SOCAR Proceedings

Fundamental scientific researches

journal home page: http://proceedings.socar.az

DIELECTRIC AND ELECTRICAL PROPERTIES OF THE $La_{0.73}Ba_{0.27}MnO_3$ COMPOUND AT HIGH TEMPERATURES

S. H. Jabarov[1], A. Kh. Nabiyeva[1], A. V. Trukhanov[2,3], S. V. Trukhanov[2,3], H. J. Huseynov[1], Y. I. Aliyev[4,5]

[1]*Institute of Physics, Ministry of Science and Education of the Republic of Azerbaijan, Baku, Azerbaijan*
[2]*Scientific-Practical Materials Research Centre of National Academy of Sciences of Belarus, Minsk, Belarus*
[3]*National University of Science and Technology MISiS, Moscow, Russia*
[4]*Azerbaijan State Pedagogical University, Baku, Azerbaijan*
[5]*Western Caspian University, Baku, Azerbaijan*

A B S T R A C T

In the presented work, comparative studies of the dielectric and electrical properties of $La_{0.73}Ba_{0.27}MnO_3$ compounds were carried out at the temperature range T = 25-225 °C and frequencies range f = 20-10^6 Hz. Temperature and frequency dependences of the real and imaginary parts of the dielectric constant, dielectric loss angle, dielectric constant, and electrical conductivity were obtained. This compound was found to have semiconducting properties under normal conditions. It has been established that with increasing temperature and frequency, the electrical conductivity in these compounds increases. This effect is explained by the release of charge carriers at deep levels due to thermal energy. At a temperature T = 140 °C, a semiconductor-metal phase transition was detected in this compound. The values of physical parameters for each of the semiconductor and metal phases are determined. The occurrence of a phase transition is explained by the mechanism of activation of charge carriers due to thermal energy.

Keywords: perovskit; dielectric properties; electrical properties; $La_{1-x}Ba_xMnO_3$.

© 2023 «OilGasScientificResearchProject» Institute. All rights reserved.

1. Introduction

The electrical properties of semiconductors and dielectrics change depending on temperature and the external electric field. Therefore, it is important to study the electrical and dielectric properties of these materials depending on external influences. It is known that the concentration of free charge carriers in semiconductors and dielectrics is lower than in metals. Therefore, conductivity in these materials is not observed under normal conditions. As the temperature increases, charge carriers at deeper levels in semiconductors become free. These charge carriers are involved in electrical conductivity. Therefore, extensive research is being conducted to study the influence of temperature on the structure and various physical properties of semiconductor materials [1-5].

Manganites with a perovskite structure also have semiconducting properties. It is known that these compounds exhibit antiferromagnetic and ferromagnetic properties. Therefore, they are widely used in modern electronics. These compounds generally exhibit magnetic properties at low temperatures. However, there are also manganites that have magnetic properties at room temperature [6,7]. It has been established that $La_{1-x}Ba_xMnO_3$ compounds have ferromagnetic properties at room temperature [8]. Their crystal structure, magnetic and thermal properties have been studied by X-ray diffraction, neutron diffraction, and differential scanning calorimetry [9, 10]. It has been established that these compounds have a highly symmetrical cubic crystal structure. At high temperatures, a structural phase transition does not occur and certain thermal effects are observed only due to the influence of water molecules present in the composition. Complex oxides $La_{0.97}Ba_{0.03}MnO_3$, $La_{0.73}Ba_{0.27}MnO_3$ and $La_{0.5}Ba_{0.5}MnO_3$ were synthesized and their structural properties were studied. The studies were carried out using XRD and SEM methods at room temperature. It has been established that with partial substitution of La→Ba in these compounds, the ideal perovskite structure is not violated, and the cubic crystal structure with space group Pm-3m is preserved. As a result of SEM studies, it was established that the crystallite size in $La_xBa_{1-x}MnO_3$ solid solutions is in the range d = 2–10 μm.

Although the structure, thermal and magnetic properties of the $La_xBa_{1-x}MnO_3$ system have been studied, its electrical properties have not been sufficiently studied. Studying the electrical properties of these materials under the influence of temperature further expands the possibilities of their use in modern electronics. Therefore, it is important to study these properties. In this work, a comparative study of the dielectric and electrical properties of the $La_{0.73}Ba_{0.27}MnO_3$ compound at high temperatures was carried out.

E-mail: sakin@jinr.ru
http://dx.doi.org/10.5510/OGP20230400931

2. Experimental

2.1. Synthesis of samples

The $La_{0.73}Ba_{0.27}MnO_3$ compound was synthesized from high-purity La_2O_3, Mn_2O_3 and $BaCO_3$ oxides using a standard procedure. First, Cu and carbon dioxide were removed from lanthanum oxide by heating La_2O_3 oxide in open air at 1000 °C for 2 hours. At the second stage, the oxides were mixed in the appropriate amount and pressed to a size of 20 mm. The prepared material was heated in open air at a temperature of 1000 °C for 5 hours, while the barium carbonate did not completely decompose. The sample was ground and mixed into a powder. At the last stage, the sample was placed on a platinum base and heated at a temperature of 1550 °C for 10 hours. After completion of the synthesis process, the sample was cooled at a rate of 80 °C/h. The structure of the resulting polycrystals was analyzed by X-ray diffraction.

2.2. Study of dielectric and electrical properties

The geometric parameters of the $La_{0.73}Ba_{0.27}MnO_3$ compound used in the experiments were taken equal to 5×3×3 mm^3. When studying this material, silver electrodes were used as electrical contacts. Experiments were carried out on an MNIPI E7-25 impedance analyzer in the frequency range $f = 20–10^6$ Hz and temperature range $T = 25–225$ °C.

3. Results and discussion

The dielectric and electrical properties of the $La_{0.73}Ba_{0.27}MnO_3$ compound were studied in the frequency range $f = 25$ Hz – 1 MHs and temperature range $T = 25–225$ °C. The frequency and temperature dependences of the real and imaginary parts of the dielectric constant are shown in figures 1 and 2 respectively. No change in the true part of the dielectric constant under the influence of frequency was observed. However, a decrease in the imaginary part was observed in the frequency dependence of the dielectric constant (fig. 1). Stabilization was observed in the imaginary part of the dielectric constant after a frequency value of approximately $f \sim 5\times10^3$ Hz. This effect is explained by a change in the concentration of charge carriers inside the material. As the frequency of the external electric field increases, charge carriers at deeper levels within the material begin to become active. As a result, the imaginary part of the dielectric constant, which characterizes dielectric losses, decreases in proportion to the frequency in the range $f < 5\times10^3$ Hz. However, in the frequency range $f > 5\times10^3$ Hz, the loss coefficient decreases or is not observed due to an increase in the concentration of charge carriers in the $La_{0.73}Ba_{0.27}MnO_3$ compound.

In the real part of the temperature dependence of the dielectric constant of the $La_{0.73}Ba_{0.27}MnO_3$ compound, practically no changes were observed. However, interesting effects were observed in the imaginary part. In general, three regions are found in the imaginary part of the dielectric constant: $T < 50$ °C, 50 °C < T < 140 °C and $T > 140$ °C. In the first approach, the observed increase in the imaginary part of the dielectric constant in the temperature range $T < 50$ °C can be associated with the presence of additional impurities or radicals inside the sample (fig. 2). Thus, under the influence of temperature, radicals or OH groups leave the sample, as a result of which an increase in the imaginary part of the dielectric constant is observed in the range $T < 50$ °C. In the temperature range 50 °C < T < 140 °C, a monotonic increase in the imaginary part of the dielectric constant was observed, which is explained by the presence of free charge carriers at a deep level of the sample. At temperatures $T > 140$ °C, a decrease in the imaginary part of the dielectric constant was observed. This case characterizes the semiconductor-metal phase transition. However, to clarify this phase transition, it is important to obtain the temperature dependences of dielectric losses and electrical conductivity.

To clarify the semiconductor-metal phase transition in the $La_{0.73}Ba_{0.27}MnO_3$ compound, frequency and temperature dependences of dielectric losses were obtained. As can be seen from figure 3, an increase in dielectric losses was observed in the frequency range $f < 10^3$ Hz. With a subsequent increase in frequency, a decrease in dielectric losses was observed. The temperature dependence of dielectric losses is presented in figure 4. From the dependence it is clear that dielectric losses are almost directly proportional to temperature. The metal-semiconductor transition is possible at T = 140 °C. Because with increasing temperature, the magnitude of dielectric losses first stabilizes and then decreases. However, it is necessary to analyze the temperature dependence of electrical conductivity in order to form a more accurate opinion about this.

To clarify the semiconductor-metal phase transition in the $La_{0.73}Ba_{0.27}MnO_3$ compound, the frequency and temperature dependences of the electrical conductivity were

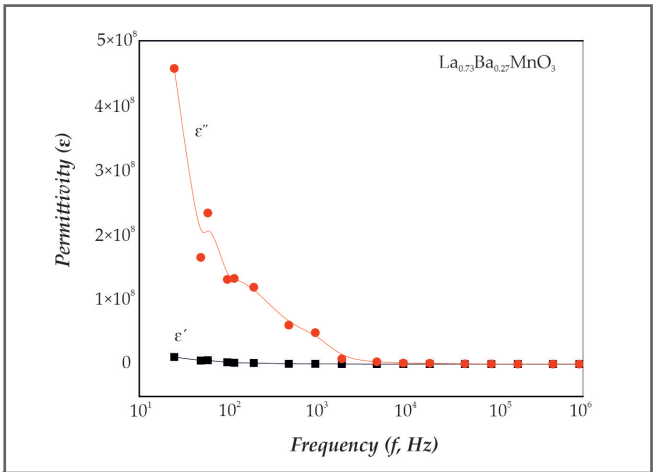

Fig. 1. Frequency dependence of the dielectric constant of the $La_{0.73}Ba_{0.27}MnO_3$ compound

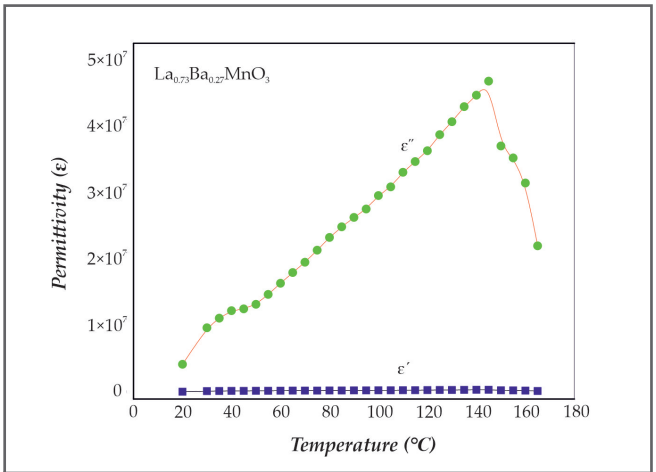

Fig. 2. Temperature dependence of the dielectric constant of the $La_{0.73}Ba_{0.27}MnO_3$ compound

obtained. In figure 5 shows the frequency dependence of electrical conductivity.

In the $La_{0.73}Ba_{0.27}MnO_3$ compound, chaos was observed at frequencies below the frequency dependence of the real part of the electrical conductivity. However, a different situation was observed in the frequency dependence of the imaginary part of the electrical conductivity. So, in this dependence, the electrical conductivity is practically constant in the frequency range $f < 5\times10^5$ Hz. However, starting from a frequency $f > 5\times10^5$ Hz, the electrical conductivity increased in proportion to the frequency. This can be explained by additional charge carriers, which begin to actively participate in conduction at high frequencies. Thus, the numerical value of electrical conductivity increased as a result of the participation of charge carriers in the conduction process at deeper levels under the influence of an external electric field. On the other hand, similar cases were observed in the temperature dependences of electrical conductivity and dielectric constant. In figure 6 shows the temperature dependence of electrical conductivity.

In the $La_{0.73}Ba_{0.27}MnO_3$ compound, no chaos was observed in the temperature dependences of electrical conductivity (fig. 6). In a general approach, we can say that the semiconductor-metal transition was observed in the temperature region $T = 140$ °C. Thus, in the temperature range $T < 140$ °C, the sample behaved like a semiconductor. The electrical conductivity of the sample increased with increasing temperature. At temperatures $T > 140$ °C, the $La_{0.73}Ba_{0.27}MnO_3$ compound behaves like a metal. In other words, at temperatures $T > 140$ °C, the electrical conductivity of the sample decreased with increasing temperature.

When analyzing the results obtained from studying the dielectric constant, dielectric loss and electrical conductivity of the $La_{0.73}Ba_{0.27}MnO_3$ compound under the influence of frequency and temperature, it was found that this compound has semiconductor properties characteristic of perovskite oxides [11-14]. In addition to the presence of semiconductor properties under normal conditions, the mechanism of formation of free charge carriers under external influences occurred according to the regularity of semiconductors [15-18]. It is known that semiconductors are the most widely used materials in modern electronics. Therefore, a lot of research is being conducted in the direction of obtaining new semiconductors, studying their structure and electrical properties [19-21]. The main advantage of the materials and results obtained in this work is that these materials are complex oxides. Compared to non-oxide materials, these materials are able to retain their properties for a longer time, and converters made from them have the ability to operate for a long time.

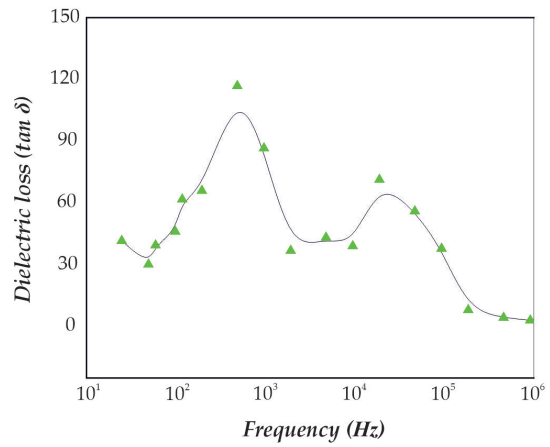

Fig. 3. Frequency dependence of dielectric losses of the $La_{0.73}Ba_{0.27}MnO_3$ compound

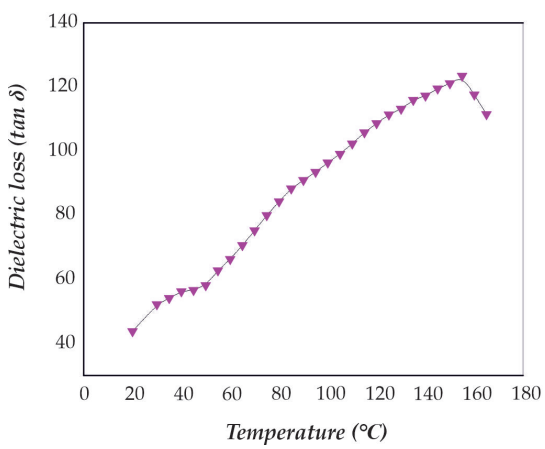

Fig. 4. Temperature dependence of dielectric losses of the $La_{0.73}Ba_{0.27}MnO_3$ compound

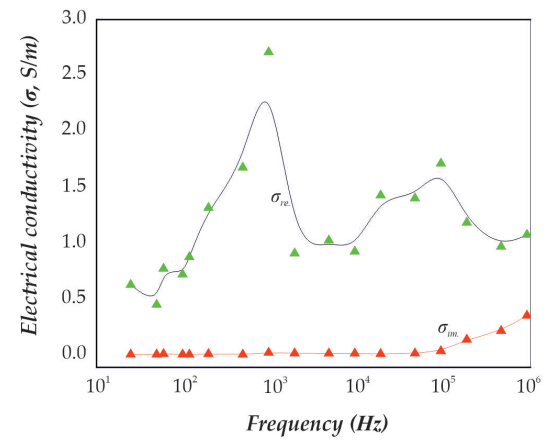

Fig. 5. Frequency dependences of the electrical onductivity of the $La_{0.73}Ba_{0.27}MnO_3$ compound

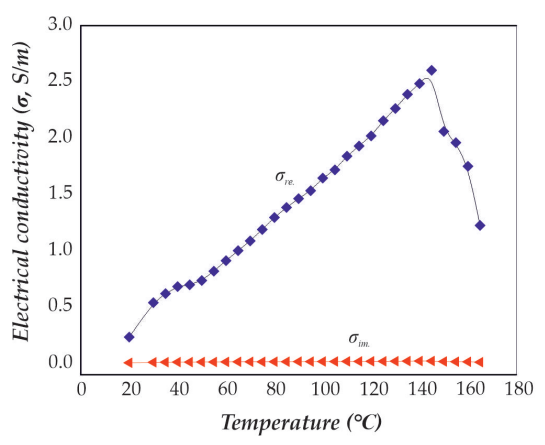

Fig. 6. Temperature dependences of the electrical conductivity of the $La_{0.73}Ba_{0.27}MnO_3$ compound

Conclusion

As a result of the analyses, it turned out that with increasing frequency of the electric field, charge carriers at deeper levels inside the material begin to become active. In the general approach, randomness was observed in the temperature dependences of dielectric constant, dielectric losses and electrical conductivity. This observed randomness was attributed to suspended OH groups interacting with atoms within the sample. It was noted that under the influence of temperature, OH groups with different binding energies with the sample under study begin to leave the atoms in parts depending on the binding energy, which leads to the observation of such waves at different temperatures. At a temperature T = 140 °C, a resonance state with a probable semiconductor-metal phase transition was observed in the $La_{0.73}Ba_{0.27}MnO_3$ compound.

References

1. Dang, N. T., Kozlenko, D. P., Kichanov, S. E., et al. (2017). Revealing the formation mechanism and effect of pressure on the magnetic order of multiferroic $BiMn_2O_5$ through neutron powder diffraction. *Journal of Electronic Materials*, 46, 3373-3380.

2. Jabarov, S. H., Ibrahimova, S. I., Hajiyeva, F. V., et al. (2022). Structural, vibrational, and dielectric properties of $CuInZnSe_3$ chalcogenide compound. *Arabian Journal for Science and Engineering*, 47(6), 7817-7823.

3. Alekperov, A. S., Dashdemirov, A. O., Shumskaya, A. E., Jabarov, S. H. (2021). High-temperature exciton photoconductivity of $Ge_{1-x}Nd_xS$ crystals. *Crystallography Reports*, 66, 1322-1327.

4. Agamirzayeva, G. M., Huseynov, G. G., Aliyev, Y. I., et al. (2023). Crystal structure and magnetıc properties of the compound $Cu_3Fe_{0.5}Se_2$. *Advanced Physical Research*, 5(1), 19-25.

5. Jabarov, S. H., Aliyev, Y. I., Ilyasli, T. M., et al. (2021). AgCuS compound as a thermodynamic system under the influence of gamma rays. *Integrated Ferroelectrics*, 221, 180-185.

6. Dang, N. T., Zakhvalinskii, V. S., Kozlenko, D. P., et al. (2018). Effect of Fe doping on structure, magnetic and electrical properties $La_{0.7}Ca_{0.3}Mn_{0.5}Fe_{0.5}O_3$ manganite. *Ceramics International*, 44(13), 14974-14979.

7. Trukhanov, S. V., Trukhanov, A. V., Dang, N. T., et al. (2018). Magnetotransport properties and phase separation in iron substituted lanthanum-calcium manganite. *Materials Research Express*, 5(8), 086108.

8. Trukhanov, S. V. (2003). Magnetic and magnetotransport properties of $La_{1-x}Ba_xMnO_{3-x/2}$ perovskite manganites. *Journal of Materials Chemistry*, 13(2), 347-352.

9. Nabiyeva, A. Kh., Jabarov, S. H., Trukhanov, S. V.,et al. (2023). XRD and SEM analyses of structural properties of $La_xBa_{1-x}MnO_3$ solid solutions. *International Journal of Modern Physics B*, 37, 2450327.

10. Hashimov, R. F., Mikailzade, F. A., Trukhanov, S. V., et al. (2019). Structure and thermal analysis of $Ba_{0.5}La_{0.5}MnO_3$ polycrystalline powder. *International Journal of Modern Physics B*, 33, 1950244.

11. Ertuğ, B. (2013). The overview of the electrical properties of barium titanate. *American Journal of Engineering Research (AJER)*, 02(08), 01-07.

12. Hayat, Kh., Nadeem, M., Javid Iqbal, M., et al. (2014). Analysis of electro-active regions and conductivity of $BaMnO_3$ ceramic by impedance spectroscopy. *Applied Physics A*, 115, 1281-1289.

13. Rached, A., Wederni, M. A., Khirouni, K., et al. (2021). Structural, optical and electrical properties of barium titanate. *Materials Chemistry and Physics*, 267, 124600.

14. Panwar, N. S., Semwal, B. S. (2011). Study of electrical conductivity of barium titanate ceramics. *Ferroelectrics*, 115, 1-6.

15. Jabarov, S. H., Ibrahimova, S. I., Hajiyeva, F. V., et al. (2022). Structural, vibrational, and dielectric properties of $CuInZnSe_3$ chalcogenide compound. *Arabian Journal for Science and Engineering*, 47(6), 7817-7823.

16. Akkad, F. El., Mansour, B., Hendeya, T. (1981). Electrical and thermoelectric properties of Cu_2Se and Cu_2S. *Materials Research Bulletin*, 16(5), 535-539.

17. El-Nahass, M. M., Sallam, M. M., Rahman, S. A., Ibrahim, E. M. (2006). Optical, electrical conduction and dielectric properties of $TlGaSe_2$ layered single crystal. *Solid State Sciences*, 8(5), 488-499.

18. Mehdiyeva, R. Z., Mammadov, A. I., Jabarov, S. H., et al. (2015). Dielectric and ferroelectric properties of $K_2Pb4Nb_{10}O_{30}$–$Na_2Pb4Nb_{10}O_{30}$–$K_6W_4Nb_6O_{30}$ across morphotropic phase region. *Journal of Alloys and Compounds*, 645, 496-503.

19. Mursakulov, N. N., Abdulzade, N. N., Jabarov, S. H., Sabzalieva, Ch. E. (2022). Investigation of $CuIn_{1-x}Ga_xSe_2$ thin films for solar cells obtained by the magnetron sputtering method from two magnetrons shifted to each other. *New Materials, Compounds and Applications*, 6(2), 140-147.

20. Aliyeva, N. A., Aliyev, Y. I., Abiyev, A. S. (2022). Study of thermal properties of $Cu_4Se_{1.5}Te_{0.5}$ and $Cu_4Te_{1.5}Se_{0.5}$ compounds by dıfferentıal thermal analysıs. *Advanced Physical Research*, 4(2), 94-99.

21. Ilyasly, T., Gahramanova, G., Abbasova, R., et al. (2021). Investıgatıon of the electrıcal properties of glasses of Tm-As-S and Tm-As-Se systems. *New Materials, Compounds and Applications*, 5(3), 227-234.

Диэлектрические и электрические свойства соединения $La_{0.73}Ba_{0.27}MnO_3$ при высоких температурах

С. Г. Джабаров[1], А. Х. Набиева[1], А. В. Труханов[2,3], С. В. Труханов[2,3], Г. Дж. Гусейнов[1], Ю. И. Алыев[4,5]

[1]Институт физики Министерства науки и образования Азербайджанской Республики, Баку, Азербайджан
[2]Научно-практический центр материаловедения Национальной академии наук Беларуси, Минск, Беларусь
[3]Национальный исследовательский технологический университет «МИСиС», Москва, Россия
[4]Азербайджанский государственный педагогический университет, Баку, Азербайджан
[5]Западно-Каспийский университет, Баку, Азербайджан

Реферат

В представленной работе проведены сравнительные исследования диэлектрических и электрических свойств соединений $La_{0.73}Ba_{0.27}MnO_3$ в интервале температур T = 25–225 °C и диапазоне частот f = 20–10^6 Гц. Получены температурные и частотные зависимости действительной и мнимой частей диэлектрической проницаемости, угла диэлектрических потерь, диэлектрической проницаемости и электропроводности. Обнаружено, что это соединение обладает полупроводниковыми свойствами при нормальных условиях. Установлено, что с увеличением температуры и частоты электропроводность в этих соединениях увеличивается. Этот эффект объясняется высвобождением носителей заряда на глубоких уровнях за счет тепловой энергии. При температуре T = 140 °C в этом соединении обнаружен фазовый переход полупроводник-металл. Определены значения физических параметров для каждой из полупроводниковой и металлической фаз. Возникновение фазового перехода объясняется механизмом активации носителей заряда за счет тепловой энергии.

Ключевые слова: перовскит; диэлектрические свойства; электрические свойства; $La_{1-x}Ba_xMnO_3$.

Yüksək temperaturlarda $La_{0.73}Ba_{0.27}MnO_3$ birləşməsinin dielektrik və elektrik xassələri

S. H. Cabarov[1], A. X. Nəbiyeva[1], A. V. Truxanov[2,3], S. V. Truxanov[2,3], H. C. Hüseynov[1], Y. I. Alıyev[4,5]

[1]Azərbaycan Respublikasının Elm və Təhsil Nazirliyinin Fizika İnstitutu, Bakı, Azərbaycan
[2]Belarusiya Milli Elmlər Akademiyası, Materialların Elmi-Praktiki Tədqiqi Mərkəzi, Minsk, Belarusiya
[3]MİSiS Elm və Texnologiya Milli Universiteti, Moskva, Rusiya
[4]Azərbaycan Dövlət Pedaqoji Universiteti, Bakı, Azərbaycan
[5]Qərbi Kaspi Universiteti, Bakı, Azərbaycan

Xülasə

Təqdim olunan işdə $La_{0.73}Ba_{0.27}MnO_3$ birləşmələrinin dielektik və elektrik xassələri T = 25–225 °C temperatur və f = 20–10^6 Hs tezlik intelvalında müqayisəli şəkildə tədqiq edilmişdir. Dielektrik sabitinin həqiqi ve xəyali hissələrinin, dielektrik itgi bucağının, dielektrik nüfuzluğunun elektrik keçiriciliyinin temperatur və tezlik asılılıqları alınmışdır. Müəyyən edilmişdir ki, temperaturun və tezliyin qiyməti artdıqca bu birləşmələrdə elektrik keçiriciliyinin qiyməti artır. Bu effekt, istilik enerjisi hesabına dərin səviyyələrdə olan yükdaşıyıcıların sərbəst hala keçməsi ilə izah edilmişdir. Temperaturun T = 140 °C qiymətində bu birləşmədə yarımkeçirici-metal faza keçidi aşkar edilmişdir.

Açar sözlər: perovskit; dielektrik xassələri; elektrik xassələri; $La_{1-x}Ba_xMnO_3$.