Impact of Biofield Treatment on Atomic and Structural Characteristics of Barium Titanate Powder

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Abstract
Barium titanate, perovskite structure is known for its high dielectric constant and piezoelectric properties, which makes it interesting material for fabricating capacitors, transducer, actuator, and sensors. The perovskite crystal structure and lattice vibrations play a crucial role in its piezoelectric and ferroelectric behavior. In the present study, the barium titanate powder was subjected to biofield treatment. Further, the control and treated samples were characterized using X-ray diffraction (XRD) and Fourier transform infrared spectrometer (FT-IR) and Electron spin resonance (ESR). The XRD analysis showed the permanent compressive strain of 0.45% in treated barium titanate powder as compared to control. Furthermore, the biofield treatment has enhanced the density upto 1.38% in barium titanate as compared to control. The FT-IR spectra showed that the stretching and bending vibrations of Ti-O bond in treated BaTiO3 were shifted towards lower frequency as compared to control. The bond length was substantially increased by 0.72 % in treated BaTiO3 as compared to control. The ESR spectra of control and treated BaTiO3 sample showed the g-factor of 2.0, and biofield treatment has substantially changed the width and height of ESR signal in treated BaTiO3 as compared to control. These observations revealed that biofield treatment has significantly altered the crystal structure, lattice strain, and bond vibration of barium titanate.

Keywords: Biofield treatment; Barium titanate; Fourier transform infrared; X-Ray diffraction; Electron spin resonance

Introduction
Piezoelectric materials are commonly used in optoelectronic industries in fabricating sensor, capacitor, and actuator owing to their piezoelectricity and wide range of dielectric constant. In these materials a strong relationship exists between mechanical displacements and electric field i.e. it induce electric polarization in response to applied stress and strained in response to applied electric fields. The perovskite structure, ABO3 type material usually exhibits spontaneous polarizations in response to mechanical stress [1]. Additionally, this perovskite structure is promising in positive coefficient (PCT) resistors, light-emission devices, and field emission displays (FEDs) [2]. The perovskite, barium titanate (BaTiO3) has recently gained significant attention due to its demand for lead-free piezoelectric materials in several industries. In addition to that, the perovskite structure of BaTiO3 attracted significant attention due to its exceptional dielectric, piezoelectric, and electro optic properties [3]. These exceptional properties make it a promising material for other applications such as multilayer ceramic capacitors (MLCCs), dynamic random access ferroelectric memories (DRAMs) [4]. This material requires non-centrosymmetric crystal structure to behave as piezoelectric, because its centrosymmetric cubic crystal structure doesn’t show piezoelectricity, whereas hexagonal, tetragonal, orthorhombic, and rhombohedral shows due to their non-centrosymmetric structure [1]. In BaTiO3, the piezoelectricity is highly depends upon its crystal structure, lattice vibration, and grain size etc. Furthermore, in order to alter its piezoelectric and ferroelectric properties, many researchers have used various doping methods to modify the dielectric and piezoelectric properties [5,6]. Recently, it was reported that distortion in perovskite BaTiO3 reduced symmetry, which enhanced its magnetic and electrical properties [7]. Moreover, Chernova et al. demonstrated that strain induced in BaTiO3 unit cell enhanced its ferroelectric polarizations [8]. Thus, after considering the vast importance of BaTiO3 and its crystal structure in several applications, authors wish to investigate an approach that could be beneficial to modify the atomic and structural properties of BaTiO3 powder.

William Tiller, a physicist, reported that the existence of a new force related to human body, in addition to four well known fundamental forces of physics such as gravitational force, strong force, weak force, and electromagnetic force [9]. Biophysicist Fritz-Albert Popp et al. reported that human physiology shows a high degree of order and stability due to their coherent dynamic states [10-13]. This coherent dynamic state of human body emits the electromagnetic waves in form of bio-photons, which surrounds the body and it is known as biofield. Therefore, the biofield consisting of electromagnetic field, generated by moving electrically charged particles (ions, cell, molecule etc.) inside the human body. Furthermore, a human has ability to harness the energy from environment/universe and can transmit into any object (living or non-living) around the Globe. The object(s) always receive the energy and responded into useful way that is called biofield energy. This process is termed as biofield treatment. Mr. Trivedi’s unique biofield treatment is known as The Trivedi effect®. Mr. Trivedi’s biofield treatment is known to alter the crystal structure and atomic level changes in various ceramics and metals [14-21]. Additionally, the biofield treatment has also transformed the molecular and cellular properties in agriculture [22-24], microbiology [25-27] and biotechnology [28,29]. Recently, it was reported that biofield treatment had increased the particle size by six fold and enhanced the crystallizate size by two fold in zinc powder [14]. In another report,

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biofield treatment has shown the significant effect in carbon allotropes, where the unit cell volume was decrease by 1% and crystallite size was increased by 100% [15]. To the best of our knowledge, this is the first report to evaluate the impact of biofield treatment on atomic and structural characteristics of BaTiO3 powder.

Materials and Methods

BaTiO3 powder was procured from the Sigma-Aldrich (MA, USA). The powder sample was divided into two equal groups i.e. control and treatment. The control group was remained as untreated and treatment group was subjected to biofield treatment.

Biofield treatment

The treatment group was handed over in sealed pack to Mr. Trivedi for biofield treatment under standard laboratory condition. Mr. Trivedi provided this treatment through his energy transmission process to the treatment group without touching the samples. After that, both control and treated samples were characterized using X-ray diffraction (XRD), Fourier-transform infrared spectrometer (FT-IR) and Electron spin resonance (ESR).

X-ray diffraction study

For XRD analysis, treated sample was further divided into two parts as T1 and T2. XRD analysis was carried out using a Phillips, Holland PW 1710 XRD system, which had a copper cathode with nickel filter. The wavelength of X-ray radiation used was 1.54056 Å. The data obtained from the XRD was in the form of chart of intensity vs.2θ° with a detailed table containing d value (Å), number of peaks, peak width 2θ°, peak count, and relative intensity of peaks, etc. The lattice parameter and unit cell volume were computed using Powder X software. The molecular weight was calculated as the sum of atomic weight of all the atoms present in a molecule. The atomic weight was calculated as the sum of the weight of all protons, neutrons and electrons present in the atom. The weight of the unit cell was calculated as: atomic weight multiplied by the number of atoms present in a unit cell. The density of the unit cell was computed as ratio of unit cell weight to unit cell volume. The percentage change in the unit cell volume was calculated using the following equation:

\[ \% \text{ change in unit cell volume} = \left( \frac{\Delta V}{V_c} \right) \times 100. \]

Here, \( \Delta V = (V_t - V_c) / V_c \) where \( V_t \) and \( V_c \) are the unit cell volume of treated and control samples, respectively. The percent change in all other parameters such as density, molecular weight, and lattice parameter were calculated in the similar way.

Fourier transform infrared spectroscopy

Both, control and treated BaTiO3 were characterized using Shimadzu, Fourier transform infrared (FT-IR) spectrometer with frequency range of 300-4000/cm.

Electron spin resonance spectroscopy

ESR analysis of control and treated BaTiO3 samples were carried out on E-112 ESR spectrometer of Varian USA of X-band microwave frequency (9.5 GHz), which had sensitivity of \( 5 \times 10^{10} \), \( \Delta H \) spins was used to analyze the electron spin properties.

Results and Discussion

X-ray diffraction study

XRD pattern of control and treated BaTiO3 are shown in Figure 1. The peaks were observed at 2θ=22.0°, 31.3°, 38.70°, 45.11°, 50.72°, 55.97°, and 65.8° in control Figure 1a, which indexed for tetragonal crystal structure of BaTiO3 as per Joint Committee on Powder Diffraction Standards (JCPDS) 05-0626. Furthermore, diffraction peaks were observed at 2θ=22.13°, 23.9°, 31.5°, 38.9°, 45.2°, 50.8°, 56.1°, and 65.8° in T1 (Figure 1b), and 22.0°, 23.9°, 31.5°, 38.8°, 45.2°, 50.9°, 56.2°, 65.8° in T2 (Figure 1c). In addition, lattice parameter and unit cell volume of control and treated samples were computed using Powder X software and result are presented in Table 1. It was found that the
To its original shape and become unstrained [30]. On the contrary, in this experiment the lattice strain was permanent, i.e. the unit cell was permanently distorted after biofield treatment. Thus, it is postulated that biofield treatment acting at atomic level to induce this permanent strain in BaTiO3. Additionally, it was also observed that the molecular weight was reduced upto 1.36% after the treatment, which indicates that the biofield treatment possibly acting at nuclear level to cause these changes. Furthermore, Y. Tanaka et al. demonstrated that compressive strain in BaTiO3 increased the remnant polarization and reduced the dielectric permittivity that enhanced the piezoelectric coefficient [31]. In addition to that, this compressive strain found in treated BaTiO3 may lead to reduce the symmetry of the crystal structure. The reduction in symmetry probably enhanced the piezoelectric properties in treated BaTiO3 as compared to control [8,9].

<table>
<thead>
<tr>
<th>Lattice parameter (Å) % change</th>
<th>Unit cell volume (cm³) % change</th>
<th>Density (g/cc) % change</th>
<th>Mol. Wt. (g/Mol) % change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.030</td>
<td>6.55 × 10⁻²³</td>
<td>5.954</td>
</tr>
<tr>
<td>Treated T1</td>
<td>4.010</td>
<td>-0.45</td>
<td>6.46 × 10⁻²³</td>
</tr>
<tr>
<td>Treated T2</td>
<td>4.015</td>
<td>-0.43</td>
<td>6.47 × 10⁻²³</td>
</tr>
</tbody>
</table>

*Table 1: X-ray diffraction analysis result of barium titanate powder.*
Where, $c=$ speed of light (cm/s), $\mu=$ effective mass of Titanium and oxygen, which can be calculated as given below:

$$\mu = \frac{M_T \times M_O}{M_T + M_O}$$  \hspace{1cm} (2)

Where, $M_T=$ Atomic mass of titanium (Kg), $M_O=$ Atomic mass of oxygen (Kg), $\nu=$ IR wavenumber (/cm).

The bond force constant ($k$) is related to average bond length ($r$) by following equation [34]:

$$k = \frac{17}{r^3}$$  \hspace{1cm} (3)

The bond length and force constant were calculated using equations (1) and (3), respectively, which are illustrated in Figure 8. Data showed that bond force constant was reduced from 2.24 N/cm (control) to 2.19 N/cm (treated) after biofield treatment. It suggest that bond force constant of Ti-O was significantly decreased by 2.12% in treated BaTiO$_3$ as compared to control (Figure 9). Furthermore, bond length of Ti-O

<table>
<thead>
<tr>
<th>IR Absorption Peaks (cm$^{-1}$)</th>
<th>Stretching Vibration (Ti-O)</th>
<th>Bending Vibration (Ti-O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>565</td>
<td>441</td>
</tr>
<tr>
<td>Treated</td>
<td>557</td>
<td>430</td>
</tr>
</tbody>
</table>

**Table 2:** FT-IR Stretching and bending vibration frequency of Ti-O bond in barium titanate powder.

![Figure 5: FT-IR spectrum of biofield treated barium titanate powder.](image)

![Figure 6: Stretching and bending vibrations of Ti-O bonds in BaTiO$_3$.](image)

![Figure 7: Effect of biofield treatment on the stretching and bending vibration frequency of Ti-O bond of barium titanate powder.](image)

![Figure 8: Bond force constant and bond length result of Ti-O bond in control and biofield treated barium titanate powder.](image)

![Figure 9: Effect of biofield treatment on bond force constant and bond length of Ti-O in barium titanate powder.](image)
which may occur due to electromagnetic field transferred through biofield treatment. This permanently strained crystal structure of BaTiO₃ led to alter its piezoelectric behavior. The FT-IR analysis result revealed that Ti-O bond length in BaTiO₃ was increased by 0.72% after biofield treatment as compared to control. Therefore, these findings indicate that biofield treatment may be acting at atomic level of BaTiO₃ to cause these modifications. Furthermore, the variation observed in width and height of ESR spectra, which suggest that particle size of treated BaTiO₃ might be altered through high energy milling process. Hence, it is hypothesized that biofield treatment has induced the electric and magnetic field that can affect the BaTiO₃ powder at electronic and atomic level. To conclude, the biofield treatment could be applied to alter the crystal structure and piezoelectricity of BaTiO₃ powder.

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