Development and Performance Evaluation of Piezoelectric-Polymer based Composite materials for Automatic Sensing

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***Abstract*-Energy is very important factor because everyone uses it in various forms in this society .When conservation of energy is done; savings on the cost of living is achieved. Study of various piezoelectric forms or the sources of Energy and its characteristics are very important to develop piezoelectricity because it is most easily available forms, cost effective aspect and nature friendly form. Composite material is the material which is developed of amalgam of variety of materials such as fibers, metal, non metal, powders, compounds etc.**

Here, in this research review paper it has been illustrated to develop a polymer based piezoelectric composite by utilizing crystal compounds , natural fibers and to analyze mechanical, electrical and mechanoelectronic performance and to analyze mechanical, electrical and mechanoelectronic performance of Lead Zerconium Titanate(PZT), Barium Zerconium Titanate (BZT) by blending with matrix reinforced with PVDF,graphite in the forms of fibers and powder which is later synthesized into solid form using electrospining, hot drawing process and powder synthesis form using milling and sintering process. The piezoelectric form of material which is developed, which is further characterized by solid state reaction and poling methods. Later the piezoelectric material is further synthesized with acoustic emissivity Sensors to sense and detect force and its displacement in typical industrial sensing application can be detected.

***Keywords:* Piezoelectric, Lead Zerconium Titanate, Barium Zerconium Titanate, Electrospinning, Composite, Polymer, Acoustic Emissivity, Sensors.**

I. INTRODUCTION

Mankind has been aware of composite materials since several hundred years before Christ and has applied innovations to improve the quality of life. Contemporary composite materials have been resulted from research and innovations from the past few decades, which have been progressed from glass fiber for automobile bodies to particulate composites for aerospace and a range of other applications. Composites that form heterogeneous structures which meet the requirements of specific design and function, imbued with desired properties, which limit the scope for classifications. However, this lapse is made up for, by fact that new types of composites are being innovated all the time, each with their specific purposes like the filled, flake, particulate and laminar composites. Fibers or particles embedded in the matrix of another material would be the best example of modern-day composite materials, which are mostly structural. In matrix based structural composites, the matrix serves to paramount purpose viz., binding the reinforcement phase in place and deforming to distribute the stress among the constituent reinforcement materials under an applied force. The demands on matrices are many. They may need to withstand temperature variations, be conductors or resistors of electricity, have moisture sensitivity etc.

They may offer weight advantages, ease of handling and other merits which may also become applicable demanding on the purpose for which matrices are chosen. Solids that accommodates stress to incorporate other constituents and provide a strong bond for the reinforcing phase or potential matrix materials. A few inorganic materials polymers and metal have found applications as matrix materials in the designing of structural composites, with commendable success. These materials remain elastic till failure occurs and show decreased failure strain, when loaded in tension and compression. Composites cannot be made from constituents with divergent linear expansion characteristics. Poling is the process where piezoelectric materials is very similar to magnetization of magnetic material wherein sufficiently large magnetic field is applied in order to align internal magnetic dipoles moments. After removal of magnetization field the dipoles holds the orientation gained by the magnetization.

The interface is the area of contact between the reinforcement and the matrix materials. In some cases, the region is a distinct added phase. Whenever there is interphase, there has to be two interphases between each side of the interphase and its adjoint constituent. Some composites provide interphases when surface of dissimilar constituent interact with each other. Choice of a fabrication methods depend on the matrix properties and the effect of matrix on the properties of reinforcement. One of the prime considerations in the selection is as follows.

This review paper proposes development and performance evaluation piezoelectric polymer composite materials for automatic sensing application which will enhance for the low cost, ease availability, synthesis of the materials through powder blending of d dielectric property materials, grinding etc which will improve the piezoelectric property wherein that characteristics will enhance to measure the strain or force applied on the system very effectively and fastly.

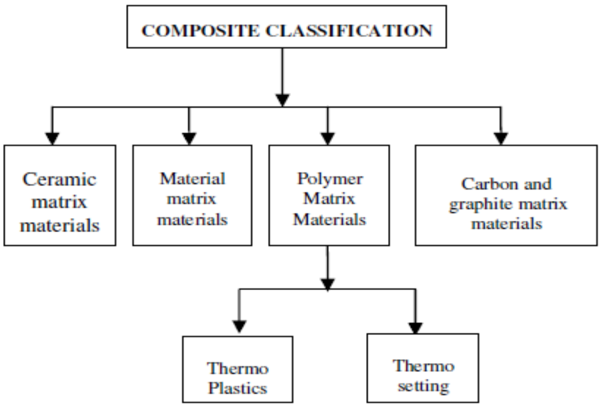

Figure 1. Block Diagram of the Composite material

II. OBJECTIVES

1. To develop a polymer based piezoelectric composite material by utilizing crystal compounds and natural fibers.
2.To analyze mechanical, electrical and mechanoelectronic performance test evaluation of the developed polymer based composite.
3. To evaluate the piezoelectric behavior of the developed set of composites for typical force sensing and detection application by utilizing Acoustic Emissive sensor setup which is developed from piezoelectric materials.
4. To develop efficient, low energy consumption and cost effective composite piezoelectric material.

III. PROBLEM STATEMENT

Most conventional system of detecting and sensing parameters such as force, pressure, wear of material, is measure using conventional measurement gauges which is of pure mechanical form. These mechanical gauges may not be able to measure and detect force, pressure, sound vibrations accurately as it may cause disturbances due to mechanical inaccuracies. Due to this it may not be able to give accurate and reliable output as a result. It also needs periodical maintenance of mechanical gauge components.
So in this direction there was a need to develop piezoelectric based composite from low cost, easily available compound to investigate force sensing and detection system known as acoustic emissivity sensor system. Due to this it can sense and detect force applied as the acoustic emissivity wave transfer from the piezoelectric source to electric wave for signals which can give accurate output with low energy consumption.

IV. PROPOSED SYSTEM

The proposed system to develop and performance evaluation of piezoelectric material and detail analysis of various characteristics both crystals and natural fibers is performed.

Selection of natural crystals, compounds and fibers reinforcements which has got very relevant information from literature survey is studied. Later stage, Identification of suitable compounds and polymeric resins towards successful synthesis of composites with relevant matrix and binders is performed Development and synthesis of a set of natural crystals and fibers reinforced composites by handlay up method, hot streaching, electro spinning technic procedures is to be performed. Testing to evaluate

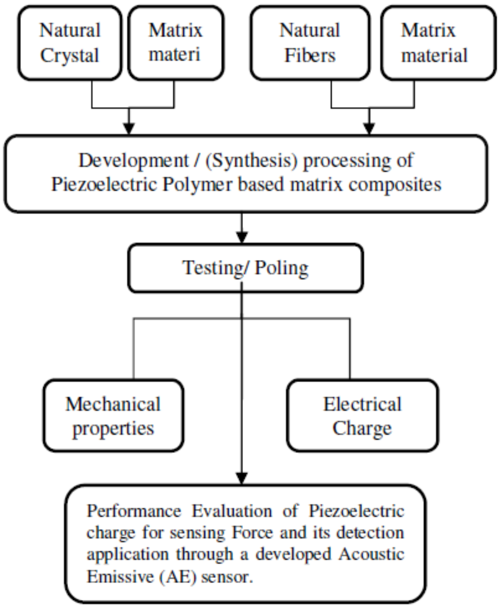

Figure 2. Proposed System

mechanical, mechanoelectronic, electrical (Piezoelectric) behavior of the developed material is performed. Later process in order to analyze and evaluate, the solid state form, poling process for the developed piezoelectric sample is done. After the development of piezoelectric material, the next procedure is to investigate the sensitivity of force detection through the developed acoustic emissivity sensor.

Lead Zirconate Titanate (PZT) Pb[ZrxTi1-x]O3:

Lead zirconate titanate (Pb[ZrxTi1-x]O3 0<x<1) is a ceramic material that shows a marked piezoelectric effect. PZT-based compounds are composed of the chemical elements lead and zirconium and the chemical compound titanate which are combined under extremely high temperatures. In general, soft PZT has higher piezoelectric constant, but larger losses in the material due to internal friction. In hard PZT, domain wall motion is pinned by the impurities thereby lowering the losses in the material, but at the expense of a reduced piezoelectric constant.

Specifications:

Density (kg/m3):	7.75 to 8.0
Young's Modulus:	5.8 to 9
Curie Temperature (deg. C):	170 to 360
Relative Dielectric Constant:	000 to 4

Barium Zerconate Titanate (BZT) BaTiZrO5:
Barium Zirconate Titanate (BZT) is a piezoelectric ceramic composed of a solid solution of barium titanate and barium

zirconate with applications as a dielectric and ferroelectric material in electronic and semiconductor devices.

Specifications:

Barium Zerconate Titanate (BZT) BaTiZrO5 Properties (Theoretical)	
Compound Formula	BaO5TiZr
Molecular Weight	356.415
Appearance.	White powder
Melting Point	1620 °C
Boiling Point	N/A
Density	5.85 g/cm3 (20 °C)
Solubility in H2O	Insoluble
Exact Mass	355.732471 g/mol
Monoisotopic Mass	355.732471 g/mol

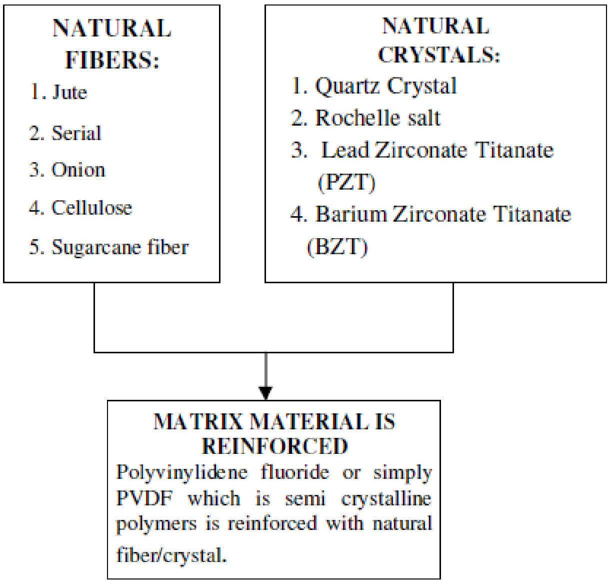

Table 4.1: Raw Materials Used in synthesis of piezoelectric material

V. METHODOLOGY

Identification and collection of Sample Reinforced Polymer Composite:

Electro spinning:
In view to study the characteristically behavior of fibers and crystal, a sample polymer matrix composite was prepared to analyze through electro spinning method. The proposed research concept is to develop natural fibers and natural crystals reinforcement with polymer matrix using Electro Spinning method in connection to generate piezoelectric effect for sensor application.

As the jet dries in flight, the mode of current flow changes from ohmic to convective as the charge migrates to the surface of the fiber. The jet is then elongated by a whipping process caused by electrostatic repulsion initiated at small bends in the fiber, until it is finally deposited on the grounded collector. The elongation and the fiber resulting from this bending instability leads to the formation of uniform fibers with nanometer-scale diameters.

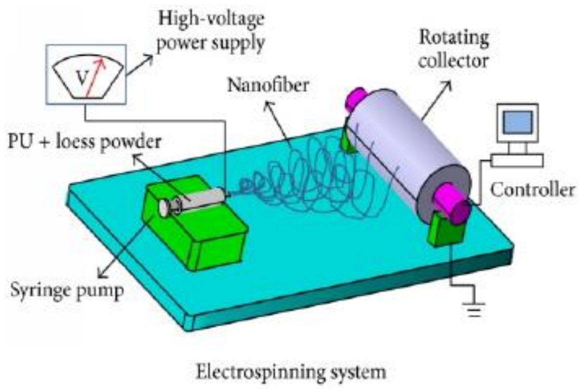

Figure 3: Electro spinning Setup

Process:
When a sufficiently high to a liquid droplet, the body of the liquid becomes charged and electrostatic repulsion surface tension and the droplet critical point a stream of liquid erupts from the surface. A mixture of power form of PZT, BZT, and PVDF is inserted into syringe pump, wherein high voltage is applied with pressure, synthesized at the tip of the syringe. eruption is known as the Taylor cone molecular cohesion of the liquid is sufficiently high, stream breakup does not occur (if it does, droplets are electro sprayed) and a charged liquid jet is formed.

PZT Powder synthesis process:
During this powder synthesis process, Zerconium,lead, oxygen ,hydrogen, mythele and its compounds is stirred well at the temperature of 25̊ c, later stage titanium tetra isopropoxide and allowed for some time to synthesis, again stirred at 60̊ c and allowed for drying and calcinations process to obtain PZT powder form.

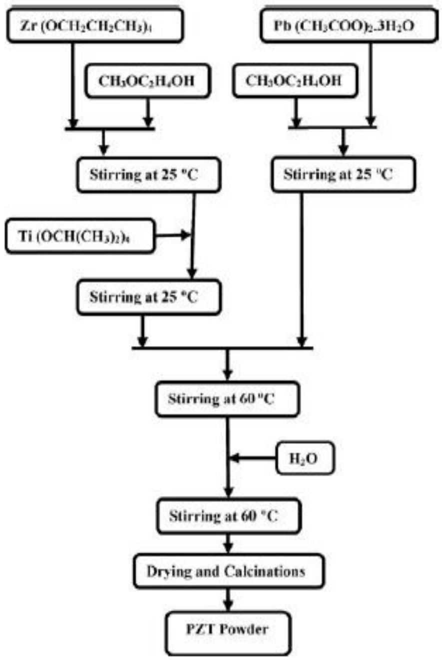

Figure 4:PZT Powder synthesis process:

PZT, Piezoelectric Powder synthesis using Milling and sintering process:

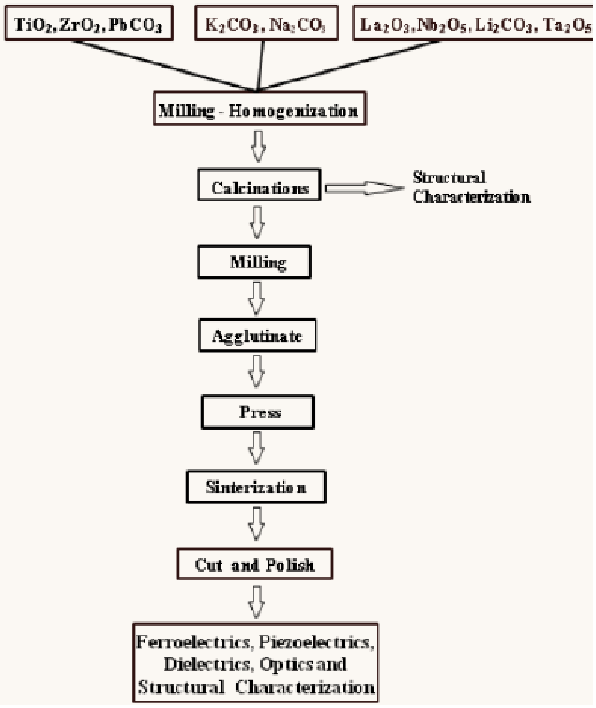

Figure 5: PZT, Piezoelectric Powder synthesis using Milling and sintering process.

Epoxy Resin:

Epoxy resins are polyether resins containing more than one epoxy group capable of being converted into the thermoset form. These resins, on curing, do not create volatile products in spite of the presence of a volatile solvent. The epoxies may be named as oxides, such as ethylene oxides (epoxy ethane), or epoxide. The epoxy group also known as oxirane contains an oxygen atom bonded with two carbon atoms, which in their turn are bound by separate bonds. The simplest epoxy resin is prepared by the reaction of biphenyl A (BPA) (80-05-7) with epichlorohydrine (ECH) (106-89-8). The value of n varies from 0 to 25. This determines the applications of the resin.

By use of the epoxy matrix, one can gain a system with following advantages: A wide variety of properties.

1. Low shrinkage during cure (lowest within thermosets).
2. Good resistance to most chemicals.
3. Good adhesion to most fibers and fillers.
4. Good resistance to creep and fatigue.
5. Good electrical properties.

Acoustic Emissivity Sensor Application:

Acoustic Emissivity Sensors respond with amazing sensitivity to motor or force in low ultrasonic frequency range (10khz –2000khz). It can detect motion as small as 10^-12 which can be detected. These sensors can hear of a breaking of single grain in a metal, a pin hole leak from liquid surface. The transducer element is positively a piezoelectric crystal which is commonly made up of ceramic such as Lead Zerconate Titanate (PZT). The main purpose of AE Sensors is to detect stress waves that cause local dynamic material displacement and convert this displacement in to electrical form of waves.

In this process, the piezoelectric material which is developed from synthesis process is made in the form of solid .This is called as source, which placed in between the chamber. Later two acoustic emissivity sensors is placed near by to the source. The sensor is connected to the acoustic emissivity detection instrument. Load, strain is applied on top of the chamber to test the loa through the acoustic emission wave. Hence the displacement is recorded and interpretated in the form of electrical signals.

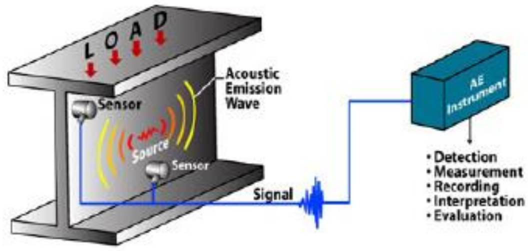

Figure 6: Acoustic Emissivity Sensor Setup

VI FUTURE CONCLUSION

This paper is only a review paper, which presents the approach to develop piezoelectric material through the synthesis process through solid-state form and dielectric detection.

This approach proves the force can be sensed and detected using the acoustic wave detection instrument. This research work is low cost, user friendly, low energy consumption unaffected from external electromagnetic fields ,natural and easily available form of material in order to detect force, pressure , sound level to the critical point , easily replaceable equipment, it will be light weight and easily to operate. Etc.

VII REFERENCES

[1] R.Jingwei Xie and Prof. Younan Xia – "Electrospinning: An Enabling Technique for Nanostructured Materials"; Material Matters 2008, 3.1, 19.

[2] Emiliano Zampetti, Andrea Bearzotti, Antonella Macagnano - "Flexible piezoelectric transducer based on electrospun PVDF nanofibers for sensing applications"; EUROSENSORS 2014, the XXVIII edition of the conference series.

[3] Filippo Pierini – "Electrospinning of conjugated polymer nanofibers: research challenges and applications"; Department of Biosystems and Soft Matter Institute of Fundamental Technological Research, Polish Academy of Sciences.

[4] Daniel Haagensen – "Development of a piezoelectric polymer fibre"; *Department of Materials and Manufacturing Technology* CHALMERS UNIVERSITY OF TECHNOLOGY Göteborg, Sweden, 2010 Report No. 43/2011.

[5] Tae hoon Kim Ana Claudia Arias – "Characterization and applications of piezoelectric polymers"; Electrical Engineering and Computer Sciences University of California at Berkeley
Technical Report No. UCB/EECS-2015-253, December 18, 2015.

[6] Ehsan Ghafari, Seyedali Ghahari, Yining Feng ,Na (Luna) Lu – "Piezoelectricity & Its Applications" Sustainable Materials and Renewable Technology (SMART) Lab Lyles School of Civil Engineering PURDUE UNIVERSITY.

[7] Nguyen Dinh Tung Luan,Le Dai Vuong,Truong Van Chuong,and Nguyen Truong Tho, The Fundamental Science Department, Hue

Industry College, Hue City, Vietnam,Department of Physics, College of Sciences,Hue University,Hue City, Vietnam; Published 20 January 2014- Structure and Physical Properties of PZT-PMnN-PSN, Ceramics Near the Morphological Phase Boundary.

[8] Swapnil D.Shamkuwar, Kunal N.Dekate; Electronics Department, G.H.Raisoni College of Engg, Nagpur, India. *IJCSMC, Vol. 3, Issue. 5, May 2014, pg.25 – 33.* Design of Piezoelectric MEMS Sensor for Energy Harvesting from Low Frequency Applications.

[9] Yasuyoshi Saito, Hisaaki Takao, Toshihiko Tani,-"High performance lead free piezoelectric material".

[10] Nawal Binhayeeniyi , Pisan Sukvisut , Chanchana Thanachayanont , Supasarote Muensit, Department of Physics, Prince of Songkla University (PSU), Songkhla, Thailand, National Metal and Materials Technology Center, 114 Thailand Science Park, Pathumthani, Thailand NANOTEC CENTER of Excellence at Prince of Songkla University, Hat yai, Songkhla 90112, Thailand; Accepted 29 October 2009- Physical and electromechanical properties of barium zirconium titanate synthesized low-sintering temperature.