ФИЗИКО-МАТЕМАТИЧЕСКОЕ ОБРАЗОВАНИЕ: ЦЕЛИ, ДОСТИЖЕНИЯ И ПЕРСПЕКТИВЫ

PHYSICAL AND MATHEMATICAL EDUCATION: GOALS, ACHIEVEMENTS AND PROSPECTS

Материалы Международной научно-практической конференции

г. Минск, 10–13 мая 2017 г.

Materials of the International Scientific and Practical Conference

Minsk, May 10–13, 2017

Министерство образования
Республики Беларусь

Учреждение образования
«Белорусский государственный
педагогический университет
имени Максима Танка»

Ministry of Education
of the Republic of Belarus

Belarusian State
Pedagogical University
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римента, например, при сопоставлении данных контрольной и экспериментальной групп, что не совсем правомочно. В педагогике для обоснования целесообразности введения разрабатываемой дидактической методологии применяют инверсионный подход при котором контрольную подгруппу с традиционными методами изложения материала формируют из лиц, показавших более высокие результаты по данным стартового установочного контроля уровня знаний. В экспериментальной подгруппе сосредотачивают представителей с низким уровнем владения материалом, которые по итогам воздействия продвинутых технологий изложения должны, в общем, показать существенное отличие в уровне знаний, то есть превзойти уровень контрольной группы. Такой принцип верификации процесса обучения также не лишен недостатков из-за его избыточной формализации по количественным меркам. Кроме того, последующее рассмотрение нулевой и альтернативной гипотезы с выявлением уровня надежности при установлении существенных отличий по рассматриваемому признаку дополнительно приводит к возможностям спекуляций данными в виду определенного произвола в выборе исходных параметров задачи.

В сообщении рассмотрена проблема верификации уровня усвоения материала по физике среди учащихся техникума с применением традиционных параметрических и ранговых принципов сопоставления данных статистики. Показано, что традиционные методы вероятностного анализа при грамотной формализации процесса расчета с привлечением корреляционных моментов высших порядков позволяют устанавливать более адекватные соотношения регрессий, которые вполне могут отразить действенность дидактических новаций. На примере рангового критерия статистической значимости Спирмена показаны возможности интерпретации результатов при сопоставлении оценок экспериментальной и контрольной групп по уровню существенных отличий в знаниях с реализацией ошибок как первого, так и второго рода.

UDC: 537.9;537.621.

V. Sobol, B. Korzun, S. Vasilevski, Ch. Fedorcov, I. Perepechko, O. Mazurenko
BSPU, Minsk, Belarus
T. Bizhigitov, S. Tomaev, B. Nushnimbaeva, A. Nauryzbaev, S. Egemberdieva
TSPU, Taraz, Kazakhstan

MAGNETIC ORDERING IN SAMPLES OF SOLID SOLUTIONS WITH PEROVSKITE STRUCTURE IN BISMUTH-IRON-OXYGEN SYSTEMHAVING A WEAK SUBSTITUTION OF BISMUTH FOR LANTHANUM, NEODIMIUM, GADOLINIUM

Last time the materials being simultaneously both the ferroelectrics and magnetic one have attracted increasing attention due to benefit of potential applications for new devices taking advantage of the multiferroic coupling. The rhombohedrally distorted $BiFeO_3$ perovskite (space group: *R3c*) is an attractive object as a magnetoelectric material because the ferroelectric and antiferromagnetic orders coexist at room temperature. The *G*-type antiferromagnetic ordering of $BiFeO_3$ takes place at about 640 K, while the phase transition from paraelectric state to ferroelectric state occurs at about 1100 K. The observation of an antiferromagnetic domain switching by an external electric field in $BiFeO_3$ films indicates that there is a principal possibility of applying these materials in novel electronic devices. The anti ferromagnetic spin configuration of $BiFeO_3$, as assumed, can be destructed by an any action on to a spiral modulated spin structure, having a 620 nm periodicity and suppresses the macroscopic magnetization that respectively minimizes prohibits to realize the linear magnetoelectric effect.

Chemical doping of $BiFeO_3$ as supposed can modified both the electric conductivity and a spiral spin structure to intensify the macroscopic magnetization. The ferroelectric distortion of $BiFeO_3$ as accepted is a result of a hybridization of the Bi 6*s* electrons with the *s/p* orbits of O. Particularly to intensify the macroscopic magnetic properties usually it is proposed to use some rare earth elements for the substitution of Bi. The three charged ion radius of lanthanum, neodymium and gadolinium being equal to 0.101, 0.099 and 0.0938 nm respectively are close to three-charged ion radius of bismuth being equal to 0.096 nm. So the replacement of Bi on to La, Nd, Gd would weaken the hybridization and affect the ligand field at the Fe ions. An investigation of the number of changes in physical properties caused by the rare earth elements substitution for bismuth has been studied already. There is an interesting fact that among the parent compounds the $GdFeO_3$ crystallizes in an orthorhombic distorted perovskite structure (space group: *Pbnm*), exhibits an antiferromagnetic ordering (T_N « 660 K), and as it was recently found to be a magnetoelectric oxide below about 2.5 K. Nevertheless, most of the reports have been devoted to the characterization only of physical properties without of analysis the substitution effects on to structure and the relationship between the structure modification and physical, particularly, optical properties. So it is, thus, desirable to extent the investigation of the mixed system on the base of $BiFeO_3$ in order to explore the novel magneto electric materials, and get an understanding of the underlying physics processes [1–5].

Here the $Bi_{1-x}Gd_xFeO_3$, $Bi_{1-x}Nd_xFeO_3$ and $Bi_{1-x-y}Gd_xLa_yFeO_3$ polycrystalline ceramics with $x < 0.2$ and $x+y < 0.2$ respectively were prepared and identified at room temperatures by X-ray powder diffraction (XRD). Some properties of the magnetization of these samples are also presented here.

Experiment and results

$Bi_{1-x}Gd_xFeO_3$, $Bi_{1-x}Nd_xFeO_3$ and $Bi_{1-x-y}Gd_xLa_yFeO_3$ ceramic samples with x = = 0.0, 0.05, 0.1, 0.15, 0.2 for single substitution and x = 0, 0.05, y = 0.15 also x = = 0.15 y = 0.05 and x = 0.1, y = 0.1 for double substitution respectively were synthesized by usual solid-state reaction. Bismuth (III) oxide (Bi_2O_3), gadolinium (III) oxide (Bi_2O_3), lantanum (III) oxide (Bi_2O_3), and iron (III) oxide (Fe_2O_3) powder ingredients have been used for synthesis in accordance with the next transformation

$$xGd_2O_3 + (1-x)Bi_2O_3 + Fe_2O_3 = 2Gd_x^{3+}Bi_{1-x}^{3+}Fe^{3+}O_3^{2-}.$$

$$xNd_2O_3 + (1-x)Bi_2O_3 + Fe_2O_3 = 2Nd_x^{3+}Bi_{1-x}^{3+}Fe^{3+}O_3^{2-}$$

$$xLa_2O_3 + yGd_2O_3 + (1-x)Bi_2O_3 + (1-y)Bi_2O_3 + 2Fe_2O_3 =$$
$$= 2La_x^{3+}Gd_y^{3+}Bi_{1-x-y}^{3+}Fe^{3+}O_3^{2-}$$

Particularly the dried starting materials, for an example Bi_2O_3, Fe_2O_3 and Gd_2O_3 (purity > 0.9999) were measured by using a high-precision balance and have been taken in stoichiometric proportion (for composition $Nd_{0.15}Bi_{0.85}FeO_3$ the start ingredient quantity was taken: Nd_2O_3 – 0.08326 g, Bi_2O_3 – 0.65332 g; Fe_2O_3 – 0.26342 g). The powders were mixed thoroughly with a mortar and pestle with a small amount of high-purity isopropanol. The prepared powder was precalcined at 750 °C for 3 h (the heating velocity of 10 °C/min, furnace colling) before being cold pressed into pellets. Than the pellets have been heated up to 820 °C with a velocity of 7.5 ° C/min and sintered for a further 2 hours with consequent furnace colling. Further grinding was applied too before leaching the powder in 15 ml of 1.0 M solution of nitric acid for 4 h to remove unwanted impurities. To carry out the phase control of synthesized samples the *X*-ray diffraction method was applied on the base of high-resolution diffractometer Dron-3 with $Cu\ K_\alpha$ radiation. A comparison of the parameters and characteristics of the magnetic ordering of bulk samples of bismuth ferrite and its substituted solid solutions was carried out from measurements of magnetization on powdered samples using the The High Field Measurement System (Cryogenic Ltd., London, UK). The temperature dependence of the magnetization in a constant magnetic field including the hysteresis loop was investigated at fixed temperatures of 5, 100, 200 and 300 K in a magnetic field up to 10 T. A laboratory facility based on a ponderomotive method was used for magnetic susceptibility for magnetization had been measured in the temperature range 80-930 K too.

The dependences of the magnetization of solid solutions of bismuth ferrite with partial replacement of bismuth ion on rare-earth ions of neodymium, lanthanum, gadolinium show the tendency of materials to exhibit properties of magnetic ordering at low temperatures. In this case, double substitution, i.e., doping in comparison is simply neodymium and complex doping with gadolinium and lanthanum affects the realization of magnetic properties more strongly. Complex doping may have a greater positive effect due to the violation of crystallochemical stoichiometry, since in this case 20 % of the bismuth ions are replaced by foreign ones.

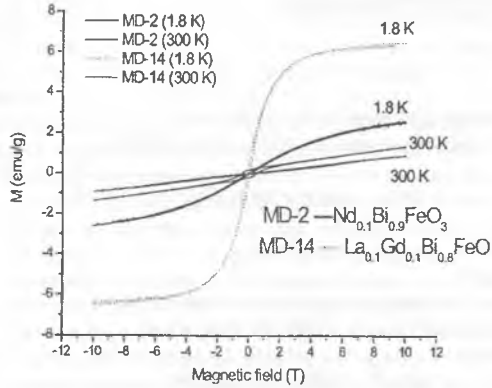

Figure – Comparative behavior of magnetization for systems neodymium - bismuth - iron - oxygen and lanthanum – gadolinium – bismuth –iron-oxygen that is Nd $_{0.1}$ Bi $_{0.9}$FeO$_3$ and La $_{0.1}$Gd $_{0.1}$Bi $_{0.8}$FeO$_3$ from the point of view of activation of ordering mechanisms in the low –temperature region.

Doping with neodymium with replacement of bismuth in an order of 10 atomic percent more affects the magnetic saturation moment both at high and low temperatures, with approximately the same proportion. At low temperatures, 20 % doping leads to a substantial saturation of the magnetic moment in a field of the order of 6–8 T. As follows from Fig., the process of destruction of the so-called spin cycloid in solid solutions is more productive when about 20% of bismuth ions are replaced by neodymium, lanthanum, gadolinium ions. Magnetization in its striving for saturation, attained at levels of induction of the external field of the order of 4–6 T, shows the prospects of the approach of the chemical internal effect on the crystal lattice of the material and the integrity of the spin cycloid. Of course, the temperature range corresponding to a level much lower than even liquid helium and the magnitude of the control field are from the point of view of direct applied importance beyond the limits, but the trends of the crystallochemical effect on magnetic properties deserve further development.

➢ **LITERATURE**

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