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FTIR characterization analysis of $BaTiO_3$ nanoparticles synthesized using *Terminalia catappa* leaf extract

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ABSTRACT

Ferroelectric materials are materials that are in great demand in high-density memory applications, such as ferroelectric random access memory, ferroelectric field effect transistors, negative capacitance field effect transistors, and ferroelectric tunnel junctions. Barium titanate ($BaTiO_3$) is a lead-free ferroelectric material with a high dielectric constant and low dielectric loss. The method used is sol gel for the synthesis of $BaTiO_3$ solution, extract for ketapang (*Terminalia catappa*) leaves, and characterized by FTIR. The FTIR spectrum synthesized with ketapang leaf extract displays several characteristic peaks in the mid-infrared region (4000 – 400 cm^{-1}). These peaks can be determined by the specific vibration mode of the structure and organic compounds contained in the ketapang leaf extract. $BaTiO_3$ has a cubic perovskite structure with a peak wave number of 600 cm^{-1}. Ketapang leaf extract is incorporated into the $BaTiO_3$ structure. $BaTiO_3$ has a Ti–O functional group. Ketapang leaf extract has C–O, C=O, C–H, and O–H functional groups.

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1. INTRODUCTION

Ferroelectric films have great potential for application in the fields of information storage, sensing, biomedicine, piezoelectric actuators, and so on because they have excellent ferroelectric, piezoelectric, and photoelectric properties [1, 2]. Ferroelectric materials are materials that are in great demand in memory and high-density applications, such as ferroelectric random access memory, ferroelectric field effect transistors, negative capacitance field effect transistors, and ferroelectric tunnel junctions [3-5]. Ferroelectric materials are piezoelectric, so they can function to convert electrical energy into mechanical energy [6, 7].

Barium titanate ($BaTiO_3$) is a lead-free ferroelectric material with a high dielectric constant and low dielectric loss [8, 9]. $BaTiO_3$ is in great demand because it is considered one of the lead-free ferroelectrics with a perovskite structure (ABO_3), has been used as a ferroelectric random access memory research system with many advantages such as polarization stability, safe to apply, easy manufacturing process [10-12]. $BaTiO_3$ is very easy to control through substrate strain and element doping [13].

Synthesis is considered environmentally friendly, non-toxic, effective, biocompatible, and harmless. Extracts with plants have phytochemical properties that function to reduce or stabilize metal semiconductor materials [14, 15]. *Terminalia catappa* or known as the ketapang fruit tree is widespread in tropical and subtropical areas. This plant is usually used traditionally in treating diseases such as inflammation, weight loss, blood pressure, lowering sugar levels, and many more health benefits [16-18]. The chemical content of the ketapang plant contains phenolics, tannins, and flavonoids [19]. Ketapang leaves are antibacterial agents that have the potential to inhibit bacterial activity [20].

Fourier transform infrared (FTIR) is an analysis technique using infrared spectroscopy. In infrared spectroscopy, infrared radiation is passed through the sample, some of the radiation will be absorbed and some will be transmitted or even passed [21, 22]. Functional group analysis using FTIR aims to determine the physical and chemical processes that occur during the synthesis process [23]. FTIR spectroscopy is an analysis that will not damage the sample and only requires simple sample preparation [24]. FTIR spectroscopy has the advantage of fast and simple sample preparation, allowing direct analysis without separation procedures [25]. This study aims to synthesize ferroelectric materials $BaTiO_3$ using plant extracts from ketapang leaves which are used as stabilizing agents and characterized using FTIR.

2. RESEARCH METHODS

2.1. Materials

Ketapang leaves were collected from the campus area of Universitas Riau, Barium titanate ($BaTiO_3$) and aqua DM were used in the synthesis.

2.2. Preparation of Ketapang leaf extract

Ketapang leaves were washed thoroughly with water. Then, the leaves were dried in the sun until completely dry to remove residual water. The dried leaves were finely ground into powder. A total of 5 grams of dried leaves and fine powder were mixed with a certain amount of deionized water in a beaker. The mixture was heated at a temperature of 100 degrees Celsius for three hours with constant stirring at a speed of 450 rpm, producing a red solution and a yellow solution. After that, the solution obtained was filtered to obtain an extract which was put into the refrigerator for the next 24 hours.

2.3. Synthesis of $BaTiO_3$ Solution via Sol-Gel Method

The relative molecular mass of $BaCO_3$ is calculated then enter the mass value of $BaCO_3$ with the composition (X) $BaTiO_3$-(1-X) $BaZr_{0.5}Ti_{0.5}O_3$. Weigh all ingredients using a digital scale to ensure the accuracy of the composition. Dissolve TiO_2 with a mixture of ethylene glycol (5 ml) and alcohol (5 ml). Stir the solution for at least 25 hours or until the TiO_2 powder is completely dissolved. Mix $BaCO_3$ with the TiO_2 solution that has been made. Add 3 drops of Acetyl Acetone to the mixture. Stir the mixture for 2 hours to ensure homogenization.

2.4. Characterization FTIR

FTIR is a sophisticated method used to identify and determine the chemical composition of a material. Its working principle focuses on the detection of molecular vibrations triggered by exposure to infrared light. In infrared spectroscopy, infrared radiation is passed through the sample. Some of the radiation will be absorbed by the sample and some will be passed or transmitted by the sample. Functional groups that absorb FTIR radiation at wave numbers and chemical vibration bonds are displayed in the fingerprint spectra because the FTIR spectral pattern, especially the fingerprint region, is a complex pattern whose interpretation requires the help of chemometrics.

3. RESULTS AND DISCUSSIONS

Based on the test results, it can be seen that the ketapang leaf extract has a wave peak produced from the FTIR analysis which is one of the characterization techniques needed to analyze the molecular structure and functional groups of various materials from the samples made. Figure 1 shows the results of the FTIR analysis of the $BaTiO_3$ nanoparticle sample synthesized with ketapang leaf extract. The FTIR spectrum provides information about the molecular structure and functional groups contained in the sample.

The FTIR spectrum of $BaTiO_3$ synthesized with ketapang leaf extract shows several characteristic peaks in the mid-infrared region (4000 – 400 cm^{-1}). These peaks can be determined by the specific vibration modes of the $BaTiO_3$ structure and organic compounds contained in the ketapang leaf extract. The peak of wave number 600 cm^{-1} indicates the bending of Ti–O–Ti in the $BaTiO_3$ structure, while the peak of wave number 1047 cm^{-1} shows the stretching of the T–O structure in the $BaTiO_3$ structure. The peaks of wave number 1400 cm^{-1} and 1634 cm^{-1} indicate the stretching of C–O and C=O in carboxylic acid compounds. The wave number peak of 2928 cm^{-1} indicates the stretching of CH in the methylene group, then the wave number peak of 3425 cm^{-1} indicates the stretching of OH in the alcohol compound. The wave number peaks in the areas of 3425 cm^{-1}, 2928 cm^{-1}, 1634 cm^{-1}, and 1400 cm^{-1} indicate the incorporation of organic compounds from ketapang leaf extract into the $BaTiO_3$ structure. These compounds can change the surface structure and dopant of $BaTiO_3$, so that it will affect the properties of $BaTiO_3$.

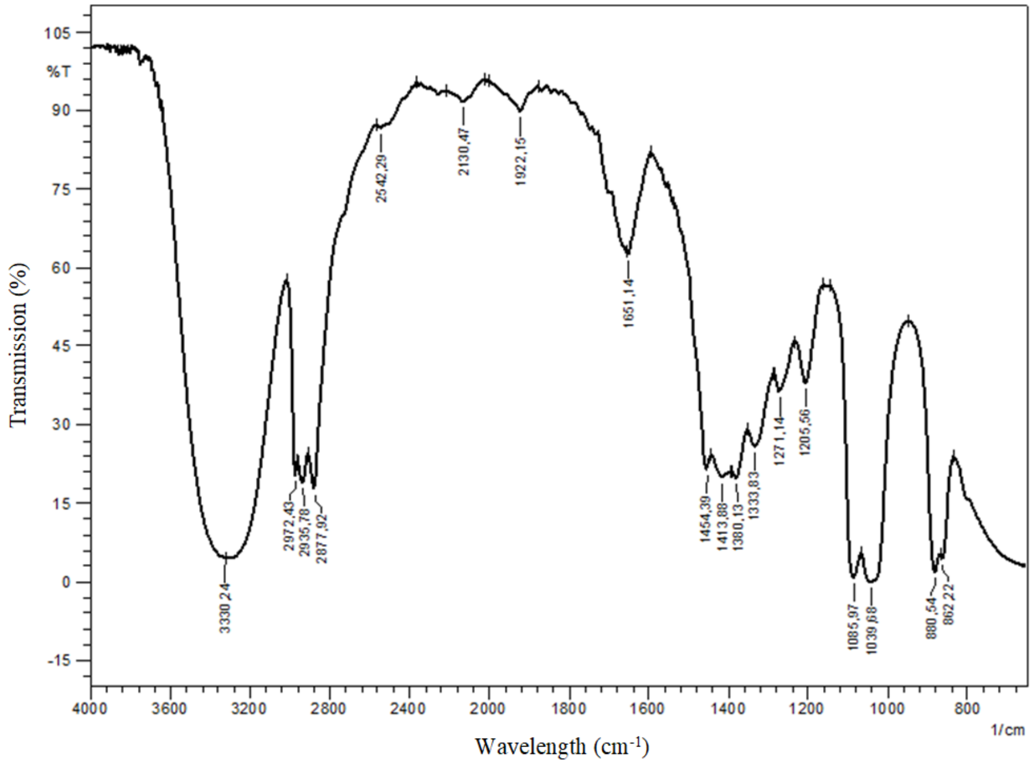

Figure 1. FTIR results of ketapang leaf extract with $BaTiO_3$.

4. CONCLUSION

$BaTiO_3$ has a cubic perovskite structure with a wave number peak of 600 cm^{-1} indicating the bending of Ti–O–Ti and a wave number peak of 1047 cm^{-1} indicating the stretching of the Ti–O structure. Ketapang leaf extract is incorporated into the $BaTiO_3$ structure, as indicated by the wave number peaks of 3425 cm^{-1}, 2928 cm^{-1}, 1634 cm^{-1}, and 1400 cm^{-1}. $BaTiO_3$ has Ti–O functional groups, as indicated by the wave number peaks of 600 cm^{-1} and 1047 cm^{-1}. Ketapang leaf extract has C–O, C=O, C–H, and O–H functional groups, as indicated by the wave number peaks of 1400 cm^{-1}, 1634 cm^{-1}, 2928 cm^{-1}, and 3425 cm^{-1}.

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