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Development of Perovskite Manganate-Based Materials as Microwave Absorbers (A Literature Study)

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Abstract. The 5.0 industrial revolution has led to the rapid development of digital devices and radar detection technology. Electromagnetic (EM) radiation generated by digital devices, such as smartphones, computers, and airplanes, is proven to cause great harm to human health. Manganese perovskite is one material that can produce changes such as its crystal structure, electron transfer, electrical properties, and magnetic properties. Doping applied to manganese perovskite-based materials can induce phenomena such as Colossal Magnetoresistance (CMR) and Magnetocaloric Effect (MCE), giving manganese perovskite-based materials great potential to be used as microwave absorbers. Through this article, the development of various manganese perovskite-based materials as microwave absorbers will be reviewed and summarized. Synthesis methods and microwave absorption mechanisms will also be reviewed. This article focuses on the doping of A-site and B-site manganese perovskite-based materials and their performance in absorbing microwaves. Hopefully, this article can be one of the guidelines for designing new manganese perovskite-based materials, to be applied as microwave absorbers.

Keywords: *Perovskite manganate, microwave absorbers, mechanism, synthesis, doping.*
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INTRODUCTION

The industrial revolution 5.0 causes the development of digital devices and radar detection technology to develop rapidly. This can make human life more comfortable, however, behind all that there is a concern that can threaten human health [1]. Electromagnetic (EM) radiation generated by digital devices, such as smartphones, computers, and airplanes, has been proven to cause great harm to human health. This radiation can heat up human cells or disrupt the intrinsic EM field of the human body, thus adversely affecting human health [2].

Therefore, developing various materials as microwave absorbers is very important. The main indicators that a material can be used as a good microwave absorber are high reflection loss (R_L), thin thickness, wide bandwidth, and low density. Some of these properties must be possessed by a material so that it has the potential to absorb most microwaves and can be used practically in many fields. These properties can be achieved by develop the size, shape, internal structure, composition, and synthesis method [2].

Recently, many materials have been designed as microwave absorbers in various types of materials, such as nanometer-scale materials, ferrites, conductive polymers, polycrystalline iron fibers and crystalline materials [3]. In general, microwave absorbing materials can be classified into magnetic type and dielectric type according to the loss mechanism. Among these absorbers, perovskite oxides have attracted wide attention among researchers due to their unique crystal structure and mixed ionic electronic conductivity, especially in manganate-based perovskite oxides [4].

Manganate perovskite is one of the materials that can produce changes in physical phenomena in a material, such as changes in crystal structure, electron transfer, electrical properties, and magnetic properties [5]. Manganate perovskite has the general formula $RE_{1-x}A_xMnO_3$, where RE is a rare earth metal ion (La^{3+}, Nd^{3+}, Pr^{3+}) and A is a divalent ion (Sr^{2+}, Ba^{2+}, Ca^{2+}). Doping applied to manganate perovskite-based materials can cause various interesting phenomena such as Colossal Magnetoresistance (CMR) and Magnetocaloric Effect (MCE). The presence of these phenomena makes manganese perovskite-based materials have great potential to be used as microwave absorbers [6].

Many researchers have reported the results of designing manganese perovskite-based materials as microwave absorbers. Based on this, it is necessary to review and summarize these research results. In this article, the mechanism of microwave absorption will be reviewed, then continued with a summary and review of the development of manganese perovskite-based material engineering as a microwave absorber starts from the synthesis method to doping on the material. Hopefully, this article can be one of the guidelines for designing new manganese perovskite-based materials, to be applied as microwave absorbers.

MICROWAVE ABSORPTION MECHANISM

According to the microwave absorption theory, the incident microwave can be divided into three parts when the incident wave hits the absorbing material, namely reflection, absorption, and transmission [2]. When the wave comes to the absorbing material, there are three possibilities: the wave can be absorbed by the material (absorption), reflected (reflection), or transmitted (transmission). In this case, the entire wave is completely absorbed by the microwave absorbing material, and nothing is transmitted. To find out what percentage of the wave is absorbed by the microwave absorbing material, we can calculate the reflection loss (R_L). This reflection loss value will reflect the material's ability to absorb microwave energy [7], [8].

Microwave absorption is characterized by its two main electromagnetic properties. Dielectric loss is the first property and magnetic loss is the second property [9]. Dielectric Loss represents the electronic characteristics between the Electric field of electromagnetic radiation resulting in reflection loss. While magnetic loss represents the characteristics of the magnetic interaction between the material and its electromagnetic waves [10].

The ability of microwave absorbing materials to absorb microwave energy can be determined by calculating the amount of reflection loss (R_L). This value will describe the material's ability to absorb energy [7], [8]. The smaller the RL value, the greater the percentage of waves absorbed by the material. Based on theory, reflection loss can be defined by Eq. 1 and Eq. 2:

$$R_L(dB) = 20 \log \left| \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \right| \quad (1)$$

$$Z_{in} = \left(\frac{\mu_r}{\varepsilon_r}\right)^{\frac{1}{2}} \tanh \left[j \left(\frac{2\pi f d}{c}\right) (\mu_r \varepsilon_r)^{\frac{1}{2}} \right] \quad (2)$$

where Z_{in} is the impedance of the absorber material, Z_0 is the impedance of electromagnetic waves in air, μ_r is the relative permeability of the material, ε_r is the relative permittivity of the material, f is the frequency, c is the speed of light, and d is the thickness of the absorption field of the material [1].

The parameters ε_r and μ_r are expressed in the equations below by considering the real and imaginary components of permittivity $(\varepsilon', \varepsilon'')$ and real and imaginary permeability (μ', μ'').

$$\varepsilon_r = \varepsilon' + j\varepsilon" \quad (3)$$

$$\mu_r = \mu' + j\mu" \quad (4)$$

The real part of the permittivity (ε') indicates the ability of the material to store electrical energy, while the imaginary part (ε'') indicates the ability of the material to release electrical energy. The same principle also applies to permeability, the real part of the permeability (μ') states the ability of the material to store magnetic fields, while the imaginary part (μ'') states the ability of the material to absorb magnetic fields [11]. The results of microwave absorption on manganese perovskite can vary, this is because the structure, doping, composition, and synthesis methods used in each material differ from one another. Discussion of the structure, doping, composition, synthesis method, and microwave absorption properties of some of the research results that have been reported, are exposed after this.

SYNTHESIS METHOD

As mentioned before, the synthesis method is one way to develop manganese perovskite-based materials for microwave absorbers. The synthesis method determines the physicochemical properties of the material. This will affect the material's ability to absorb microwaves. Some methods that are commonly used to synthesize manganate perovskite-based materials are solid reaction method, sol-gel method, and co-precipitation method [4].

Solid-State Reaction Method

The solid reaction method is a conventional method to synthesize manganate perovskite-based materials, the process of this method is fairly simple. In general, the main compounds of the related elements (especially oxide-based ones) are weighed

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according to the stoichiometric ratio. Then the alloy of the related compounds will be calcined at high temperature after mixing, mixing is usually assisted by high-energy ball milling. The advantage of this method is that there are no impurity phases and the doping characteristics are easy to control. The disadvantage of this method is that it is difficult to obtain a single phase. This will result in grain size that does not match the specific surface area and inadequate absorption strength. The high energy consumption factor and long reaction time are also disadvantages of this method [4].

S. Saptari et al [12]–[14] synthesized the materials $La_{0.67}Ba_{0.33}Mn_{1-x}Ni_xO_3$ (x = 0; 0.02; 0.04; 0.06), $La_{0.67}Ba_{0.33}Mn_{1-x}Ti_xO_3$ (x = 0; 0.02; 0.04; 0.06), and $La_{0.67}Ba_{0.33}Mn_{1-y}Ni_{y/2}Ti_{y/2}O_3$ (y = 0.02; 0.04; 0.06) using the solid recitation method. In $La_{0.67}Ba_{0.33}Mn_{1-x}Ni_xO_3$ (x = 0; 0.02; 0.04; 0.06), the constituent compounds were mixed according to the stoichiometric ratio for 25 hours, then calcined at 800℃ for 10 hours, and sintered at 1200℃ for 2 hours. The results show that for the price of x = 0-0.04 the sample has a single phase with a monoclinic crystal structure and space group I 1 2/c 1, while for the value of x = 0.06 the sample has a dual phase, namely $La_{0.67}Ba_{0.33}Mn_{1-x}Ni_xO3$ with a monoclinic crystal structure and $BaMnO_3$ with a hexagonal crystal structure. The XRD pattern of $La_{0.67}Ba_{0.33}Mn_{1-x}Ni_xO_3$ (x = 0; 0.02; 0.04; 0.06) sample can be seen in Figure 1.

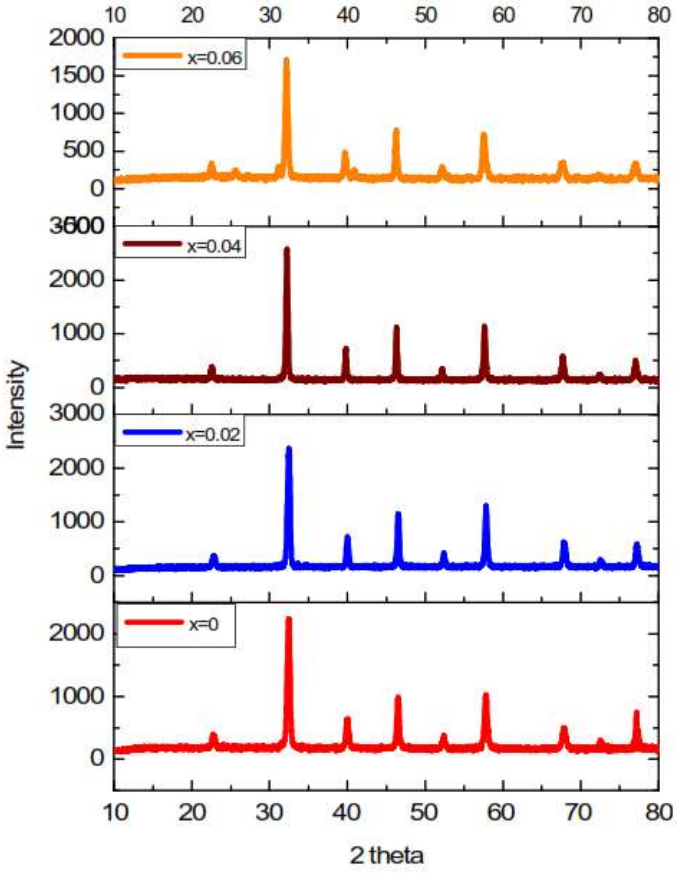

Figure 1 XRD pattern of $La_{0.67}Ba_{0.33}Mn_{1-x}Ni_xO_3$ sample [12].

In $La_{0.67}Ba_{0.33}Mn_{1-x}Ti_xO_3$ material (x = 0; 0.02; 0.04; 0.06), the constituent compounds were mixed according to the stoichiometric ratio for 25 hours using Planetary Ball Milling with a fixed powder/ball ratio of 1:10. The samples were then calcined at 800℃ for 10 hours and sintered at 1200℃ for 2 hours. The results show that the samples have a single

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phase without any impurities for all x values with monoclinic crystal structure and space group I 1 2/c 1. The XRD pattern of $La_{0.67}Ba_{0.33}Mn_{1-x}Ti_xO_3$ sample (x = 0; 0.02; 0.04; 0.06) can be seen in Figure 2.

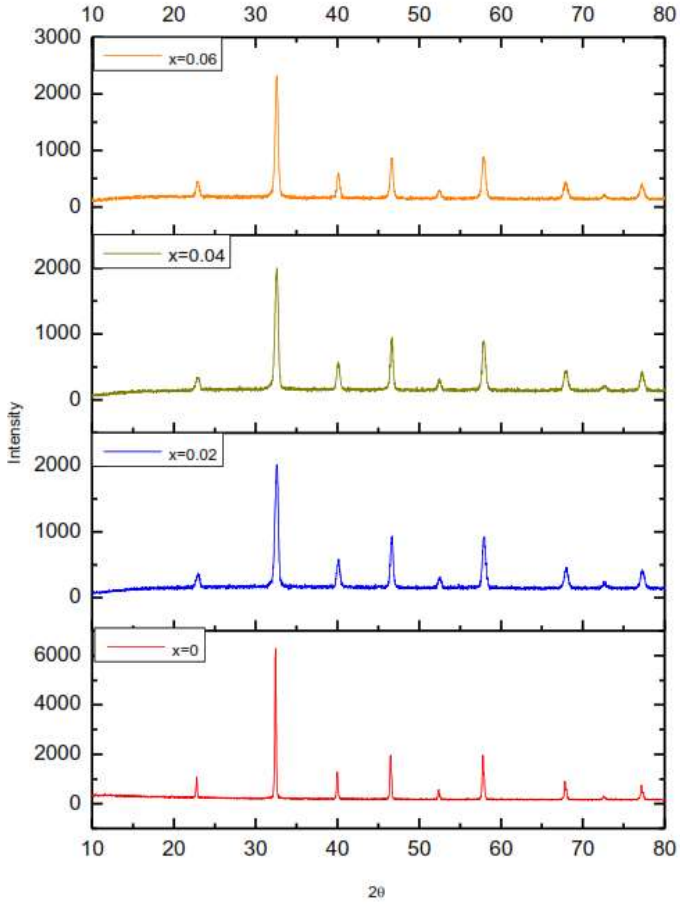

Figure 2 XRD pattern of $La_{0.67}Ba_{0.33}Mn_{1-x}Ti_xO_3$ sample [13].

In $La_{0.67}Ba_{0.33}Mn_{1-y}Ni_{y/2}Ti_{y/2}O_3$ (y = 0.02; 0.04; 0.06), the constituent compounds were mixed according to the stoichiometric ratio for 40 hours using planetary ball milling. The samples were then calcined at 900℃ for 10 hours and sintered at 1200℃ for 10 hours. The results show that the sample has a single phase without any impurities for all x values with monoclinic crystal structure and space group I 1 2/c 1. The XRD pattern of $La_{0.67}Ba_{0.33}Mn_{1-y}Ni_{y/2}Ti_{y/2}O_3$ (y = 0.02; 0.04; 0.06) sample can be seen in Figure 3.

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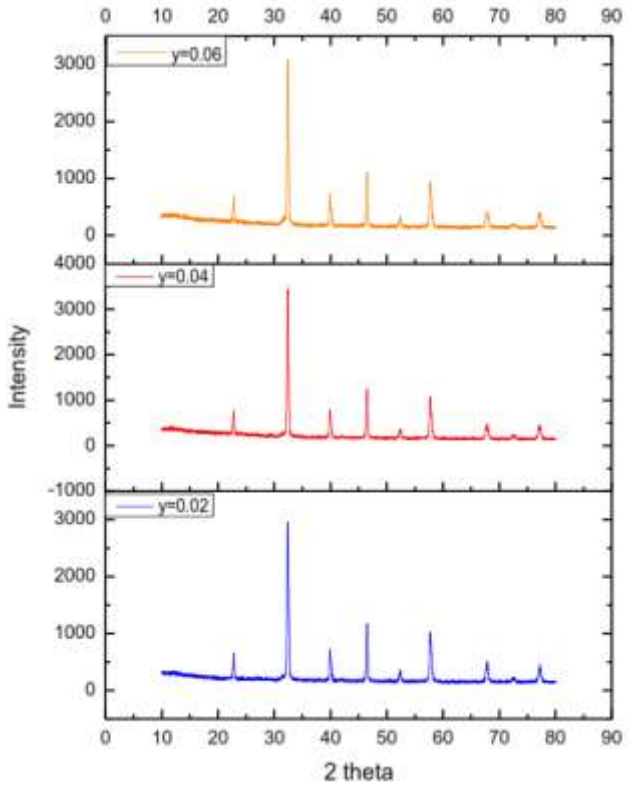

Figure 3 XRD pattern of $La_{0.67}Ba_{0.33}Mn_{1-y}Ni_{y/2}Ti_{y/2}O_3$ sample [14].

S. Zhang et al [15] also synthesized $La_{0.7}Sr_{0.3}MnO_3$ material using the solid reaction method with variations in sintering temperature. The samples were sintered in the temperature range of 900℃-1150℃ with an increase of 50℃ in each sample. The results show that at 900℃ and 950℃ the perovskite phase has not yet formed. The perovskite phase began to form at 1000℃. The XRD pattern of $La_{0.7}Sr_{0.3}MnO_3$ sample can be seen in Figure 4.

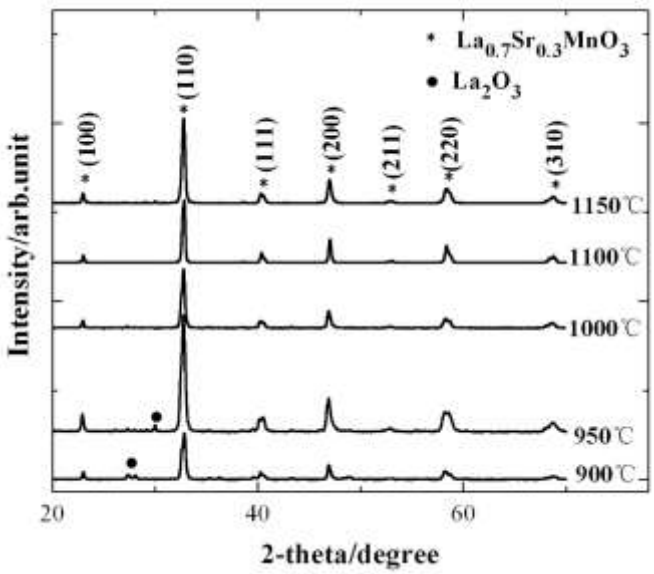

Figure 4 XRD pattern of $La_{0.7}Sr_{0.3}MnO_3$ sample [15].

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Sol-Gel Method

The sol-gel method is one of the most frequently used methods to synthesize manganese perovskite-based materials. In this method, "sol" is first formed by hydrolysis or alcoholization of metal compounds or inorganic metal salts. Afterwards, a "gel" will be obtained through a polycondensation process. The "gel" forming compounds used in this method include citric acid, ethanol, ammonia, polyvinyl acrylate (PVA). This method is often referred to as the citric acid method, as citric acid is commonly used as a ligand in this method. The structure, chemical properties, and particle size of the sample can be adjusted by controlling the sintering temperature. Products produced from this method usually have high purity and uniform particle distribution [4].

J. W. Liu et al [16] synthesized $La_{1-x}Ca_xMnO_3$ (x = 0 - 0.5) material using sol-gel method. All precusors were mixed according to stoichiometric calculations. After forming the gel, the sample was calcined at 800 ℃ for 2 hours. The results show that the sample has a single phase with a perovskite structure. The XRD pattern of $La_{1-x}Ca_xMnO_3$ sample can be seen in Figure 5.

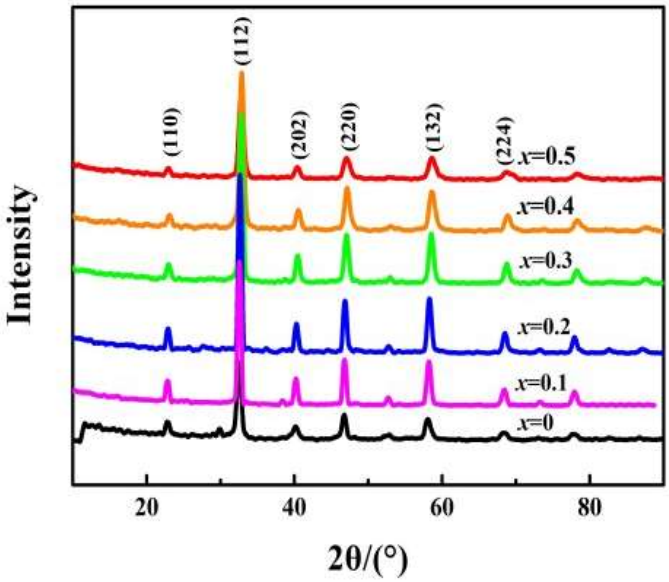

Figure 5 XRD pattern of $La_{1-x}Ca_xMnO_3$ sample [16].

F. Rizky et al [17] synthesized $La_{0.7}Ca_{0.3}Mn_{1-x}Ti_xO_3$ (x = 0; 0.1; 0.2; 0.3) material using sol-gel method. All precursors were mixed according to stoichiometric calculations. After gel formation, the samples were calcined at 600℃ for 6 hours and sintered at 1000℃ for 12 hours. The results show that all samples have a single phase without any impurities. The XRD pattern of $La_{0.7}Ca_{0.3}Mn_{1-x}Ti_xO_3$ sample can be seen in Figure 6.

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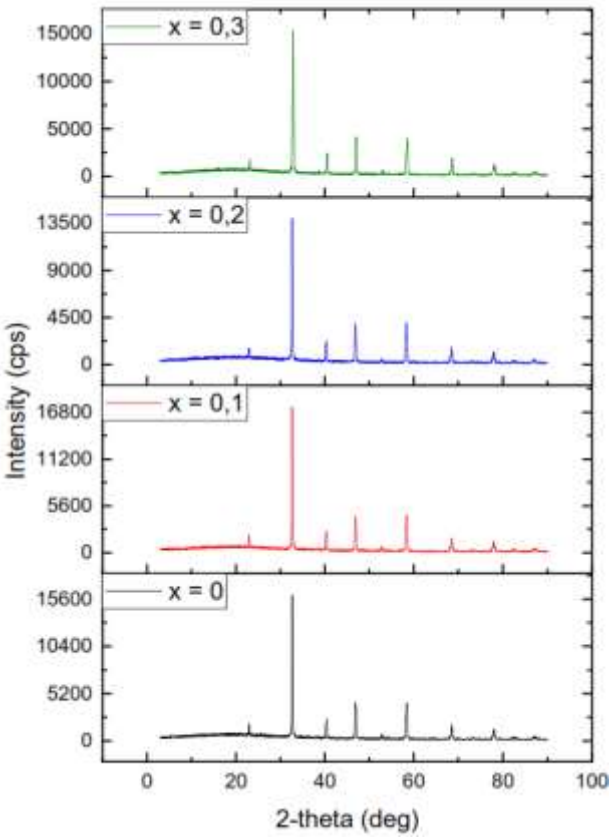

Figure 6 XRD pattern of $La_{0.7}Ca_{0.3}Mn_{1-x}Ti_xO_3$ sample [17].

N. H. Latifah et al [18] synthesized $La_{0.7}Sr_{0.3}Mn_{1-x}(Ni,Ti)_{x/2}O_3$ (x = 0.1; 0.3; 0.5) material using sol-gel method. All precursors were mixed according to the stoichiometric calculation. After gel formation, the samples were calcined at 600℃ for 6 hours and sintered at 1000℃ for 12 hours. The results show that all samples have a single phase without any impurities. The XRD pattern of $La_{0.7}Sr_{0.3}Mn_{1-x}(Ni,Ti)_{x/2}O_3$ sample can be seen in Figure 7.

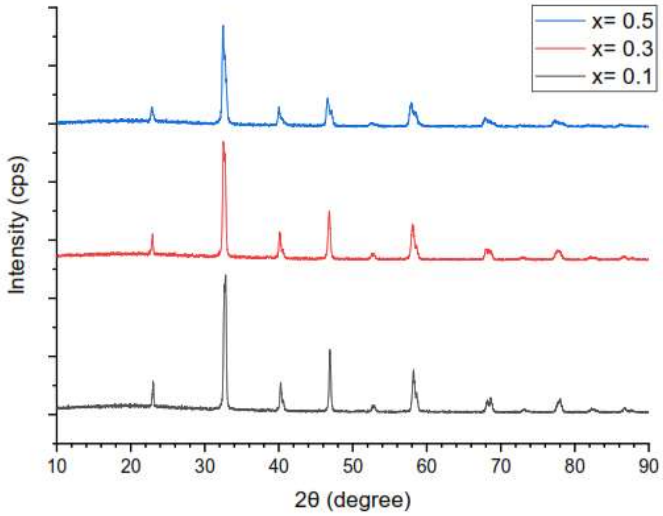

Figure 7 XRD pattern of $La_{0.7}Sr_{0.3}Mn_{1-x}(Ni,Ti)_{x/2}O_3$ sample [18].

Copreticipation Method

In general, the coprecipitation method begins by mixing salt solutions of two or more metals used according to a pre-calculated stoichiometric ratio, the solution is then filtered to obtain the precipitate. Then the precipitate is washed and calcined to obtain the desired perovskite phase. Alkaline earth metals are one of the most commonly used precipitants in synthesizing manganate perovskite-based materials. The advantage of this method lies in the short synthesis cycle. The disadvantage of this method is that the resulting sample is easily agglomerated due to high local concentration when the resulting precipitate is not uniform, this can affect the uniformity of particle size. To overcome these problems, dispersion technology needs to be used to ensure the uniformity of the samples produced from the precursors used, such as ultrasound, microwave, and freeze drying [4].

F. Jiang et al [19] synthesized $La_{0.1}Ca_{0.9}MnO_3$ and $CaMnO_3$ materials using the coprecipitation method. All precursors were mixed according to stoichiometric calculations in solution form. The samples were then dried at 70℃ in a thermoelectric thermostat drying box, then the samples were calcined at 950℃ for 3 hours. The XRD test results show that the samples have a single phase, $La_{0.1}Ca_{0.9}MnO_3$ and $CaMnO_3$, respectively.

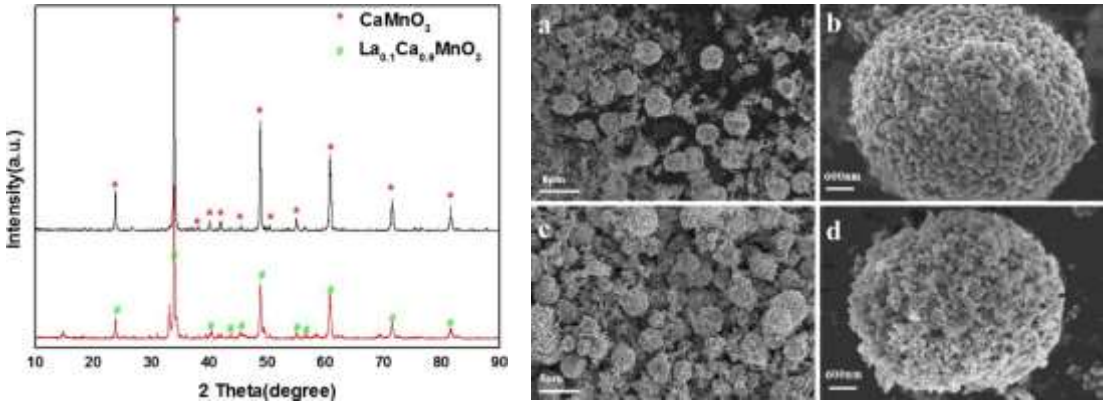

Figure 8 XRD pattern and morphology of $La_{0.1}Ca_{0.9}MnO_3$ and $CaMnO_3$ sample [19].

While the SEM results show that the particles have an irregular granular shape with a size of about 200 nm and a grain size of 4-6 μm.The XRD pattern and morphology of the samples can be seen in Figure 8 and Figure 9.

DEVELOPMENT OF MANGANESE PEROVSKITE AS MICROWAVE ABSORBER

The unique chemical and physical properties of manganese perovskite-based materials such as insulator-metal phase switching that are strongly related to temperature, it causes a phenomenon called the Giant Magnetoresistance Effect. The presence of this phenomenon attracts wide attention in the application of manganese perovskite-based materials as microwave absorbers [4].

Unmodified manganate perovskite-based materials have a weak absorption ability to microwaves, which is related to the limited dielectric, conductive, and magnetic properties that are not suitable. Ions on the A site and B site on manganate perovskite can be substituted with other metal elements. The doping of these ions can change the

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physicochemical properties of a manganate perovskite and cause distortions in the crystal lattice (Jahn-teller effect). Manganate perovskite-based materials are known to have ferromagnetic properties, therefore, doping is generally carried out using metals that have semiconductor conductivity values or conducive metals. As a result, the crystal structure will change from lower to higher symmetry and change the electric dipole moment thus increasing the dielectric loss value [20], [21].

Develop by simply doping ions on the A site and B site is widely researched because it can affect the crystalline degree directly and the Jahn-teller effect occurs, engineering with this formation produces manganate perovskite-based materials that have the ability to absorb microwaves [1], [4]. S. Zhang et al [15] performed Sr^{2+} ion doping on $LaMnO_3$ material into $La_{0.7}Sr_{0.3}MnO_3$ with a sintering temperature variation of 900℃ - 1150℃ to see its absorption performance against microwaves. The results show that $La_{0.7}Sr_{0.3}MnO_3$ material sintered at 1000℃ and 1100℃ has the best absorption performance with values of -10.71 dB at 9.96 GHz and -17.46 dB at 15.87 GHz, respectively. There is a decrease in the absorption value when the sample is sintered at 1150 ℃ to -9.01 dB at a frequency of 12.51 GHz. It can be seen that as the sintering temperature increases, the absorption peak shifts to higher frequencies, then shifts to lower frequencies.

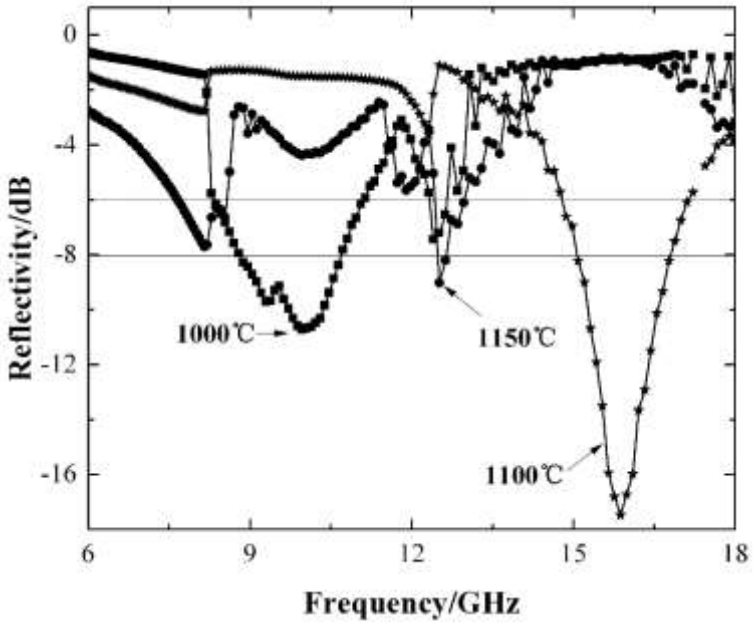

Figure 9 Reflectivity of x with different sintered temperature [15].

The effect of Ba2+ ion doping on the microwave absorption ability of $La_{1-x}Ba_xMnO_3$ (x = 0.1; 0.2; 0.3; 0.4; 0.5) material in nanoparticle form was reported by J. Deng [22]. The results show that the x = 0.2 and 0.3 prices have the best absorption performance with values of -21 dB at 8.4 GHz and -21.4 dB at 7.7 GHz, respectively. It can be seen that the composition of Ba2+ ions can affect the absorption performance of $La_{1-x}Ba_xMnO_3$ material towards microwaves.

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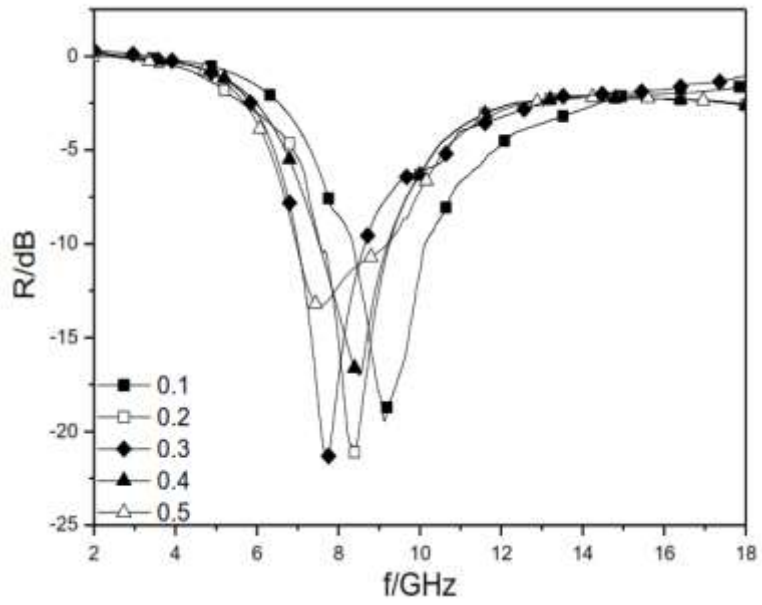

Figure 10 Reflectivity curve $La_{1-x}Ba_xMnO_3$ with different Ba composition [22].

J. W. Liu et al [16] studied the effect of Ca^{2+} ion doping on $La_{1-x}Ca_xMnO_3$ material (x = 0 - 0.5) to see its microwave absorption ability. The sample is made with a thickness of 2 mm, the results show that for the value of x = 0.1 has the largest absorption capability of -42 dB at a frequency of 10.5 GHz with a bandwidth of 3.5 GHz.

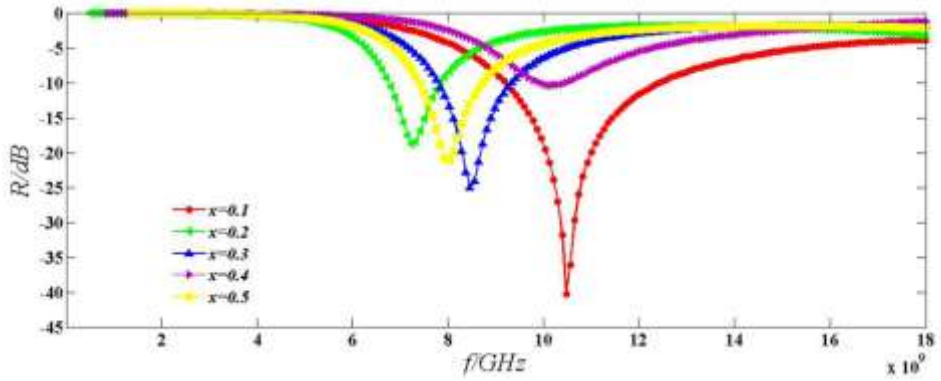

Figure 11 Reflectivity curves of the samples with different doping concentration x (2mm) [16].

F. Jiang et al [19] also studied the microwave absorption performance of $La_{0.1}Ca_{0.9}MnO_3$ and $CaMnO_3$ materials. The samples were made with a thickness of 6 mm. The results show that the $CaMnO_3$ sample has an RL value of -10 dB at 5 GHz and -15 dB at 16.6 GHz. While the $La_{0.1}Ca_{0.9}MnO_3$ sample has the largest RL value of -31 dB at a frequency of 11.5 GHz.

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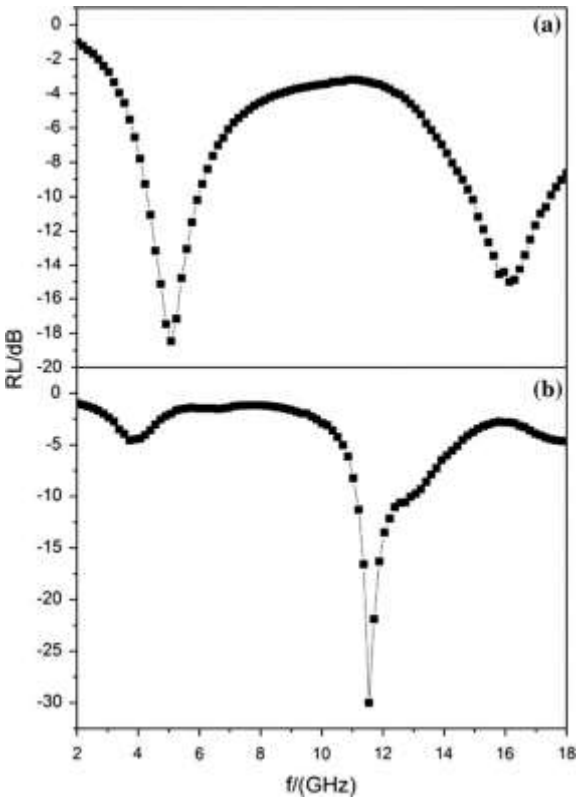


Figure 12 Frequency dependence of reflection loss (RL) for (a) $CaMnO_3$ sample and (b) $La_{0.1}Ca_{0.9}MnO_3$ sample [19].

R. I. Admi et al [23] studied the effect of two ions (Ca^{2+} and Sr^{2+}) doped on the A site of $La_{0.7}(Ca_{1-x}Sr_x)_{0.3}MnO_3$ material (x = 0; 0.1; 0.2; 0.3) with a thickness of 1.5 mm. The results show a decrease in absorption capability as the x value increases. When x = 0, $La_{0.7}(Ca_{1-x}Sr_x)_{0.3}MnO_3$ material has a maximum absorption value of -3.53 dB at a frequency of 10.44 GHz with an absorption ability of 55.64%.

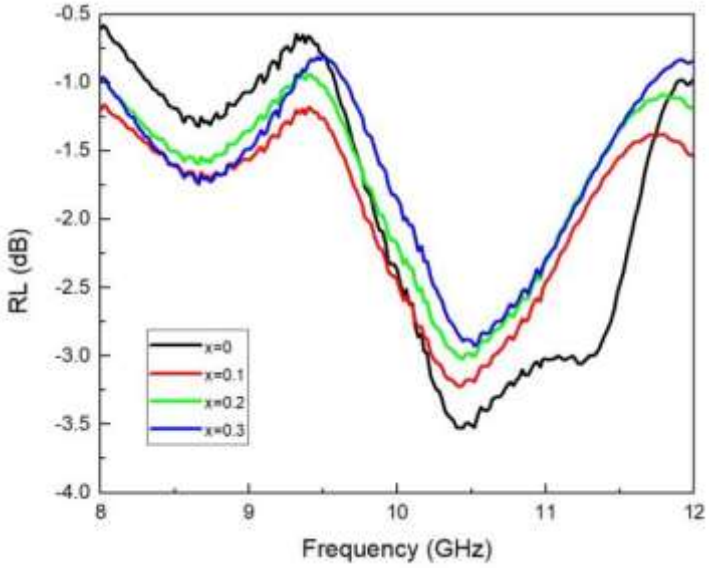


Figure 13 Microwave absorption performance of $La_{0.7}(Ca_{1-x}Sr_x)_{0.3}MnO_3$ [23].

F. Rizky et al [17] studied the effect of Ti^{3+} doping on the microwave absorption performance of $La_{0.7}Ca_{0.3}Mn_{1-x}Ti_xO_3$ material (x = 0; 0.1; 0.2; 0.3). The results show that the x = 0.3 value has the highest absorption value among other x values. The absorption value for x = 0.3 is -10.07202 dB at a frequency of 10.4 GHz with a material absorption capability of 90.16%.

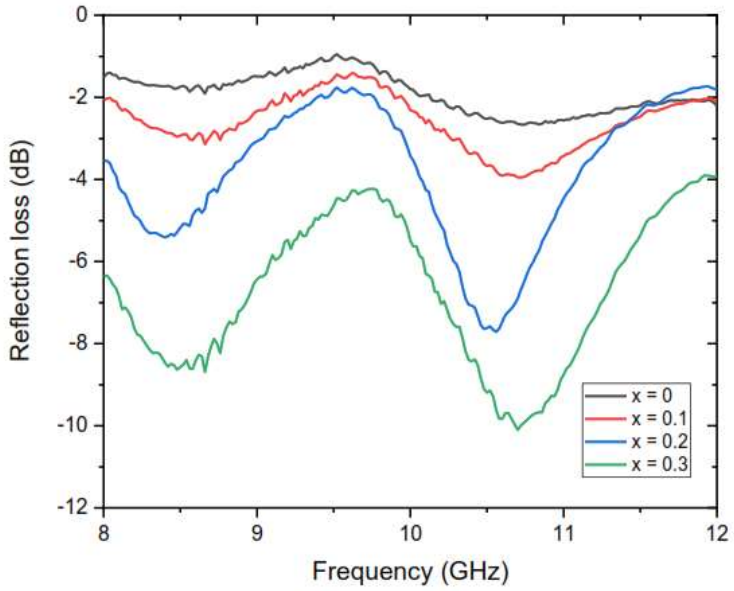
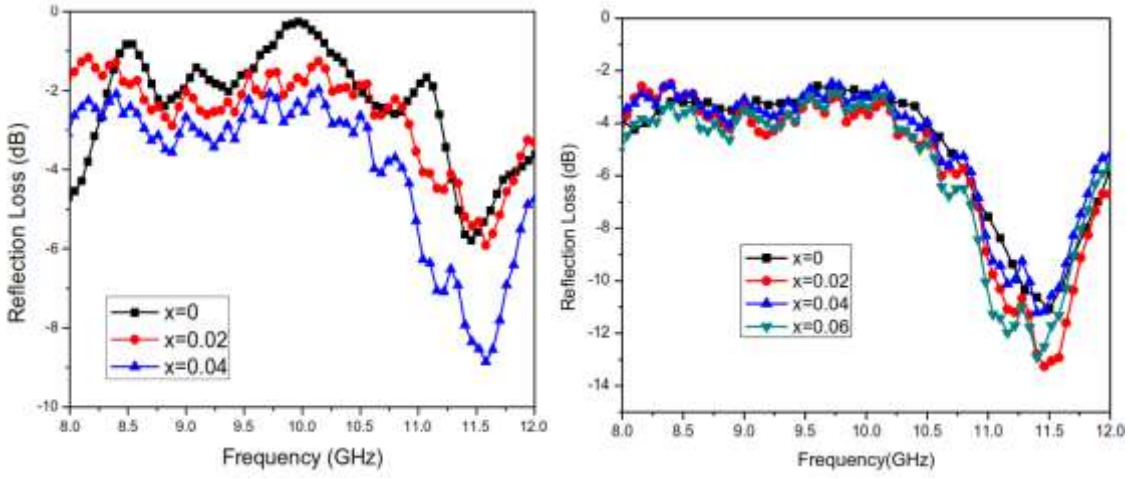


Figure 14 Microwave absorption performance of $La_{0.7}Ca_{0.3}Mn_{1-x}Ti_xO_3$ [17].

S. Saptari et al [12]–[14] studied the effect of Ni^{3+} and Ti^{3+} ion doping on the B site on the microwave absorption performance of $La_{0.67}Ba_{0.33}Mn_{1-x}Ni_xO_3$ (x = 0; 0.02; 0.04; 0.06), $La_{0.67}Ba_{0.33}Mn_{1-x}Ti_xO_3$ (x = 0; 0.02; 0.04; 0.06), and $La_{0.67}Ba_{0.33}Mn_{1-y}Ni_{y/2}Ti_{y/2}O_3$ (y = 0.02; 0.04; 0.06). The largest R_L value of the $La_{0.67}Ba_{0.33}Mn_{1-x}Ni_xO_3$ (x = 0; 0.02; 0.04; 0.06) material is when x = 0.04 at -8.85 dB at a frequency of 11.58 GHz. The largest R_L value of the material $La_{0.67}Ba_{0.33}Mn_{1-x}Ti_xO_3$ (x = 0; 0.02; 0.04; 0.06) is owned when x = 0.02 amounting to -13.26 dB at a frequency of 11.46 GHz. While the largest R_L value in $La_{0.67}Ba_{0.33}Mn_{1-y}Ni_{y/2}Ti_{y/2}O_3$ (y = 0.02; 0.04; 0.06) material is owned when the value of y = 0.06 amounting to -14.30 dB at a frequency of 11.28 GHz.



(a) (b)

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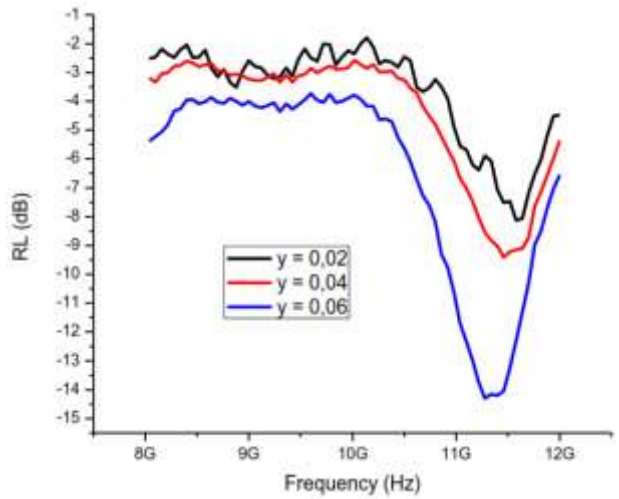

(c)

Figure 15 Reflection loss spectra of (a) $La_{0.67}Ba_{0.33}Mn_{1-x}Ni_xO_3$, (b) $La_{0.67}Ba_{0.33}Mn_{1-x}Ti_xO_3$, and (c) $La_{0.67}Ba_{0.33}Mn_{1-y}Ni_{y/2}Ti_{y/2}O_3$ sample [12]–[14].

N. H. Latifah et al [18] also studied the effect of doping Ni^{3+} and Ti^{3+} ions on the B site on the microwave absorption performance of $La_{0.7}Sr_{0.3}Mn_{1-x}(Ni,Ti)_{x/2}O_3$ material (x = 0.1; 0.3; 0.5). The results show that $La_{0.7}Sr_{0.3}Mn_{1-x}(Ni,Ti)_{x/2}O_3$ material has a maximum absorption value of -11.8 dB at a frequency of 10.58 GHz when x = 0.5, with an absorption capability of 93.39%.

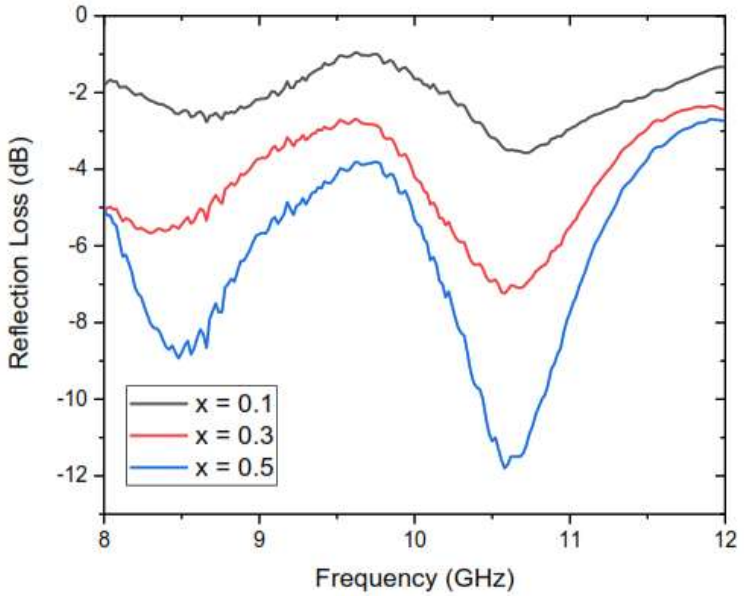

Figure 16 The absorption curve of electromagnetic waves on the material $La_{0.7}Sr_{0.3}Mn_{1-x}(Ni,Ti)_{x/2}O_3$ [18].

F. A. Kurniawan et al [24] also studied the effect of Fe and Ti ion doping on the B site on the microwave absorption performance of $Nd_{0.6}Sr_{0.4}Mn_xFe_{1/2(1-x)}Ti_{1/2(1-x)}O_3$ material (x = 0; 0.1; 0.2). The results show that when x = 0.2, the $Nd_{0.6}Sr_{0.4}Mn_xFe_{1/2(1-x)}Ti_{1/2(1-x)}O_3$

material has a maximum absorption value of -17.5 dB at a frequency of 9.5 GHz with a material absorption capability of 98.22%.

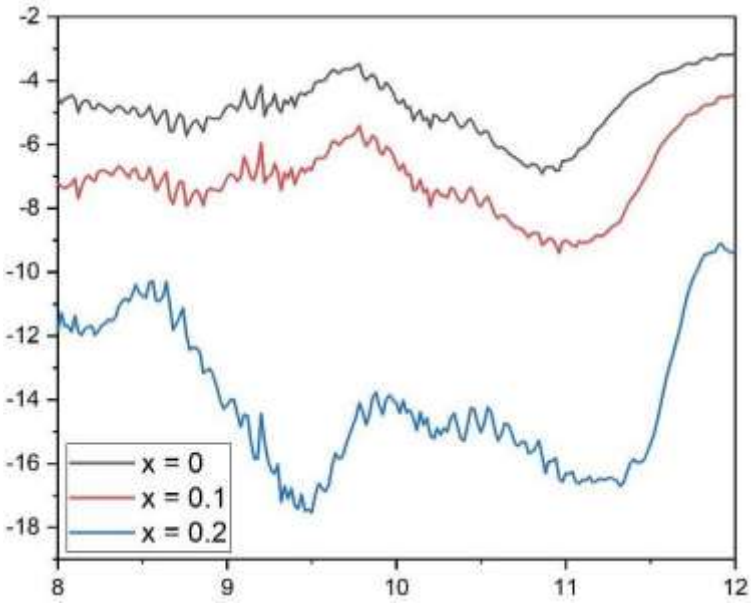

Figure 17 Electromagnetic wave absorption curve on $Nd_{0.6}Sr_{0.4}Mn_xFe_{1/2(1-x)}Ti_{1/2(1-x)}O_3$ material [24].

Through the various research results that have been presented, it can be seen that manganese perovskite-based materials doped in A site and B site have better absorption capabilities when compared to manganese perovskite-based materials doped only in A site. The ability to absorb microwaves is caused by several factors such as double exchange interaction, permeability, and permittivity of the material [16], [17]. Table 1 summarizes the maximum absorption capability of manganese perovskite-based materials.

Table 1 summarizes the maximum absorption capability of manganese perovskite-based materials.

Materials	RL max (dB)	Frequency (GHz)	References
$La_{0.7}Sr_{0.3}MnO_3$	-17.46	15.87	[15]
$La_{0.7}Ba_{0.3}MnO_3$	-21.40	7.70	[22]
$La_{0.9}Ca_{0.1}MnO_3$	-42.00	10.50	[16]
$La_{0.1}Ca_{0.9}MnO_3$	-31.00	11.50	[19]
$La_{0.7}Ca_{0.3}MnO_3$	-3.53	10.44	[23]
$La_{0.7}Ca_{0.3}Mn_{0.7}Ti_{0.3}O_3$	-10.07	10.40	[17]
$La_{0.67}Ba_{0.33}Mn_{0.96}Ni_{0.04}O_3$	-8.85	11.58	[12]
$La_{0.67}Ba_{0.33}Mn_{0.98}Ti_{0.02}O_3$	-13.26	11.46	[13]
$La_{0.67}Ba_{0.33}Mn_{0.94}Ni_{0.03}Ti_{0.03}O_3$	-14.30	11.28	[14]
$La_{0.7}Sr_{0.3}Mn_{0.5}Ni_{0.25}Ti_{0.25}O_3$	-11.80	10.58	[18]
$Nd_{0.6}Sr_{0.4}Mn_{0.2}Fe_{0.4}Ti_{0.4}O_3$	-17.50	9.50	[24]

CONCLUSIONS

Manganate perovskite-based materials have enormous potential as microwave absorbers because they have unique crystal structures and are easily engineered by doping. Based on the reviews discussed earlier, commonly used methods to synthesize manganate perovskite materials have been described. There are advantages and disadvantages to each method. The method that needs to be considered to synthesize manganate perovskite-based materials is the sol-gel method. Through this method the particle size and distribution can be controlled by selecting the calcination and sintering temperatures. There are differences in microwave absorption performance between one material and another, this is influenced by the doping carried out on each site. In this regard, it can be seen that the microwave absorption performance of manganate perovskite-based materials is not high enough. So there are still opportunities for further development of manganate perovskite-based materials as microwave absorbers.

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