A Simulation of Various Piezo Materials for the Study of EM Stored Energy in Piezoelectric Actuator

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Abstract-The hub of this paper is to study the EM stored energy of piezoelectric MEMS material. This performance analysis of piezoelectric material is done by using COMSOL multiphysics.An investigative relationship has been developed based on EM stored energy caused by frequency variations in piezomaterials.however displacement measured corresponds to max stored EM energy.in PZT materials energy is stored in form of vibrations which is produced during the actuation.By using the actuation principle of different material,energy harvesting can be analysed.We have observed the graph between freq and total stored EM energy of various materials.And the best material found from the analysis is lead zirconate titanate as it provides maximum displacement which corresponds to maximum energy harvesting.this model investigates how the ambient vibrations harvest the energy and also enhances the quality.

Keywords- MEMS, Energy harvesting, COMSOL,Piezoelectric materials, Rasonators, NEMS, Tumable actuator, EM energy.

• INTRODUCTION

MEMS (Micro Electro Mechanical System) technology is a best technology for low loss applications. Piezoelectrically transduced resonator have become a very interesting topic in research field. Energy harvesting is the process by which energy is derived from external sources, captured and stored for small, wireless autonomus devices like those used in wearable electronics and wireless sensors networks. For example Piezoelectric crystals and fibers generates a small voltage whenever they are mechnacially deformed. Thus; vibrations from engines can stimulate piezoelectric materials, as can be pushing of a button.

In general, electromechanical energy conversion devices can be divided into three categories:

(1) Transducers (for measurement and control)
These devices transform the signals of different forms. Examples are microphones, pickups, and speakers.
(2) Force producing devices (linear motion devices)
These type of devices produce forces mostly for linear motion drives, such as relays, solenoids (linear actuators), and electromagnets.
(3) Continuous energy conversion equipment
These devices operate in rotating mode. A device would be known as a generator if it convert mechanical energy into electrical energy, or as a motor if it does the other way around (from electrical to mechanical).

• TUNABLE PIEZOELECTRIC ACTUATOR

A piezoelectric device can trigger a cantilever beam simply by applying an AC voltage over the device. The cantilever beam itself has resonant modes that causes peaks in the vibration when the frequency of the applied voltage passes the resonance frequency of each mode. If another piezoelectric device is attached to the cantilever, it is possible to tune the resonance by connecting that device to a passive external circuit as shown in Figure 6. This model analysis how the external circuit influence the resonance peaks of the cantilever beam. The actuator consists of a thin bar of silicon with an active piezoelectric device below the bar, and a second passive piezoelectric device on top. These devices are located at one end of the actuator. The piezoelectric material is lead zirconate titanate (PZT), and each of the devices has two electrical connections to an external circuit, realized with the Floating potential boundary condition of the Piezo Plane Strain application mode.

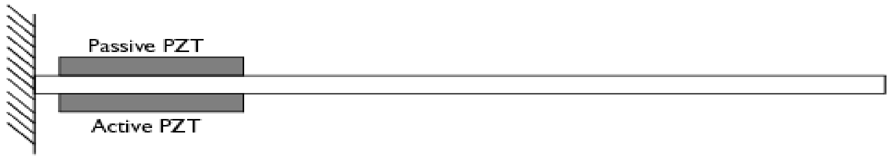

Figure 1: Geometry of PZT(5-A)

A piezoelectric actuator with an active piezoelectric device below and a passive piezoelectric device above the silicon bar.

MODELLING OF PIEZOELECTRIC ACTUATORS WITH VARIOUS MATERIALS

QUARTZ MATERIAL-The most important property of quartz crystal is piezoelectricity discovered by Jacques and Pierre curie in 1880. when piezoelectric materials are mechanically deformed ,their surfaces get electrically charged and the reverse is also true.

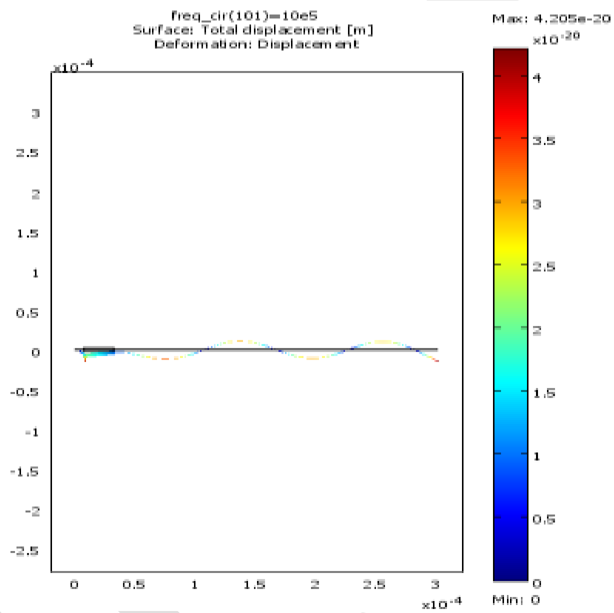

Figure 2 : Simulation of Quartz material.

Figure show that dispalacement of piezoelectric actuator. In this, we use cantilever beam of silicon and piezoelectric device is of quartz material. It has a displacement of 4.205e-20 which is very low.

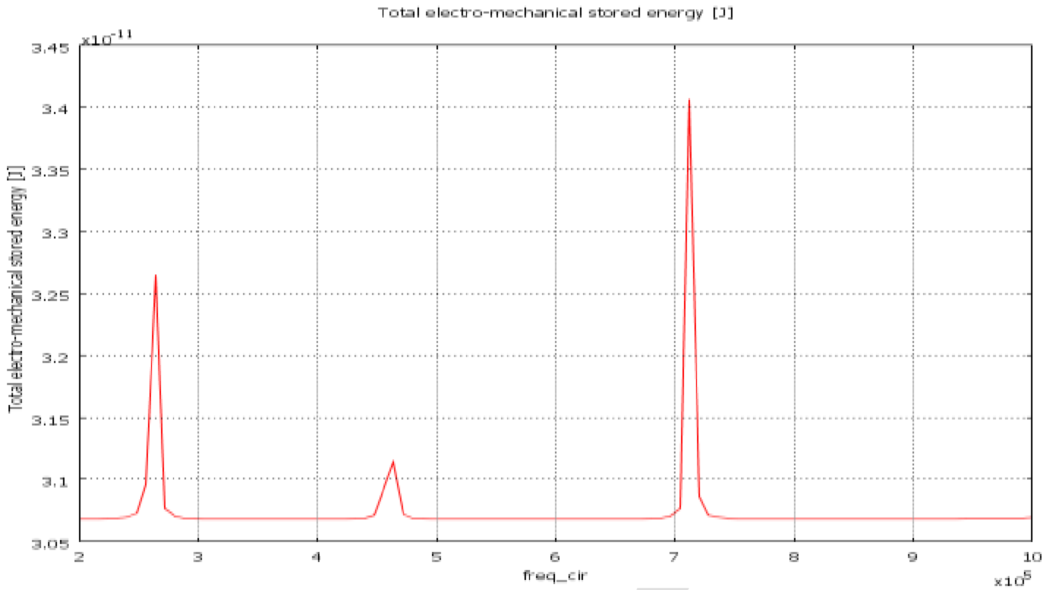

Figure3 : EM stored Vs Frequency Curve.

This graph shows EM stored energy when we use quartz material in piezoelectric device which is varying with frequency. For lowest frequency(2.5e5) it has a value of 2.26e-11 and for higher frequency (6.9e5)it shows (3.4e-11). Aluminium Nitride is a covalently bonded ceramic. It is stable in inert atmospheres at temperatures .It exhibits high thermal conductivity property while remaining a strong dielectric.

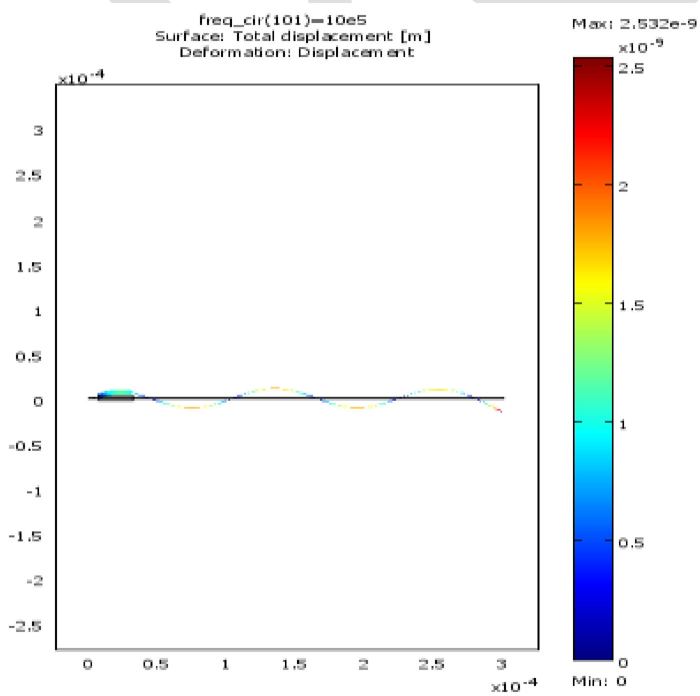

Figure 4 : Simulation of Aluminium Nitride

This Figure 4 shows the displacement of piezoelectric actuator. In this, we use cantilever beam of silicon and piezoelectric device of aluminium nitride material. It has a displacement of (2.532e-9).

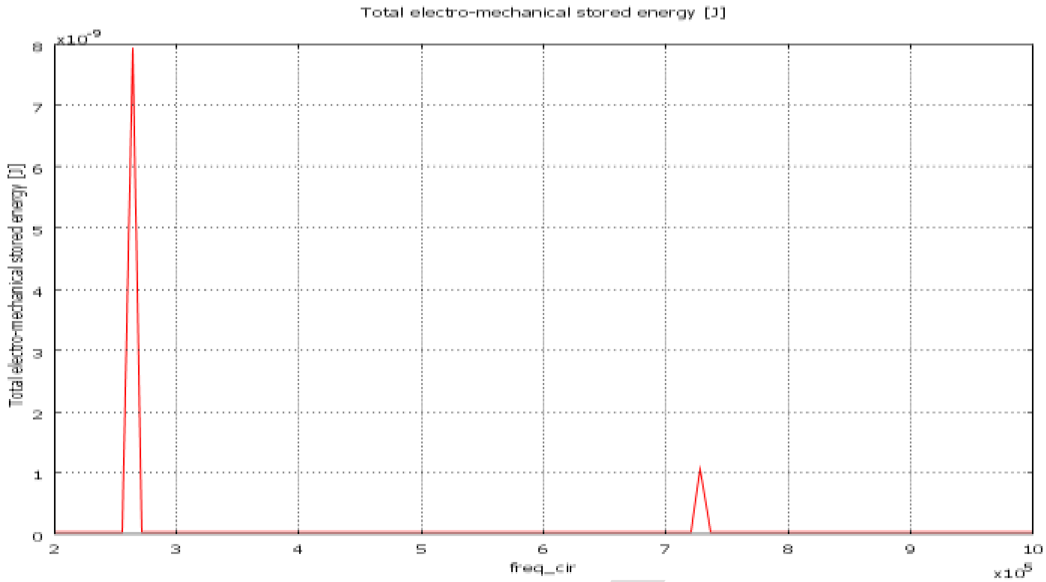

Figure 5：EM stores Vs Frequency Curve.

This Figure 5 shows EM stored energy when we use aluminium nitride material in piezoelectric device.which is varying with frequency.For lowest frequency(2.5e5)it has a value of (8e-9) and for higher frequency it posses a value of (1.1e-9).

BARIUM TITANATE is common ferroelectric material with a high dielectric constant widely used to manufracture piezoelectric transducers and a variety of electro optic devices. Pure barium titanate is an insulator whereas on doping it transforms into a semiconductor and is used in actuators applications.

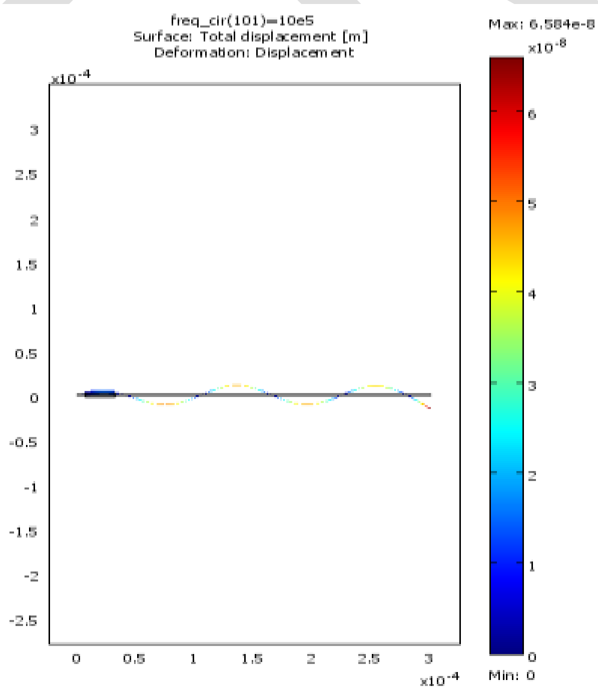

FIGURE 6 : Simulation of Barium Titanate.

This Figure 6 shows the displacement of piezoelectric actuator.In this,we use cantilever beam of silicon and piezoelectric device of barium titanate material.It has a displacement of (6.584e-8).

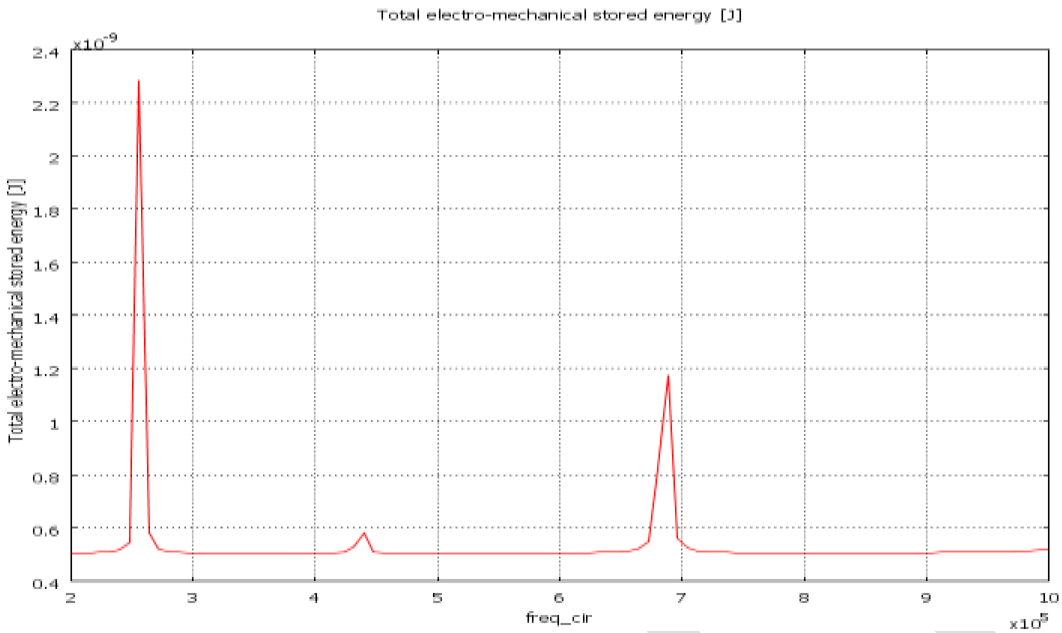

Figure 7: EM Stored Vs Frequency C urve.

This Figure 7 shows EM stored energy when we use barium titanate material in piezoelectric device which is varying with frequency. For lowest frequency(2.5e5)it has a value of 2.3e-9 and for highest frequency it posses a value of (1.1e-9).

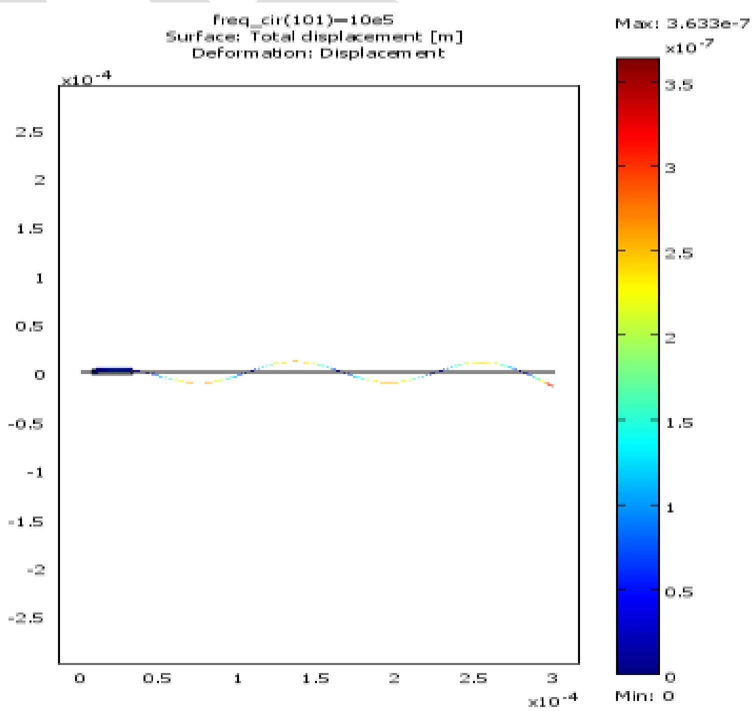

Figure 8 : Simulation of PZT-5A.

This Figure 8 shows the displacement of piezoelectric actuator.In this,we use cantilever beam of silicon and piezoelectric device of PZT-5A material.It has a displacement of (3.633E-7).

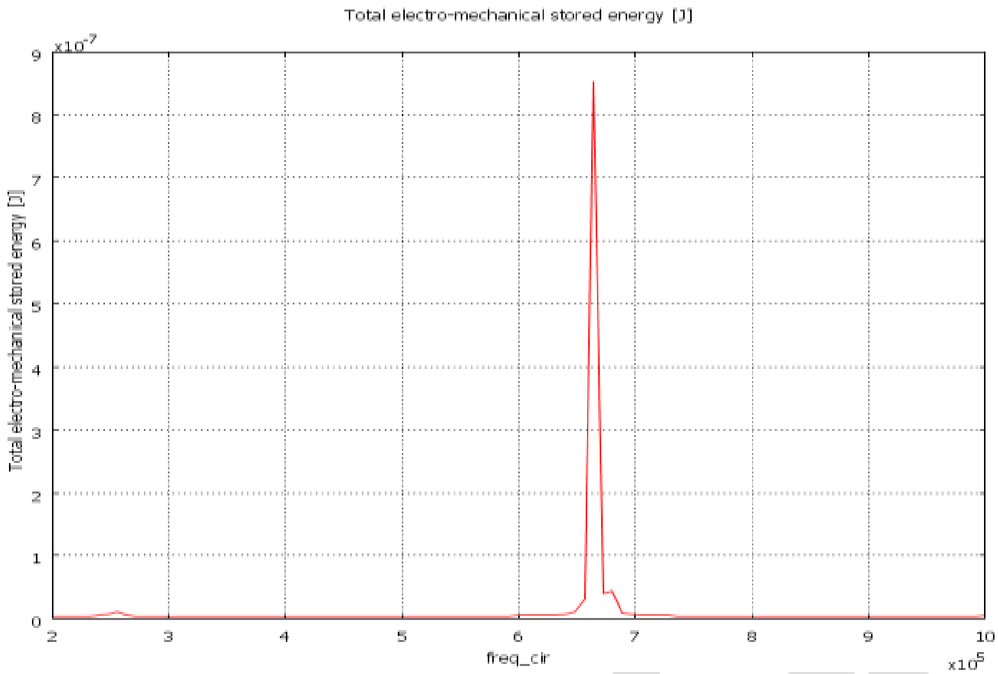

Figure 9 : EM Stored Vs Frequency Curve.

This Figure 9 shows EM stored energy when we use PZT-5A material in piezoelectric device which is varying with frequency. For lowest frequency (2.5e5) it has a value of (0.01e-7)and for higher frequency (6.8) it posses a value of 8.9e-7.

ZnS prototypical sermiconductor material which can adopt the structures of many other semiconductors upon doping making it an excellent transducer material for MEMS resonators and mechanical switches.

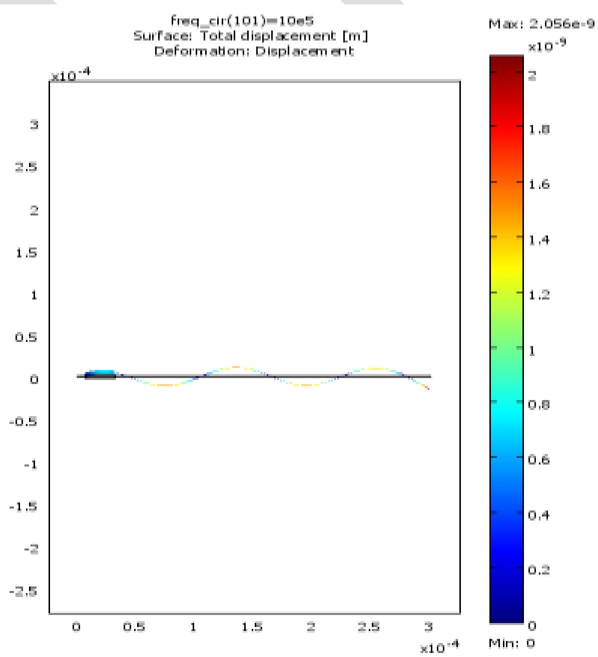

Figure10 : Simulation of Zinc Sulphide.

Figure10 shows the displacement of piezoelectric actuator.In this,we use cantilever beam of silicon and piezoelectric device of ZnS material. It has a displacement of (2.056e-9).

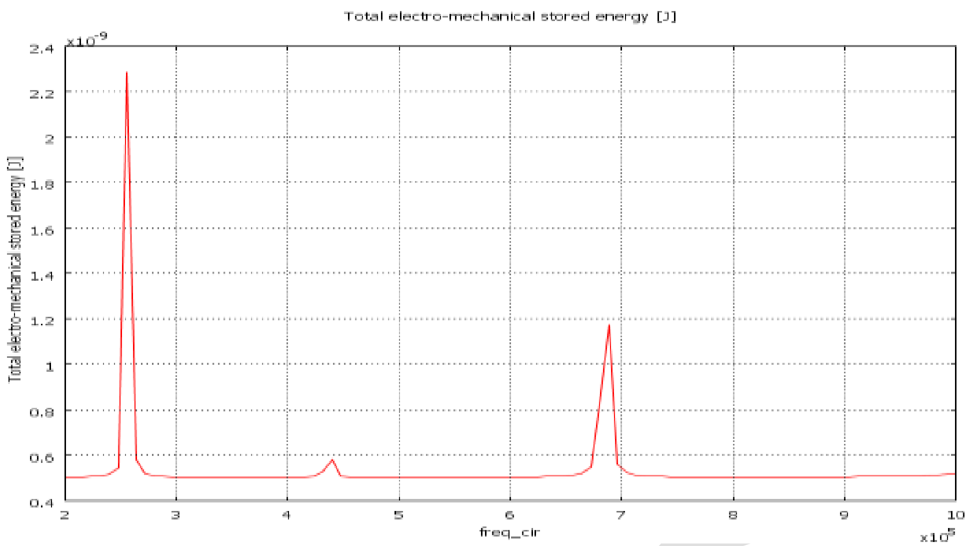

Figure 11 : EM Stored Vs Frequency Curve**.**

This Figure 11 shows EM stored energy when we use zinc sulphide material in piezoelectric device which is varying with frequency. For lowest frequency(2.5e5) it has a value of (2.3e-9) and for higher frequency (6.9)it posses a value of (1.119e-9)

- **CONCLUSION**

We have concluded that all materials i.e (PZT-5A, QUARTZ, ZINC SULPHIDE, ALUMINIUM NITRATE and BARIUM TITANATE) shows various changes in EM stored energy with frequency respectively . By using EM stored energy , Quality of material has been analysed . PZT-5A has high energy stored in energy harvesting technique i.e-.8.9e-7 . This analysis is done by using high end software COMSOL Multiphysics.

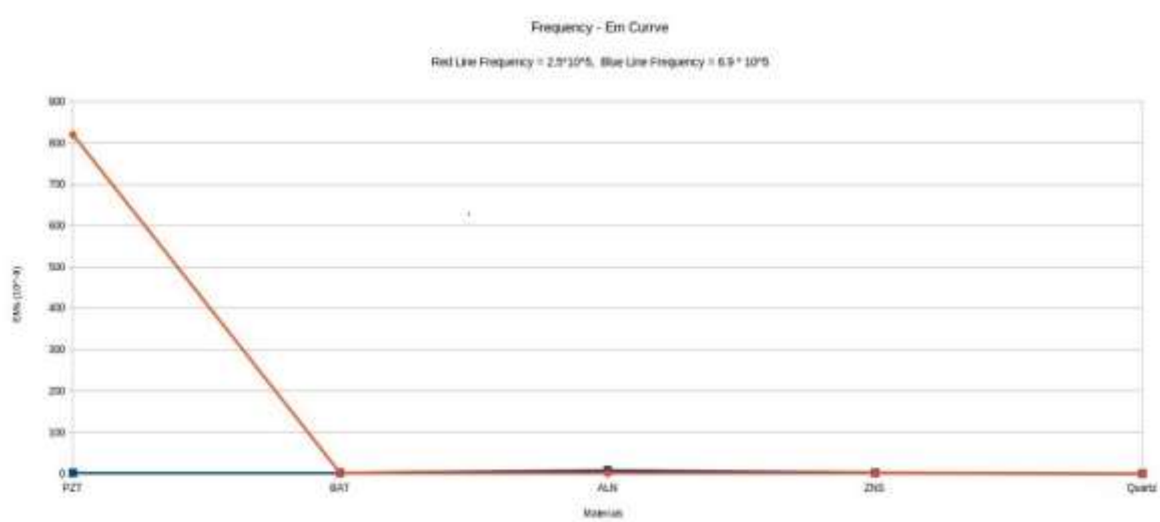

Figure 12 : Comparison of various material(EM stored Vs frequency).

This curve show that EM stored energy is maximum for lower and higher frequency of PZT material so this energy is further used for the energy harvesting purpose .

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