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Properties of $BaTiO_3$ nanoparticles based on FTIR derived using *Nephelium lappaceum L.* leaf extract

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ABSTRACT

The properties of barium titanate ($BaTiO_3$) nanoparticles synthesized with rambutan leaf extract (*Nephelium lappaceum L.*) were analyzed using Fourier transform infrared spectroscopy (FTIR) characterization techniques. Rambutan leaf extract contains bioactive compounds that have the potential to enhance unique physical and chemical properties. This study aims to analyze the properties of the nanoparticles and to characterize the functional groups present in $BaTiO_3$ nanoparticles synthesized using rambutan leaves. The nanoparticle synthesis process involved extraction, followed by the preparation of a $BaTiO_3$ solution and doping. The FTIR spectrum displayed characteristic peaks identifying the presence of functional groups. The results indicated that the region 3500 – 3200 cm^{-1} corresponds to O–H groups (alcohol and phenolic), the region 1700 – 1600 cm^{-1} to C=O groups (carbonyl), the region 1600 – 1500 cm^{-1} to C=C groups (alkene), and the region 1200 – 1000 cm^{-1} to C–O groups (ether). Each functional group exhibits distinct properties.

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1. INTRODUCTION

Barium titanate ($BaTiO_3$) is a widely used piezo-ceramic due to its good piezo characteristics [1]. $BaTiO_3$-based dielectric or ferroelectric materials have received much attention for energy storage applications in the last two decades. Crystal orientation has a major influence on their dielectric properties, determining their interaction with electric fields [2, 3]. In ferroelectric materials such as $BaTiO_3$, where the crystal structure is very important, the orientation determines the dipole alignment and polarization behavior. For example, in a single crystal with uniform orientation, the dielectric constant can vary significantly along different crystallographic axes, affecting the overall dielectric response of the material [4-6]. Titanium and titanium alloys have been widely used for various applications [7]. $BaTiO_3$ as an example of a material with a perovskite crystal structure, has a cubic structure when its temperature is above the Curie temperature (130°C) [8, 9], but can transform into tetragonal, orthorhombic, and rhombohedral structures below that temperature. $BaTiO_3$ is generally produced in powder form, and due to the undesirable grain growth during the time-consuming conventional sintering process, the SPS method may be better for sintering such crystal structures [10-12]. A common strategy to enhance the piezoelectric response of ferroelectric materials at room temperature is to regulate the doping of organic materials [13].

Hydroxyapatite is a biomaterial that has a chemical composition of calcium and phosphate similar to human hard tissues, such as bones and teeth, so it is widely used in the health sector as a bone substitute [14, 15]. To improve the mechanical properties of hydroxyapatite, additional materials in the form of polymers are needed. One of the polymers derived from plants is a polyphenol compound known as tannin. Rambutan (*Nephelium lappaceum L.*) leaves are one of the plants that

contain tannin compounds [16-19]. Hydroxyapatite can be synthesized chemically using chemical reagents, or naturally by utilizing calcium sources from natural materials [20].

Rambutan plants are horticultural plants that belong to the Sapindaceae family. In addition to being delicious to eat rambutan fruit, rambutan plants also have a number of health benefits. One part of the rambutan plant that can be beneficial for health is rambutan leaves [21, 22]. Rambutan leaves contain tannins and saponins. Several studies have been conducted to determine the distinguishing characteristics of rambutan. Rambutan leaves vary greatly so that they have the potential to be studied as a cultivation marker compared to fruit. Several rambutan leaf characters have been assessed as specific markers, but the specific characters have not been obtained. Unlike morphological characters, molecular characters have been widely used as markers in various cultivars and to detect genetic variability at many levels between species [23, 24]. Doping or alloying is a technique used in the manufacture of gemstones or crystals. This involves attaching uncut stones to the end of a small stick using resin or wax. When the stone is heated or glued to the stick, the stone can be cut and shaped more easily. Doping or alloying plays a role in adding impurities to a material or sample [25].

2. RESEARCH METHODS

2.1. Extraction Process

Rambutan leaves are washed and cleaned from dirt with running water, then dried in the open air. Rambutan leaves are weighed as much as 25 grams, ground and mashed into powder. The powder is extracted using the maceration technique, which is soaked in ethanol and stirred for 3 hours using a hot plate stirrer at room temperature. Then the rambutan leaf powder that has been stirred is left for 24 hours. The sample is filtered using 125 mm filter paper. So that a clear solution is obtained.

2.2. $BaTiO_3$ Solution Making Process

The relative molecular mass of barium carbonate ($BaCO_3$) material is weighed as much as 2 grams then Ti is added as much as 0.494. All materials are weighed using a digital scale, then TiO_2 is dissolved with 5 ml of ethylene glycol and 5 ml of alcohol and then stirred for at least 25 hours. $BaCO_3$ is mixed with TiO_2 solution then added with 3 drops of acetyl acetone.

3. RESULTS AND DISCUSSIONS

In this study, $BaTiO_3$ doped with rambutan leaf extract was identified its functional groups using Fourier transform infrared (FTIR) spectroscopy characterization to determine the chemical components of $BaTiO_3$ doped with rambutan leaf extract. The resulting infrared spectra are shown in Figure 1.

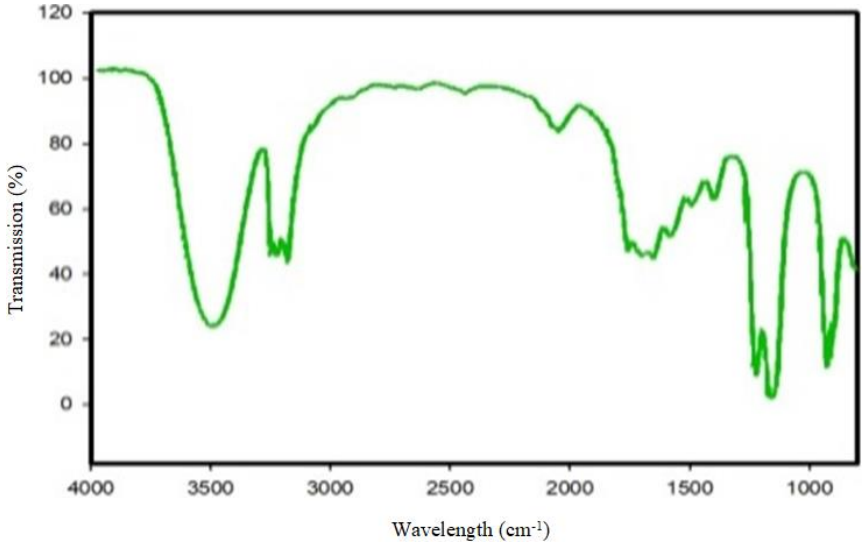

Figure 1. FTIR spectrum of $BaTiO_3$ doped rambutan leaf extract sample.

The FTIR spectrum of rambutan leaf extract shows several significant absorption peaks, indicating the presence of certain organic functional groups in the extract. The 3500 – 3200 cm^{-1} region is a wide and strong absorption peak in this region indicating the presence of O–H functional groups (alcohols and phenolics) (see Table 1).

Table 1. Results of FTIR spectrum analysis of rambutan leaf extract doping.

Functional group	Peak position absorption (cm^{-1})	Description
O–H (alcohol and phenolic)	3500-3200	Wide and strong
C=O (carbonyl)	1700-1600	Strong
C=C (alkene)	1600-1500	Strong
C–O (ether)	1200-1000	Moderete

This functional group is generally found in compounds such as carbohydrates, alcohols, and phenolics. The 1700 – 1600 cm^{-1} region has a strong absorption peak in this region indicating the presence of C=O functional groups (carbonyl). This functional group is generally found in compounds such as aldehydes, ketones, carboxylates, and esters. The 1600 – 1500 cm^{-1} area is a strong absorption peak in this area indicating the presence of a C=C functional group (alkene). This functional group is generally found in compounds such as alkenes and aromatics. The 1200 – 1000 cm^{-1} area is an absorption peak in this area indicating the presence of a C–O functional group (ether). This functional group is generally found in compounds such as ethers and polysaccharides. The data obtained can be applied by conducting further research.

4. CONCLUSION

Dielectric or ferroelectric materials based on $BaTiO_3$ crystal structure is very important, orientation determines the alignment of the dipole and its polarization behavior. In the study of $BaTiO_3$ doped with rambutan leaf extract, its functional groups were identified using FTIR characterization to determine the chemical components of $BaTiO_3$ doped with rambutan leaf extract. The FTIR spectrum of rambutan leaf extract shows that in the region of 3500 – 3200 cm^{-1} the absorption peak indicates the O–H functional group (alcohol and ferrolic), in the region of 1700 – 1600 cm^{-1} indicates the C=O functional group (carbonyl), in the region of 1600 – 1500 cm^{-1} indicates the C=C functional group (alkene) and in the region of 1200 – 1000 cm^{-1} indicates the C–O functional group (ether).

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