International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 11
November 2017

Impedance and Dielectric Modulus Analysis of PCT Nanoparticles

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ABSTRACT
The lead cobalt titanate (PCT) nanoparticles are synthesized via the sol-gel technique and further microwave heated at 750°C for 45 minutes. Formation of lead cobalt titanate (PCT) phases is confirmed by using X-Ray diffraction study and the average crystallite-size is found to be of order of nanometer range. The impedance and real (M') and imaginary part (M") of dielectric modulus are investigated as a function of frequency.

KEYWORDS: Nanoparticles; X-ray Diffraction; Impedance Spectroscopy; dielectric modulus;

1. INTRODUCTION:
Nanoparticle synthesis techniques have got more significance than the bulk synthesis techniques owing to their versatile and potential applications in biomedical sciences, sensors, nanofibers, carbon nanotubes, quantun dots, dielectric, ferroelectric and piezoelectric properties [1]. Lead titanante (PT) is a ternary oxide with noteworthy ferroelectric nature which exhibits the Curie transition temperature of ~ 763 K [2]. The PT pedestal ceramic materials can be extensively used as electronic devices like multilayer capacitors and ultrasonic transducers because of the large pyroelectric coefficient and diminutive assessment of dielectric constant [3]. These PT nanoparticles were geared up by various techniques like sol-gel method, hydrothermal method and solid-state reaction method [2]. The morphological results of above mentined methods articulated that the $PbTiO_3$ particles were mostly in nonspherical shape such as tabular, plate and cube shape [2]. The PT based complex perovskite ceramics like lead zirconium titatante (PZT) [4] and lead strontium titanante (PST) [5] have been comprehensively probed due to their exceptional electrical properties for charge stored capacitor, transducer and actuator applications. In particular, the bulk PZT works as a ferroelectric material [4] while the bulk PST is well-populared glass ceramic material [5]. At some stage in the vast literature survey made by the instigators, very limited reports were found on divergent properties of magnetic element doped PT. For that reason, an intension has been made to look into the outcome of magnetic cations (cobalt) in the PT structure via microwave heated sol-gel synthesis method.

2.EXPERIMENTAL PROCEDURE
The lead cobalt titanate (PCT) ceramic is synthesized by using sol-gel method. First all the starting materials are weighed on a sensitive digital weighing balance according to their stoichiometric ratio. Glacial acetic acid is used as the solvent. The glacial acetic acid solution was taken in a beaker which is kept on a magnetic stirrer for persistent mixing of the content. Then $Pb(CH_3CoO)_2$ is added to the glacial acetic acid solution and

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stirrer well until Pb $(CH_3CoO)_2$ gets dissolved. After that $Co(NO_3)_2$ $6H_2O$ is added. Temperature is maintained at 50°C throughout the process. After about thirty minutes, Ti (OC_4H_9) is added drop by drop using a rubber head dropper. The whole solution is allowed to mix thoroughly for 2 hrs. Using a burette, solution of ethanol and water is introduced into the above solution. After few hours a gel like solution is acquired. This gel is dried naturally for forty eight hours and then using a hot air oven for about one hour. In this way a rigid crystal form is obtained which is grinded into a fine powder. The powder achieved is then sintered using a microwave furnace at 750° C for 45 minutes. After sintering, the crystalline powder is again grinded into a fine powder.

3. RESULTS AND DISCUSSIONS

STRUCTURAL ANANLYSIS

Fig.1 illustrates the diffraction pattern of PCT nanoparticles prepared via microwave heated sol-gel technique. This implies that the structure of PT is not changed upon the doping of cobalt cations. The maximum intensity of 2229 counts was noticed for the reflection plane of (101).

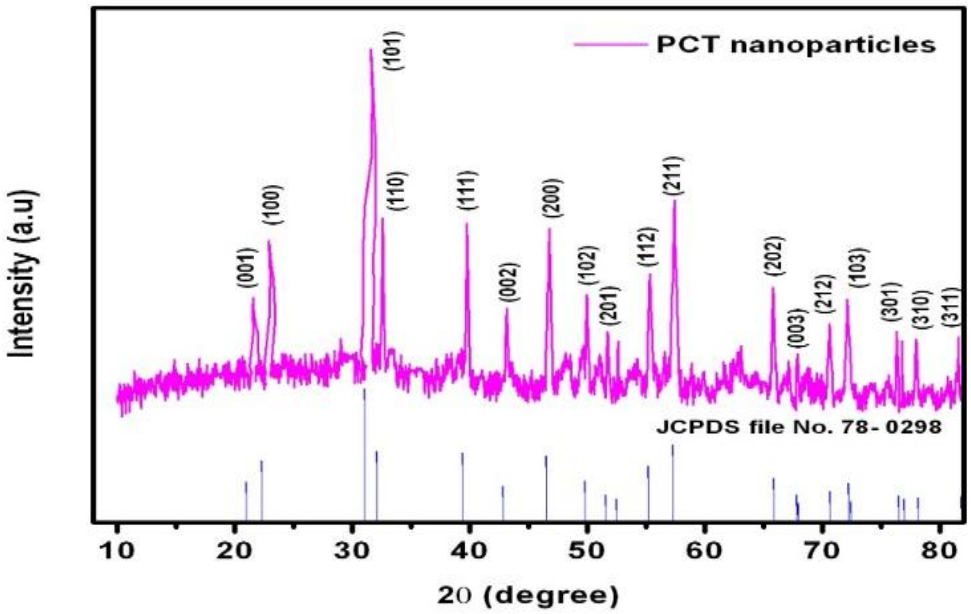

Fig.1. XRD pattern of PCT nanoparticles

The bulk density of PCT decreased upon doping the cobalt element. It can be accredited to the diminish of molecular weight of PT thereby cobalt toting up. In addition the specific surface area is a distinguishing physical property of bulk and nano materials. Basically bulk materials will have petite value while nanomaterials will have large surface area [6] that may affect effectively the electrical and ferroelectric properties of nanomaterials. The largest specific surface area (S) of PCT was acquired to be of 107.32 m^2/g.

DIELECTRIC MODULUS AND IMPEDANCE ANALYSIS:

Thedielectric modulusformalismiswrittenas$M = M^I + JM^{I.}$,*whe* $M^I = \left(\frac{\varepsilon^I}{\varepsilon^{I2}+\varepsilon^{I.2}}\right)$ *a* $M^{I.} = \left(\frac{\varepsilon^{I.}}{\varepsilon^{I2}+\varepsilon^{I.2}}\right)$aretherealandimaginaryparts[7]. The frequency dependence of M^I and $M^{I.}$ PCT nanoparticles are depicted in figure (2). Itis evidentfromtheplotsthattherealpartofallcompositionsisverysmallatsmallerfrequenciesand isrisingwithfrequency.

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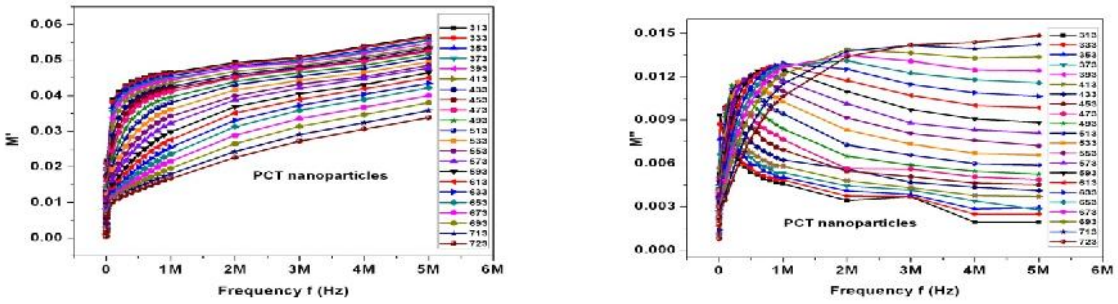
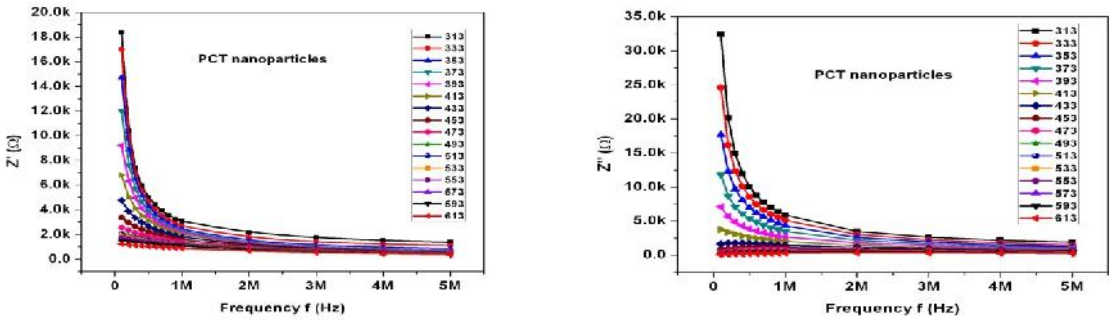


2. (a) **2. (b)**

Frequency dependence of (a) real part (M^{I}) (b) imaginary part (M^{II}) of dielectric modulus.

Impedanceanalysis of PCT nanoparticles iscarriedoutfromNyquistplots, whichareusedtoprobeelectricalconductionasafunctionofmicrostructurevariation.Fromthe figure (3),itisconfirmedthattheelectricalconductionmaybesolelyhappened throughgrainorbulk.However,slightdistortionsareseenfromthe Nyquistplots [7].Thesedistortions mayperhapsbeduetovariationofgrainsize distribution,stress,strain,volumefractionand improperatomicarrangementatgrainandgrainboundarywhich lead toincreaseofelectronscattering.



3.(a) **3.(b)**

Impedanceanalysis of PCT nanoparticles

CONCLUSIONS

The lead cobalt titanate nanoparticles are synthesized via the sol-gel technique and further microwave heated at 750ºC for 45 minutes. The diffraction study revealed the formation of $PbCoTiO_3$ phases. The average crystallite-size is found to be in nano range.Thedielectric modulusisverysmallatsmallerfrequenciesand isrisingwithfrequency.Impedanceanalysis of PCT nanoparticles iscarriedoutfromNyquistplots.

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