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Analysis of ferroelectric material $BaTiO_3$ and mangosteen leaf extract using FTIR characterization

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ABSTRACT

Perovskite materials, including barium titanate ($BaTiO_3$), are important ferroelectric materials in industry and research today. Ferroelectrics have unique properties such as piezoelectricity, high permittivity, and electrocaloric and electrooptic effects that are beneficial in technological applications. $BaTiO_3$, for example, is a lead-free ferroelectric material relevant for FeRAM and ferroelectric tunnel junctions. However, research on $BaTiO_3$ flexible thin films is still limited, especially in the context of flexible substrates. Therefore, research in the preparation of stable and flexible BTO ferroelectric films is crucial for the advancement of nonvolatile memory devices. The manufacturing method in this study is the Sol Gel Method where the relative molecular mass of $BaCO_3$ material is calculated, then the mass value is entered with the composition of (X)$BaTiO_3$-(1-X)$BaZr_{0.5}Ti_{0.5}O_3$. After the test is performed using mangosteen leaves, the resulting wave peaks from the FTIR Spectroscopy analysis can be seen. This is one of the characterization methods used to analyze the molecular structure and functional groups of various materials from which samples are made. This analysis indicates that mangosteen leaves contain various organic compounds, including alcohols, alkanes, and carbonyl compounds. In this research, further development is needed so that improvements can be made in the synthesis of ferroelectric material $BaTiO_3$ used as a stabilizing agent.

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1. INTRODUCTION

The photoelectric effect, i.e. the emission of electrons from matter when it is ionized by short-wavelength radiation, has been well known for more than 100 years and is widely used as a probe in materials research. The effect is also of fundamental significance because at low intensities, it represents evidence for the quantum structure of light and photons as light particles [1-3]. At long wavelengths, on the other hand, photoelectron emission and photoionization are limited to very high photon intensities using, for example, powerful optical lasers. This process can be explained by treating intense light as a high-field-strength electromagnetic wave that strongly affects the electrons of atomic structures [4, 5], and references therein. However, the combination of short wavelengths and very high intensities is still an unexplored area of classical photo-effect physics meets the regime of strong-field phenomena. Here, as we show, the mechanism of photon-matter interaction does not seem to be fully understood. At the highest radiation level to date of almost 1016 W/cm^2 in the extreme ultra-violet (EUV) at a wavelength of 13.3 nm, we have observed, based on ion mass-to-charge spectroscopy, a very high degree of photoionization of the xenon atom [6-8]. Neither a pure particle nor a pure wave picture of light seems to provide a satisfactory explanation of our experimental results which nicely demonstrate the dual nature of light. Work has been done at the new free electron laser at Hamburg FLASH [9, 10] and may be important for any investigations of current and future X-ray laser facilities [11, 12] in areas such as plasma physics, new materials, femtochemistry, and biochemistry of structure and dynamics. Perovskite materials are the most frequently used ferroelectric materials in industry and are the subject of recent research. One of them is barium titanate ($BaTiO_3$) [13-15]. Ferroelectric materials are materials that have several functional properties, namely piezoelectricity, high permittivity, as well as electrocaloric and electrooptic effects, which play an important part in technological applications. Ferroelectrics can develop spontaneous electric polarization when below the Curie temperature [16-18].

$BaTiO_3$ is a lead-free ferroelectric material with high dielectric constant and low dielectric loss. It has important applications in ferroelectric random access memory (FeRAM) and ferroelectric tunnel junctions. However, research on flexible barium titanate (BTO) thin films is still limited, while most previous studies have focused on rigid substrates. Therefore, the preparation of BTO ferroelectric films with high stability and flexibility is essential for the advancement of nonvolatile memory devices. Mica is an excellent substrate in the field of flexible materials, due to its unique high temperature resistance and surface smoothness at the atomic level [19, 20].

Infrared (IR) or Fourier transform infrared (FTIR) spectroscopy has a wide range of applications, ranging from the analysis of small molecules or molecular complexes to the analysis of cells or tissues. Tissue imaging is one of the latest developments in infrared spectroscopy, taking advantage of infrared microscopy and the use of synchrotron IR radiation. It is used for mapping cellular components (carbohydrates, lipids, proteins) to identify abnormal cells [21, 22]. FTIR spectroscopy is also increasingly applied to protein studies. This concerns the analysis of protein conformation, protein folding, and molecular details of the active site of proteins during enzyme reactions using reaction-induced FTIR difference spectroscopy [23-25]. This study aims to synthesize ferroelectric materials $BaTiO_3$ using plant extracts from mangosteen leaves used as a stabilizing agent and characterized using FTIR.

2. RESEARCH METHODS

2.1. Materials

The materials used are mangosteen leaves, ethanol, aquades, $BaCO_3$ (barium carbonate), $BaTiO_3$, TiO_2 (titanium dioxide), ethylene glycone, alcohol, and acetylacetone.

2.2. Preparation of *Garcinia mangostana L.* Leaf Extract

Mangosteen leaves are cleaned with water, then ground with a blender until smooth. Mangosteen leaf powder is soaked in methanol for 3 × 24 hours at room temperature. The resulting filtrate is filtered with filter paper. The soaking filtrate is evaporated with the solvent to obtain a thick extract. The 100% stock solution is then diluted with aquades to produce concentrations of 20%, 40%, 60% and 80%.

2.3. Method of Making BT Solution with the Sol Gel Method

The relative molecular mass of the $BaCO_3$ material is calculated, then the mass value is entered with the composition $(X)BaTiO_3$-$(1-X)BaZr_{0.5}Ti_{0.503}$. All materials are weighed on a digital scale TiO_2 is dissolved in 5 ml of ethylene glycol and 5 ml of alcohol, then stirred for at least 25 hours or until the powder dissolves. $BaCO_3$ is mixed with TiO_2 solution then added 3 drops of acetylacetone. Then stir for 2 hours.

2.4. FTIR Characterization

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 chemometric assistance.

3. RESULTS AND DISCUSSIONS

After testing using mangosteen leaves, the wave peaks produced from the FTIR spectroscopy analysis can be seen. This is one of the characterization methods used to analyze the molecular structure and functional groups of various materials from the samples made. Figure 1 shows the results of FTIR analysis of a $BaTiO_3$ nanoparticle sample synthesized with mangosteen leaf extract. The FTIR spectrum shows the molecular structure and functional groups of the sample.

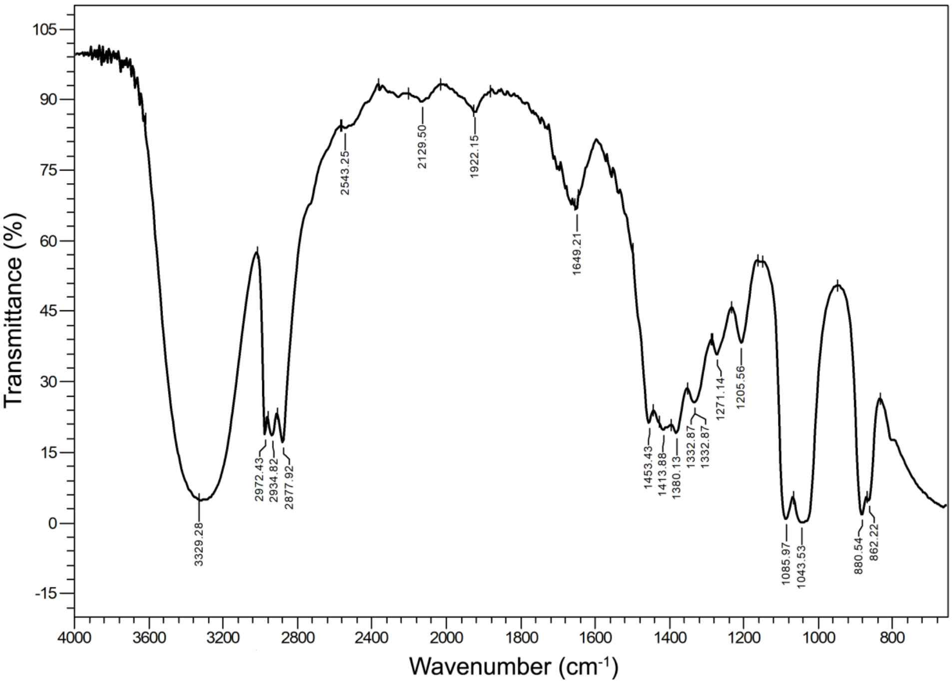

Figure 1. FTIR results of mangosteen leaf extract with $BaTiO_3$.

This spectrum shows several significant absorption peaks at various wave numbers ranging from (4000 – 400 cm^{-1}), which represent various functional groups in the sample. The peak at around 3329.28 cm^{-1} can be identified as the O–H stretch, which is commonly found in compounds containing hydroxyl groups, such as water or alcohol. Strong peaks around 2917.49 cm^{-1} and 2847.92 cm^{-1} indicate C–H stretching, which is usually associated with alkane bonds in organic compounds. In the fingerprint region, there are several significant peaks, such as the peak at 1649.21 cm^{-1} which can be attributed to C=O stretching of carbonyl groups in aldehydes, ketones, or carboxylic acids. Peaks around 1453.43 cm^{-1} and 1380.18 cm^{-1} indicate C–H stretching and deformation of methyl or methylene groups. Peaks at 1085.97 cm^{-1} and 1049.63 cm^{-1} can be attributed to C–O stretching of alcohols, ethers, or esters. Finally, the peaks around 889.54 cm^{-1} and 805.22 cm^{-1} may indicate the out-of-plane deformation of aromatic C–H bonds. This analysis indicates that mangosteen leaves contain various organic compounds, including alcohols, alkanes, and possibly some carbonyl compounds.

4. CONCLUSION

Perovskite materials, especially $BaTiO_3$, have important functional properties for technological applications. Flexible and stable BTO thin films are essential for the advancement of nonvolatile memory devices. FTIR spectroscopy analysis was performed on $BaTiO_3$ nanoparticle samples synthesized with mangosteen leaf extract. The results of the analysis showed wave peaks that can be used to analyze the molecular structure and functional groups of the materials.

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