# ANALYSIS OF STRUCTURAL, AND DIELECTRIC PROPERTIES OF ALZNTIO$_3$ AND ALZNNITIO$_3$ NANOPARTICLES

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## Abstract

*Using the solid-state process, powdered ZnO and $TiO_2$ were combined in a 1:1 molar ratio to produce $ZnTiO_3$. Dielectric parameters like dielectric constant (r) and dielectric loss (tan ) have been investigated between 200 Hz and 5 MHz throughout a temperature range of 40oC to 400oC in 10oC increments. The high dielectric constant of 50 found may be useful in capacitors that store large amounts of charge. FTIR and UV-Vis Spectra were also used to investigate the optical characteristics. UV-Visible Spectra were used to determine the band gap. X-ray diffraction patterns showed a change in phase from tetragonal to cubic as x increased from 0.2 to 0.4 to 0.8. Nanosphere-like features were seen in the surface morphology. For 1 MHz samples with x = 0.2-0.6, the dielectric constant was raised from 230 to 710, respectively. Dielectric constant (ε') = ~-58.5 and dielectric loss (ε'') = -417 at 8 MHz were observed in the x = 0.6 nanocomposite, which was an unexpected finding. Similarly, at 6 GHz, the ac-electrical conductivity (ac) of the x = 0.6 sample was -0.159 S/cm. As a result, high-capacity stored-charge capacitors and excellent absorber applications are possible with these materials. Materials that combine magnetic and dielectric characteristics into a single entity are known as magneto-dielectric composites. Because of the interaction between the electric and magnetic fields, the electric polarization may be manipulated by adding a magnetic field, and vice versa for ferroelectric materials. Composites' magneto-dielectric characteristics can be altered significantly by manipulations of phase connectivity and phase morphology. The synthesis technique is a powerful tool for investigating the composites' magneto-dielectric characteristics and microstructure. In this study, we utilize three different synthesis techniques to make magneto-dielectric composites. Both in-situ synthesis and solid-state mixing may be traced back to combustion. For its intermediate permittivity, loss, and piezoelectric constant, $BaTiO_3$ was chosen for the ferroelectric phase. For the ferrite phase, we use materials that are hard (CoFe2O4), soft (ZnFe2O4), and non-magnetic (Co0.5Zn0.5Fe2O4). Magneto-dielectric composites with varying percentages of ferrite (20%, 30%, 40%) were employed. Composites were investigated for their structure, microstructure, and magneto-dielectric characteristics. The composites' dielectric, magnetic, and magneto-dielctric characteristics were shown to be highly method-dependent. When tetragonal BaTiO3 was sintered with ferrites, traces of hexagonal*

*BaTiO3 were found. BaTiO3 grew into a plate-like morphology alongside a nearly spherical shape in composites obtained from the solid state, but there was no indication of plate-like $BaTiO_3$ in composites formed in situ. Both solid-state and in-situ synthesized composites based on cobalt ferrite exhibit a negative magneto-capacitance response, which is not seen in other ferrite systems.*

## Paper Identification

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**INTRODUCTION**

In response to rising global awareness of environmental and safety issues, a new wave of research and development towards lead-free BT ceramics has emerged. Due to its high dielectric constant, low dielectric loss, and ferroelectric and piezo-electric properties, barium titanate ($BaTiO_3$) is widely used in a wide range of electronic devices, including Multi-layered Ceramic Capacitors (MLCCs), memory devices, PTC thermistors, and a number of electro-optical devices. Unfortunately, pure $BaTiO_3$ ceramics are restricted to a certain field of usage due to their low dielectric strength and small stable operating temperature range. The functional features of $BaTiO_3$ perovskite cells are drastically altered when other ions are substituted for Ba2+ at either the A or B locations. Better thermal stability over a wide temperature range can be induced by isovalent replacement on Ti sites with elements like BaZrxTi1-xO3, Hf, Ce, or BaTi1- $xSnxO_3$ for particular purposes such as increased material constants (permittivity, pyro- and piezo-electric constants). As technology develops, tiny electronic portable gadgets serving several purposes are in high demand. The need for thinner Multilayer Ceramic Capacitors (MLCC), piezoelectric sensors and actuators, and other tiny electronic components has sparked significant interest in the development of novel miniaturized ferroelectric materials within the electronics industry. BT ceramics produced from nano particles are said to have significantly improved electrical and piezoelectric characteristics. Chemical coprecipitation, the sol-gel method, and hydrothermal synthesis are just a few examples of the several approaches for the manufacture of nanoceramic powders that may be used to generate nanoscale BT powders. Yet, the high-energy ball milling method is still viewed as a straightforward and inexpensive approach to manufacturing nanoceramic powders at industrial scale. As a result of the present trend toward shrinking and integration of electronic components, mechanical treatment of ceramic powders can reduce particle size and enable obtainment of nanostructured powders.

**NANOPARTICLES**

Matter at the nanometer scale (109 m = 1 nm) is the focus of nanotechnology, which also includes the study of atomic and molecular-level manipulation. Nanoparticles, the building blocks of nanostructures, are far smaller than the world of common things defined by Newton's laws of motion yet larger than the atoms and simple molecules regulated by quantum mechanics. In 2000, the United States launched the National Nanotechnology Initiative (NNI), which was quickly followed by an explosion of nanotechnology-related initiatives across almost all federal agencies the following year. The National Science Foundation (NSF), which reports directly to the President of the United States and whose mission it is to support the most promising basic research in science and technology, has since allocated funding to about twenty research centers. When it came to carrying out the NNI in the United States, NSF was in the driver's seat. The term "nanotechnology" quickly piqued the interest of the media (newspapers, TV shows, the internet, etc.) and the general public. Nanoparticles typically range in size from 1 to 100 nm. Different from bulk metals, metallic nanoparticles have unique physical and chemical properties that could be useful in a wide range of industrial contexts, including lower melting points, larger specific surface areas, distinct optical properties, greater mechanical strengths, and stronger magnetizations. How a nanoparticle is understood and defined, however, is very context dependent.

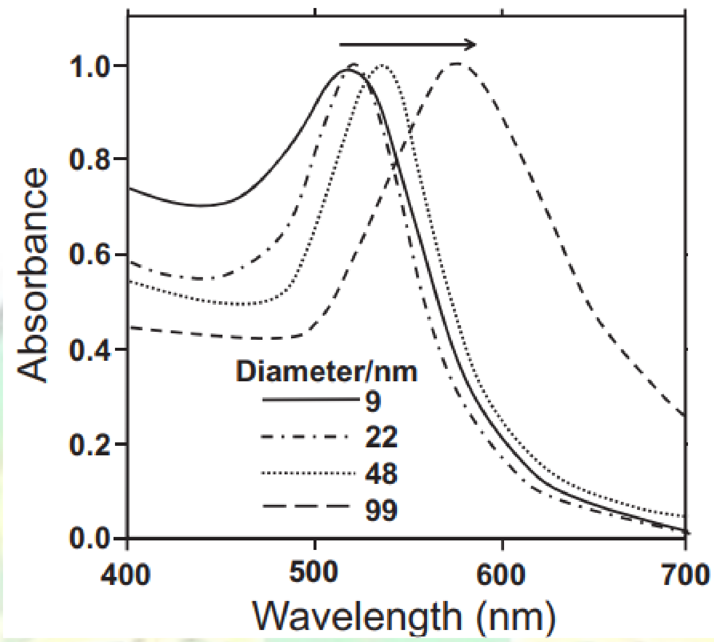
Some historic cathedrals have blatant examples of nanotechnology. Stained glass windows in the Middle Ages often had a ruby red hue made possible by early nanotechnology. Located on the historic French pilgrimage route to Santiago de Compostela (Spain), the Le ó n Cathedral (Spain) is one of these rare masterpieces, and its imposing 2000 m2 colorful windows give a vista that is unmatched and well worth a visit as an example of these uses. Of course, the medieval craftsmen who used nanotechnology didn't know that they were doing so. They had an intuitive understanding that a certain technique created a stunning result. Cathédrale Notre-Dame de Chartres in France, for instance, features a beautiful rose shown in stained glass, and is on the UNESCO list of World Heritage Sites. Medieval stained glass windows are on show. The chemistry of the time period shed light on the origins of the hue. The size and shape of the gold and silver nanoparticles determined the intensity of the colors produced. Jin and colleagues have lately examined the connection between particles and their respective hues. The New York Times published a summary of the correlation between stained glass color and nanoparticle size and shape on February 22, 2005. (see Figure 1.3). Many decades and the advent of analytical tools later, the components of stained glass (colored glass) in various cathedrals became clear. Contributions to nanotechnology from those without formal training are on the rise.

**METHODS OF NANOPARTICLE SYNTHESIS**

Nanoparticle (nanomaterial) preparation methods are outlined. From ancient times, two methods have been used to make ultrafine particles. For starters, there's the breakdown (top-down) technique, in which a solid is subjected to an external force, causing it to shatter into smaller pieces. The second is the construction (bottom-up) approach, which uses atomic transformations or molecular condensations to create nanoparticles from gas or liquid atoms. The process of reducing a solid into smaller pieces is known as "top-down" processing, and it may be further subdivided into "dry" and "wet" grinding. Particles' surface energy increases during grain refining procedures, leading to a rise in particle aggregation. The solid material is processed using a shock, compression, or friction in the dry grinding process, with common equipment including jet mills, hammer mills, shear mills, roller mills, shock shear mills, ball mills, and tumble mills. Grain refining makes it difficult to achieve particle sizes of less than 3 m because condensing of tiny particles also takes place simultaneously with pulverization. Nevertheless, a tumbling ball mill, vibratory ball mill, planetary ball mill, centrifugal fluid mill, agitating beads mill, flow conduit beads mill, annular gap beads mill, or wet jet mill is used for wet grinding of a solid substrate. Wet processing is preferable to dry because it prevents condensation of the produced nanoparticles, allowing for the production of highly distributed nanoparticles. Some well-known top-down techniques include mechanochemical synthesis and mechanical alloying.

**Control of Size, Shape, and Structure**

Nanomaterials' composition is simply one factor in determining their physical and chemical characteristics; particle size and shape also play important roles. This means that the ability to regulate particle size and shape is a must for any good synthesis technique. The surface Plasmon resonance of an Au Nano sphere, for instance, may be changed from 530 nm to the longer wavelength side by increasing the diameter of the sphere. So, if nanoparticles vary in size, there will be substantial differences in their optical qualities..




**Visible-light spectra of Au nanospheres with various particle sizes**

Minimizing the size distribution of nanoparticles is crucial for their optical uses. Consequently, while creating nanoparticles, it is crucial to construct them with a certain size in mind. Producing monodispersed nanoparticles often requires extremely slow growth of the nanoparticles following the quick production of the seed particles. Aggregation of nanoparticles is aided by an increase in their surface energy if their size is reduced (i.e., their specific surface area is increased). After reaching the ideal size, it will be required to apply a dispersion agent to the particles to keep them from clumping together. Lea reported in 1889 that Ag colloids were protected by citrate, therefore the use of dispersing agents in nanoparticle syntheses is not new. Unfortunately, the protective function of the organic substrate (citrate) is not powerful enough to prevent aggregation at extremely high nanoparticle concentrations, thus decentralized stability decreases in these regions. Studies of dispersing agents that keep the nanoparticles widely dispersed at varying concentrations have therefore been widely documented. Substrates with thiol (R-SH) and phospine (P-R 3) functional groups, both of which are categorized as soft bases, have been shown to be effective dispersing agents, in accordance with the hard and soft acids and bases (HSAB) rule. Using 1-dodecanethiol as the dispersion agent in Au nanoparticle production, the 1-dodecanethiol molecule may create a monomolecular layer on the surface of the Au nanoparticles, and firmly stabilize the dispersed Au nanoparticles, according to early research published by Brust and coworkers. This publication has clearly had a large influence in the world of chemistry, as it is the third most referenced article in the history of the journal Chemical Communications. The reduction in steric hindrance and the rise in alkyl chain length from 1-dodecanethiol to alkyl chains of octane, decane, and hexadecane allow for larger nanoparticles. Because of this, 1-dodecanethiol is also utilized to regulate particle size. Research into polymer synthesis as dispersants has also been conducted. Here, the molecular weight of the polymer and the affinity of the nanoparticle surface are what establish the barrier's effectiveness.

**ELECTRICAL AND DIELECTRIC PROPERTIES OF BIO-NANOPARTICLES**

The astounding advancement in the field of microelectronics is responsible for the creation of nanotechnology. The number of transistors per microchip has increased exponentially since the integrated circuit was created in 1958, and this expansion has been accompanied by a reduction in the lowest wire width in electronic circuits. Due to the development of incredibly powerful computers and effective communication technologies, our daily lives have undergone a significant transformation. Natural and manufactured structures on the nanoscale scale, or in the range of 1 m to 10, are the focus of nanotechnology. In an ordinary solid, a line of five nearby atoms' distance from one end to the other is approximately equal to one nanometer (1 nm=109 m). These materials are outstanding and essential in many facets of human endeavor due to their special size-dependent characteristics. Any pharmacologically and systemically inert substance or mixture used for implantation into or integration with a biological system to augment or replace the activities of live tissues or organs is referred to as a biomaterial. A biomaterial must come into touch with live tissues or bodily fluids to accomplish that goal, creating an interface between living and non-living materials. Due to its extensive use in several medical specialties, bone as a tissue was chosen as the focus of the current inquiry. In addition to serving as protective coverings, bones also help in breathing and movement. Understanding of alterations in the surface chemistry of the implant and responses in the tissues is gained via in vitro and postmortem assessment of biomaterial surfaces and tissue material interfaces. While designing medical devices, the physiology, anatomy, biochemistry, and biomechanics of healthy tissues are taken into account. In this study, the most recent advancements in the field of applied nanomaterials—particularly their use in biology and medicine—are summarized. Solid substances like polymers, electrical insulators, computer boards, ceramic substrates, etc. will function well as dielectrics. The detection of explosives, plastic and metal weapons, narcotics, and chemical and biological substances may all be done with the use of dielectric measurements. For numerous industrial, scientific, and medical uses of microwave radiation, the dielectric measurements on a wide range of materials under various physical circumstances are necessary.

**LITERATURE REVIEW**

**Karma, Nikita & Siddiqui, Kamran & Harinkhere (2022)** Bi2O3 nanoparticles were created in the current study using the auto combustion approach (auto chemical method). The monoclinic crystal structure of the produced Bi2O3 nanoparticles (P21/c space group) was verified by the X-ray diffraction pattern. Dielectric characteristics are highly valuable and have a low loss factor. The de-trapping of charge carriers from various trapping locations causes a rise in ac conductivity.

Zirconum-based oxide nanoparticles with the general formulas Ba1-xPbxZrO3 and Ba1-xSrxZrO3 with dopant concentrations ranging from 0 to 1 are explored in Ubaidullah, Mohd, and Ahmad's (2022) study. There are now hundreds of different dielectric materials being produced.

Sharif, Adnan & Mustaqeem (2022) Due to the wide range of applications for polymer nanocomposites, including devices, limiting diodes, photodetectors, solar cells, and spin coating, significant progress has been made in their production. In the current work, Mg0.5Zn0.5Fe2O4 nanoparticles are used to include PVA nanocomposites into a mix. Mg0.5Zn0.5Fe2O4 nanoparticles were created using the micro-emulsion technique and then implanted into the PVA network using a liquid-phase process aided by ultrasound.

Sandeep, Yalagala, and Rambabu (2022) used a low-temperature citrate aided self-ignited technique to create the productive $Gd^{3+}$ substituted mixed $Ni_{0.7}Zn_{0.3}Gd_xFe_{2-x}O_4$ spinel ferric material (where = 0.000, 0.005, 0.010, 0.015, 0.020, and 0.025). By using XRD, SEM, EDX, and TEM inquiry, the structure, microstructure, and elemental investigation were evaluated.

Bhargava, Richa, and Khan (2020) used citric acid as a fuel in the sol-gel process to create pure $ZrO_2$ and $Zr_{0.9}Gd_{0.1}O_2$ nanoparticles. The structural and optical characteristics of the samples were assessed using X-ray diffraction, Fourier transform infrared spectroscopy, and dielectric spectroscopy.

**DI-ELECTRIC PROPERTIES OF ALZN TIO3 AND ALZNNI TIO3 NANO PARTICLES USING SOL-GEL POWDER**

With the proliferation of modern communication tools and electronic devices comes an increase in electromagnetic and microwave radiation pollutions. As a result, efforts are being made to develop materials that can block radiation and microwaves. Magneto plumbite hexaferrites are well suited for use as electromagnetic interference (EMI) suppressing and radar absorbent materials due to their low magnetic losses at gigahertz frequencies. You may categorize hexagons into six different types: M, W, X, Y, Z, and U. Complex hexaferrites may be built from structurally dissimilar $S(2MFe_2O_4)$, R ($Sr/Sr\ Fe_6O_{11}$), and/or T ($(Ba/Sr)_2\ Fe_8O_{14}$) blocks. However, their Gibbs free energy of synthesis and thermodynamic conditions for their production are identical. The stoichiometry of one Hexaferrite may lead to the formation of another Hexaferrite with a slightly different collection of structural blocks depending on the reaction mixtures utilized. X-type hexaferrites, which have low coercivity and high saturation magnetization, are among the most challenging to manufacture, but they are among the various varieties of hexagonal ferrites that are perfect for microwave absorption.

Perovskite materials, such as manganite $La_{0.70}Sr_{0.30}MnO_{2.85}$, are used in electronic devices due to their high quality physical and chemical properties, and the effects of magnetic fields and hydrostatic pressures on the magnetic properties and phase separation of perovskite materials have been studied by S.V. Trukhanov et al. But there's another group of oxide materials, including complex iron oxides, that show just as much promise for real-world use. Composites based on barium titanate ($BaTiO_3$) have found use in the manufacture of multilayer ceramic capacitors (MLCCs), sensors, actuators, permittivity thermistors, etc. $BaTiO_3$ has strong performance at high frequencies and is stable at high temperatures. $BaTiO_3$ is well-known for being an eco-friendly, lead-free perovskite. The manufacturing of dielectric nanocomposites has improved as a result of the growth in sophistication of electronic devices. UV/Vi's spectroscopy was used to investigate the optical qualities of the ceramic samples. Dielectric characteristics as a function of frequency and temperature were studied in relation to the amount of $Al_2O_3$ added to $BaTiO_3$ (by %wt.). For their potential usage as multilayer ceramic capacitors (MLCCs), the composites' dielectric characteristics have been extensively researched.

**CONCLUSION**

This study highlighted two key advantages of the sol-gel method: the low crystallization temperature (600 °C) and exceptional purity of the sg-ZT powders. The sg-ZT powders also have very small crystal sizes. A disadvantage was that the powder tended to clump together. This technique has a detrimental effect on the densification of the ceramics. Tests on attrition milling, ultrasonication, and pulverization were done in order to determine which method of deagglomeration was the most successful. The lack of agglomerates in the sg-ZTattr powder made densifying the ceramic easier. Additionally, a significant peak between 550 and 700 nm is visible in the UV/Vis spectra. According to Raman spectra, there is a peak at 900 nm that splits into $Al_2O_3$ and $BaTiO_3$. The FT-IR picked up several peaks at a very low wave number (900 cm-1) that were attributed to $Al_2O_3/BaTiO_3$. Ultimately, the temperature and frequency dependence of the dielectric properties were significantly influenced by the $Al_2O_3/BaTiO_3$ nanoparticles. Koop's theory suggests that the frequency- and temperature-dependent dielectric behavior of $Al_2O_3/BaTiO_3$ may be explained by the Maxwell-Wagner type of polarization. The dielectric constants as a function of temperature also demonstrate the phase change in $BaTiO_3$. Nanoscale $ZnTiO_3$ was created using the sol-gel method. The nanoparticles were studied using TGA/DTA analysis, X-ray diffraction, TMA analysis, and scanning electron microscopy. With crystallite sizes of 10 nm, sol-gel powders were discovered to have crystallized at 600 degrees Celsius. Most of the created $ZnTiO_3$ nanoparticles are clumped together, according to the SEM study. Sol was successful in creating ceramic nano-composites made of ($Al_2O_3/BaTiO_3$). According to experimental data, adding $Al_2O_3$ to $BaTiO_3$ caused the particle size and structure to shift from tetragonal (7–9 mm) to orthorhombic (400–600 nm). Between 550 and 700 nm in the UV/Vi spectrum, there may be a highly noticeable peak. Lastly, it was investigated how temperature and frequency affect the effect of $Al_2O_3$ nanoparticles on the dielectric properties. The dielectric characteristics of the composites have been extensively studied for their prospective use as multilayer ceramic capacitors in electrical devices.

Using barium acetate and titanium isopropoxide as the starting ingredients, the sol-gel process was effectively used to create $BaTiO_3$ nanoparticles with a particle size in the range of 30-35 nm. The produced nanoparticles were tetragonal and almost spherical, as demonstrated by the XRD and TEM data, and SAED further demonstrated the crystal nature of the particles. Due to the poor tetragonality of our sample, the DSC curve exhibited no clear peak and the TGA curve revealed a little weight loss in the temperature range of 25–1000oC. Little impurities were visible in the FTIR spectrum, and UV-Vis spectroscopy revealed that the band gap for $BaTiO_3$ nanoparticles was shrinking. Dielectric and electric tests showed that the Curie temperature had changed from 130°C to somewhere around 50°C, which was caused by a number of reasons that were discussed in the paper. The tetragonal phase was confirmed by XRD and TEM measurements. The prepared sample was further characterized by TGA, DSC, FTIR, UV-Vis and PL spectroscopy. The obtained nanoparticles were quasi-spherical in shape with particle size lying between 30 nm and 35 nm, as obtained by TEM. The low tetragonality of the obtained nanoparticles was confirmed by XRD and TEM. Raman modes in perovskite are closely connected with a particular lattice vibration, revealing details about changes brought on by chemical substitution in the substance. In order to address these flaws, $BaTiO_3$ based nanomaterials were created in this study that could either induce or suppress charge (i.e., vacancies at the B-site). Raman spectroscopy is utilized in addition to the phase transition to assess any potential Fe ion occupancy. According to Raman spectra, a minor quantity of Fe is present in place of a Ti ion with a higher doping concentration. $BaTi_{1-x}Fe_xO_3$ ($x$ = 0.0, 0.05, 0.10) materials exhibit a reduction in dielectric constant with increasing Fe content. An increase in Fe doping is indicated by the abrupt transition peak from the ferroelectric to paraelectric phase widening. Without much dielectric loss to sustain it, the influence of an ideal quantity of Fe on ferroelectric behavior is seen and noted. The $BaTi_{1-x}Fe_xO_3$ ($x$ = 0.05, 0.10) materials exhibit a mixed ferromagnetic and antiferromagnetic unsaturated hysteresis loop. Configuring the characteristics of the Fe valance state, or $Fe^{3+}$, with the use of XPS spectroscopy opens the door to developing a magnetic state mechanism. The occupied Fe ions at the B-site cause ferromagnetic effects by reducing the bond angle between Fe-O-Fe in the Ti-O sub lattice. The ferroelectric and magnetic phases are found in $BaTiO_3$ with an ideal Fe content. For some multiferroic applications in the samples at hand, ferroelectric and magnetic ordering makes sense.

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