding to the studied coefficient, and on another – the signal proportional to tension magnetic a floor, the electromagnet created between poles is given. Thus receive dependence of the studied size on tension of magnetic field.

The electromagnet is established on the rotating disk, and the holder with a sample is fixed not movably between electromagnet poles. Therefore by rotation of an electromagnet it is possible to change orientation of tension of magnetic field concerning the plane of the studied sample.

If the signal corresponding to a certain kinetic coefficient a tax on one entrance of ПДС-021М recorder, and on other angle of rotation of an electromagnet, then on the tablet of the recorder is drawn the curve describing dependence of the studied size on the direction of tension of magnetic field.

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Лантаноидтар манганиттеріндегі гальваномагниттік құбылыстарды зерттеуге арналған құрылғы

Компьютердің дискісінен алынатын ақпараттардың мөлшері, оларды өңдеу жылдамдығы бұл мақсат үшін пайдаланылатын сезгіш тетіктердің қасиеттеріне тікелей байланысты. Қазіргі кезде осы мақсатта қолданылатын магнит кедергісіне негізделген сезгіш тетіктер ақпаратты өңдеу саласының жоғары талаптарын қанағаттандыра алмайды. Кейінгі кезде табылған алып магнит кедергі құбылысы бөлме температурасында өте әлсіз магнит өрісін тіркей алатын сезгіш тетіктерді жасау мүмкіндігін ашты. Алып магнит кедергісін пайдалану арқылы компьютердің жедел жадысын дамытуға, энергияны үнемдеуге, ақпаратты өңдеу жылдамдығын арттыруға, тағы басқа жаңалықтарды өндіріске тез ендіруге мүмкіндік береді. Іргелі физиканың негізгі мақсаты — алып магниттік кедергінің пайда болу табиғатын, оның ерекше қасиеттерін анықтап, өмірде қолдану аясын кеңейту. Осы тұрғыдан алып магниттік кедергісі бар заттарды тауып, электрфизикалық қасиеттерін зерттеп, оларды әлсіз магнит өрісін сезетін сезгіш тетіктер жасау үшін пайдалану мәселесінің маңызы ерекше. Кейінгі кезде сирек кездесетін жер элементтерінің лантаноид манганиттерінде $La1-x(Sr, Ca)xMnO_3$ алып магниттік кедергілерінің табылуы олардан әлсіз магнит өрісін сезе алатын сезгіш тетіктерді жасау мүмкіндігін ашты. Алайда әлсіз магнит өрісін сезгіш тетік жасау үшін манганиттерде алып магниттік кедергінің пайда болу табиғатын жете білу керек. Жаңа материалдарды іздеу үдерісінде гальваномагниттік құбылыстарды зерттеудің алатын орны ерекше. Гальваномагниттік құбылысты зерттеу арқылы жаңа материалдардың сезгіш тетіктер жасауға мүмкіндік беретін қасиеттерінің ерекшеліктерін анықтауға мүмкіндік береді. Жұмыста материалдың электрфизикалық қасиеттерінің магнит өрісіне тәуелділігін зерттеуге мүмкіндік беретін құрылғы құрылысы және онда жұмыс істеу әдісі баяндалған.

Кілт сөздер: құрылғы, магниттік жартылай өткізгіштер, алып магниттік кедергі, гальваномагниттік құбылыс, сезгіш тетік, ферромагнит құрылымы, электрмагнит, қорек көзі, Холл құбылысы, лантаноидтар манганиттері, температура, потенциометр.

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Установка для исследования гальваномагнитных эффектов в манганитах лантаноидов

В проблеме увеличения объема и скорости обработки информации, снимаемой с жестких дисков компьютеров, большую роль играют свойства используемых для этих целей сенсоров. Современные магниторезистивные датчики не в полной мере удовлетворяют предъявляемым требованиям, что сдерживает развитие компьютерной техники. Обнаруженные сравнительно недавно эффекты колоссального и гигантского магнетосопротивления (КМС и ГМС) дают возможность создавать более совершенные сенсоры, способные работать при комнатных температурах и в области слабых магнитных полей. С точки зрения технических приложений использование эффекта КМС — это не просто усовершенствование уже существующих компьютерных и полупроводниковых технологий это создание принципиально новых элементов оперативной компьютерной памяти, использование которых приведет к существенному снижению энергозатрат и повышению энергонезависимости не только компьютеров, но и таких устройств, как сотовые телефоны, электронные органайзеры, цифровые камеры и пр. Задача фундаментальной физики — понять природу уменьшения электросопротивления под воздействием магнитного поля, т. е. механизм возникновения КМС. В связи с этим весьма актуальной является проблема поиска и создания материалов, обладающих эффектами колоссального и гигантского магнетосопротивления, пригодных для создания датчиков слабых магнитных полей. Примерами таких материалов могут служить манганиты лантаноидов, имеющие сложную структуру. Аномалии физических свойств манганитов, которые могут быть использованы для создания подобных сенсоров, обусловлены богатым разнообразием физических явлений, присущих манганитам редкоземельных элементов со структурой перовскита $La_{1-x}(Sr, Ca)_xMnO_3$. Однако для эффективного практического применения манганитов необходимо понимание физических механизмов, ответственных за наблюдаемые явления. Исследование гальваномагнитных эффектов играет определяющую роль в поиске новых материалов, поскольку они позволяют получить сведения о фундаментальных свойствах полупроводников. Эти эксперименты позволяют определить те параметры новых материалов, которые являются основными критериями возможности использования их для создания тех или иных сенсоров и датчиков. В работе приведено описание экспериментальной установки для изучения магнитополевых зависимостей кинетических коэффициентов, их измерения, определения основных характеристик материалов.

Ключевые слова: установка, магнитные полупроводники, колоссальное магнетосопротивление, гальваномагнитные явления, сенсоры, датчики, ферромагнитные структуры, электромагнит, источник питания, эффект Холла, манганиты лантаноидов, самописец, температура, фотокомпенсационный усилитель, потенциометры постоянного тока, блоки управления.

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