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ORIGINAL CONTRIBUTION

Fabrication of optimized remote thermal sensors for determining the temperature of hazardous chemicals using La modified PZT electro nano ceramics

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ABSTRACT

The work presented in this paper focuses on the structural and electrical characterization of La doped PZT (70/30) by sol gel technique. The structural characterization of doped and undoped material is extensively carried out by SEM and XRD techniques followed by detailed study and analysis of dielectric values and its variations with respect to temperature. It is hereby proposed that La modified PZT(70/30) material with varying concentration of La can prove to be excellent material for the fabrication of thermal sensors which can appropriately measure remotely the temperature of stored hazardous chemicals and its variation without any need of conventional physical contact with the stored chemical concerned, thereby proving its merit in the field of sensors and their applications.

KEYWORDS: PZT nano ceramics, temperature sensors, XRD, sol-gel technique.

1. INTRODUCTION

Lead Zirconium Titanate (PZT) Pb [$Zr_xTi_{(1-x)}$]O_3 Electro-Piezo Ceramic system, discovered by Jaffe et. al. finds vast and wide range applications in the field of electrical and electronics Engineering as smart structures[1],memory devices[1,2], piezoelectric electromechanical actuators[3], high sensitivity compact sensors[4] and ceramic capacitors[4,5] of various configurations, shapes and sizes, due to its well known piezoelectric properties for different values of x, where x <1. Since its discovery about four decades back, it has always remained a point of attraction for various researchers and scientists because of its highly modifiable piezoelectric and dielectric properties, obtainable by replacing either whole or a part of the host atom in ABO_3 type perovskite structure of PZT, by external foreign ions [6]. Analogous to semi-conductors; these foreign ions are also called dopants, broadly classified as isovalent, acceptors, and donors. The PZT system is still under extensive research and experimentation for further improvement in its piezoelectric properties as well as in the application scenario. It has been reported by many authors and researchers that significant changes can be achieved by addition of various dopants in PZT with a view to their dielectric and piezoelectric properties [6]. La is one of the widest accepted hard dopant for PZT nano ceramic systems generally used to enhance the material's temperature sensing capacity. The synthesis of $Pb[Zr_{0.7}Ti_{0.3}]O_3$ nanoceramics is mainly carried out by Sol-Gel process with the raw materials Lead Acetate Trihydrate $Pb(CH_3COO)_2.3H_2O$ (Merck), Zirconium Propoxide $Zr(C_3H_7O)_4$ (Aldrich) and Titanium iso-Propoxide $Ti[(CH_3)_2CHO]_4$ (Aldrich). The virgin PZT powder obtained from the Sol-Gel process is mixed with 1.75 and 3.15 weight percent of La (from La_2O_3, Merck USA) followed by suitable calcination at 950^OC to prepare the

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appropriate La modified PZT powder which are transformed into cylindrical pallets of 9.0 mm diameter and 1.35 mm thickness using a hydraulic press at 120 psi. The ceramic discs obtained are coated with silver on both sides by VPD process to produce a capacitive structure in its design.

2. METHODOLOGIES, RESULTS AND DISCUSSIONS

1: Sensor Material Characterization

The developed virgin PZT (70/30) and the La modified nano ceramic material are intensely subjected to structural analysis for studying the compactness and lattice structure using Scanning Electron Microscopy and X Ray Diffractometry tools. The studies provide the foundation of determining the suitability of the structures for fabrication of non contact type thermal sensors. The XRD graph with 1.75% doped sample clearly shows the inclusion of La ions in correct and predetermined position of the crystal lattice as shown in the fig 1. As remote temperature sensing with definite precise level of sensitivity depends on compactness of the sensing material, detailed comparison of SEM micro photographs are carried out to determine the same. Introduction of La+ ions as dopants increase the compactness as evident from the fig 2 and fig 3. However it is worth mentioning higher concentration of La doping causes deformation of the crystal structure as noted from the peak splitting effect in the XRD graph shown in fig 4. This will cause induction of non linearity in measurement of any physical parameter including temperature.

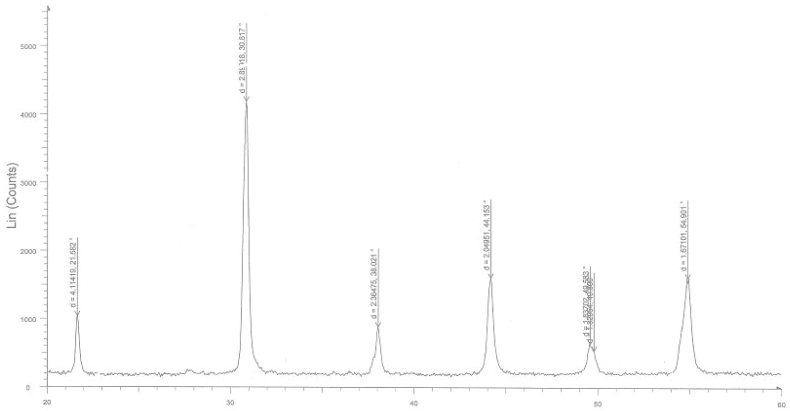


Figure 1: XRD graph of 1.75 % La modified PZT showing inclusion of La ions in precise lattice position

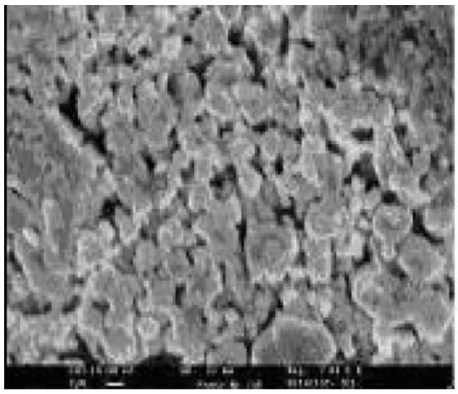


Figure 2: SEM Micrograph of PZT (70/30) magnification of 4K

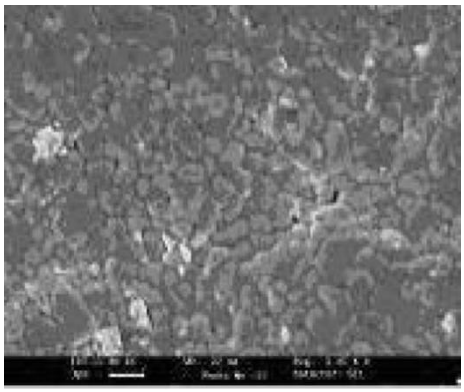


Figure 3: SEM micrograph of 1.75% La at a modified PZT (70/30) at a magnification of 4K

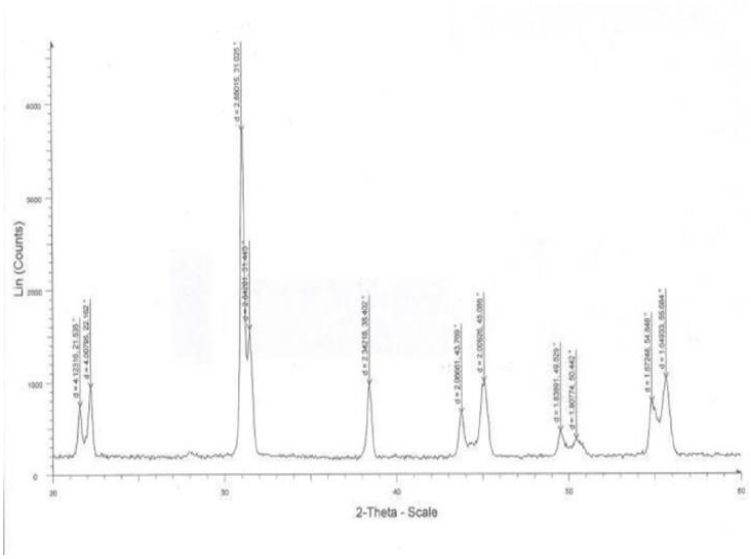


Figure 4: XRD graph of 3.15% La modified PZT showing peak splitting effect

2: Sensor Calibration and Temperature Detection

Fig 5 shows the La modified PZT capacitive configuration sensors developed on lab scale for remote detection of the temperature and its related fluctuations of a radiating container with hazardous chemical. The sensors are subjected to measurement of the variation in dielectric constant with temperature using an isotropic thermal radiator having a controlled radiating temperature ranging from 37.5^{O}C to 103.3^{O}C. This is very important aspect and its plays a key role in sensing.The developed capacitive sensors are placed at a radial distance of 120 mm (12 cm) from the radiator within a controlled atmosphere lab having a temperature of 25^{O}C and RH < 80%. The variation of 'K' with radiating temperature is plotted as shown in fig 6. As already discussed in the previous section the variation of K shows considerable linearity within the temperature of the radiating chemical container for 1.75 % La modified PZT sensor as compared to 3.15% modified sensor, thereby making it more suitable and sensitive to temperature fluctuations of the stored chemical. The actual temperature being recorded using a standard industrial grade thermocouple.



Figure 5: Fabricated sensor in capacitive configurations using La modified PZT (70/30)

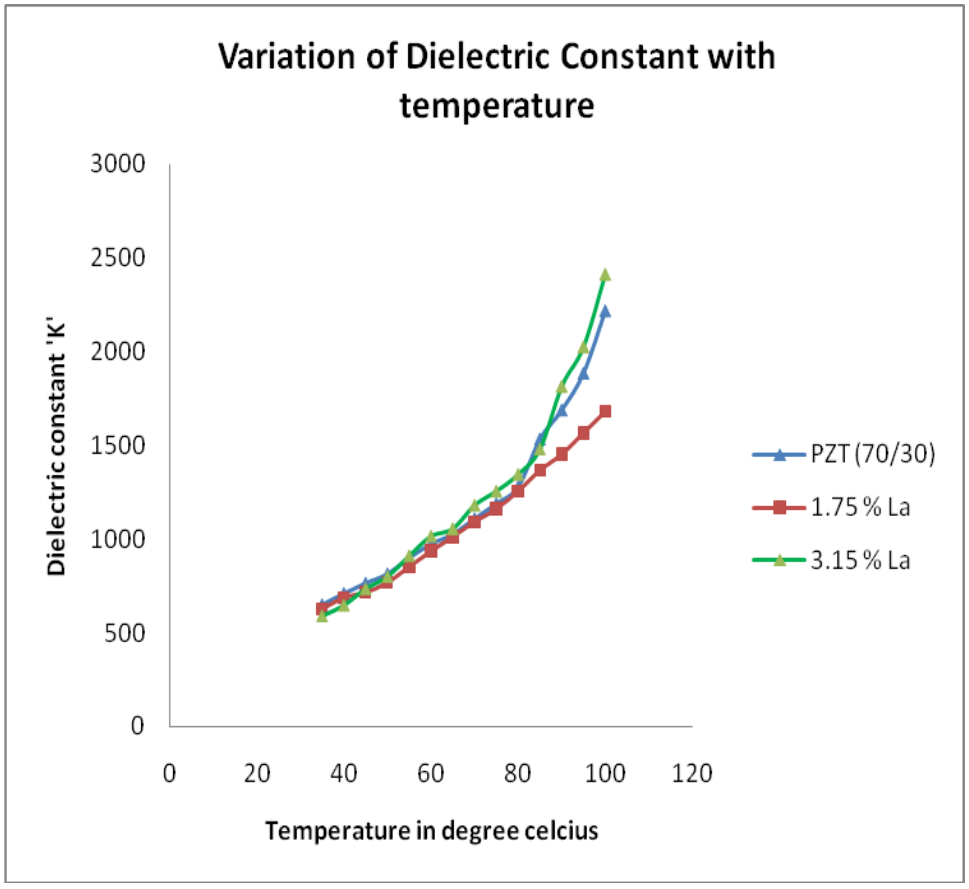


Figure 6: Variation of dielectric constant 'K' with simulated chemical container

3: Sensor Designing

In order to measure the temperature and its variation with accuracy in the isotropic radiator simulating the chemical container; the capacitive sensors fabricated can be easily

incorporated in an electronic circuit where variation in K can be directly calibrated for change in temperature. The overall power consumption can be restricted to less than 12 watt if the overall distance of 12 cm is maintained between the radiator and the sensing element. This also ensures low level of power consumption for such designed sensor and is certainly a great advantage in this context.
Fig 7 shows the circuit diagram for the entire measurement setup that employs nano ceramic variable capacitive sensor.

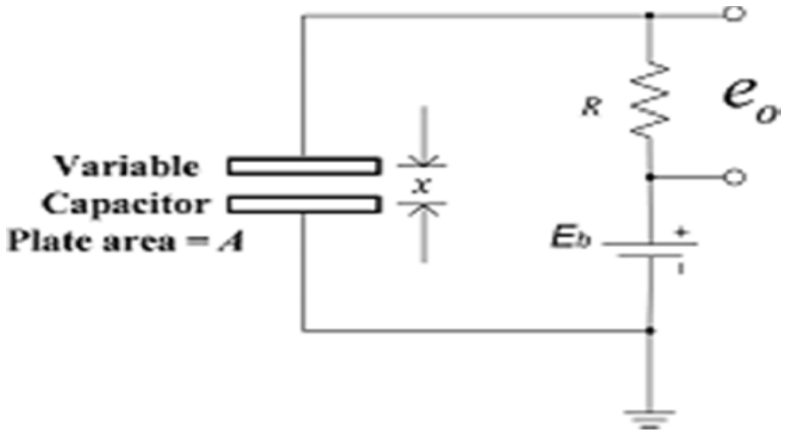


Figure 7: The circuit diagram of incorporating the nano ceramic variable capacitive sensor

3. CONCLUSION

It is hereby concluded that 1.75% La modified PZT electro nano ceramic material developed is one of the optimal La doping levels, best suited for non contactual remote measurement of temperature for hazardous chemicals stored in industries and factories. The lower doping level concentration further ensures the desired compactness of the sensing element proposed along with preserving its linearity and sensitivity to temperature changes. The variations observed aptly justify the role of PZT being used for sensor applications. The method proposed in this paper is expected to be of immense help to field engineers, researchers and technicians in avoiding direct contact with hazardous chemicals or acids. Besides, very less power consumption makes the system portable and considerably compact for ease of mounting and transport simultaneously.

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