BTP REPORT (Jan-May 2021)

TITLE : Fabrication of PZT based Thermal Sensor
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Examiner 2 :Prof.Subramani Kanagaraj

Introduction

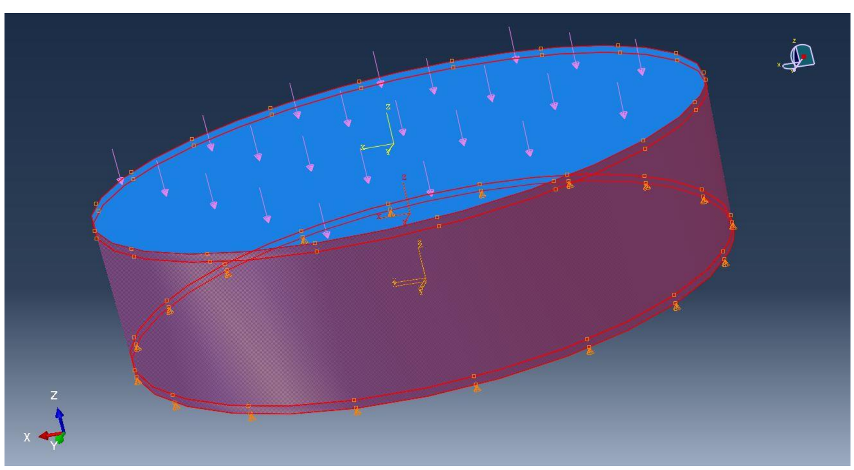
Ultrasound transducers, accurate positioning actuators, cameras, and energy harvesters all use lead zirconate titanate (PZT) piezoelectric ceramics. PZT, on the other hand, usually demands a sintering temperature of over 1200°C. As a result, a variety of techniques, including hot pressing, liquid phase sintering etc have been researched to reduce the maximum processing temperature of PZT to 700C-1000◦C.

The **cold sintering method (CSP)** allows for the densification of ceramics at ultralow temperatures (300◦C) under uniaxial pressure in the presence of a transient liquid phase, lowering the processing temperature considerably,ultralow temperatures (300◦C) in the presence of a transient liquid phase under uniaxial pressure.

Congruent dissolution favors rapid densification via cold sintering but is not always available in solids with complex chemistries. For example, in the case of BaTiO3, the use of water as a liquid phase promotes leaching of Ba^{+} with subsequent formation of BaCO3 and passivation of the powder surfaces with an unreactive hydrated titanium-rich surface layer that prevents densification. Thus, to avoid incongruent dissolution of BaTiO3, a water based suspension of Ba(OH)2 and TiO2 can be utilized during cold sintering. A challenge with the BaTiO3 system was the fact that CO2 stabilized an amorphous phase that fills the pores between the crystalline particles. This kinetically limited the sintering process until the carbonate is decomposed at a temperature of ~830◦C. To further densify and equilibrate the grain structures, a post-annealing stage was performed. In comparison to traditional methods, a post-annealing at 900◦C provided high-quality $BaTiO_3$ with a net temperature reduction of 300-500◦C. As a consequence, well-densified ceramics with excellent dielectric properties are made.

Finally, using $Pb(NO_3)_2$ as a sintering aid, PZT ceramics are cold sintered. While powder selection and processing parameters need to be fine-tuned, early studies found that cold sintering achieved a relative density of 90% at 300°C. In addition, 700◦C annealing also indicated promising densification for longer annealing times. The post-annealing step results in ceramics with high relative permittivity, well-developed polarisation switching with high remanent polarizations, and good piezoelectric coefficients, as well as improved densification and equilibration of a nanosized grain structure.

Fig. Picture of die and punch(above),Picture of loading on the subject(below).



LITERATURE REVIEW

Thin film electrodes (~100 nm thickness) are commonly used for piezoelectric devices to apply an electric field or to obtain a generated charge signal. In order to be effectively used in high-temperature sensors, these thin film electrodes should be capable of long term high-temperature operation (**Da Cunha et al. 2008**).

Various thin film electrodes, including Pt, Pt-based alloys, and other metallic alloys or conductive ceramic electrodes have been researched for high temperature sensing applications.

Simple structure, fast response time, and ease of integration, all give high temperature piezoelectric (HTPE) sensors an advantage and make them of particular interest. Various piezoelectric materials have been extensively researched for high-temperature applications, including quartz (SiO_2), lithium niobate ($LiNbO_3$, LN), gallium orthophosphate ($GaPO_4$), langasite and aluminium nitride, (**Damjanovic et al., 1998**).

Schulz, M et al. 2009 Kim et al. (2012), has investigated a shear mode piezoelectric accelerometer with optimized structure design for high-temperature applications using YCOB single crystals. For high-temperature applications, shear mode sensors can offer higher temperature stability with reduced thermal effects from the sensor base, compared to the compression mode sensor.

Platinum electrodes were not used for this sensor in order to avoid sensor failures due to thin-film electrode degradation at high temperatures. In addition, the assembly was accomplished by tightening the nut and bolt to compensate for the thermal expansion effect of each component. **Zhang et al.** (2012), have successfully demonstrated a compression mode piezoelectric accelerometer using YCOB single crystals for ultrahigh temperature applications.

Objectives of the project

1. **Detailed Literature review of PZT thermal sensor.**
2. **Simulation of a 3D model in ANSYS and fabrication of a PZT based thermal sensor and perform its analysis.**
3. **Development of the circuit and Designing a Thermal sensor.**
4. **Calibrating the sensors and testing the performance.**

Methodology

Raw ZnO powders (99.9% purity) were purchased for the various synthetic processes.The ZnO raw powder had an average particle size of around 3.285 m. The purified water was combined with polyvinyl alcohol, which was used as a binder for the ZnO powder.

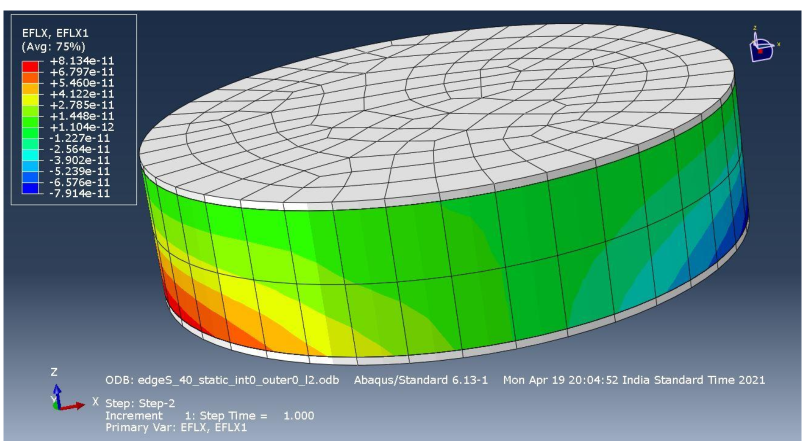
The slurry binder and ZnO powder mixture was then fully dried to extract bulk ZnO.

After lubricating the interior of the steel for simple detachment of the ZnO ceramics from the steel mould, the ZnO powders were pressed into a steel mould in uniaxial pressing. The mould was 10 mm in diameter, and the highest pressure used to compress ZnO was 10 MPa for 1 minute.To burn off the binder from the ZnO samples, all of the specimens were preheated in air at 400°C for 1 hour. Then, without using any additional gases, continuous sintering was carried out for 2 hours at 900°C.The post-annealing step not only shows densification improvement, and equilibration of a nanosized grain structure, but also it produces ceramics with high relative permittivity, well-developed polarization switching with high remanent polarizations, and strong piezoelectric coefficients.

Work done during Jan 2021-April 2021

- In this semester we have continued the literature review and also used a software named ANSYS to stimulate some experimental conditions of the subject and find out the probable outcomes and assess them.
- **To start with the dimensions of the subject chosen :**

1. We have selected a thin circular plate of 10mm diameter and 5 mm height.
2. This circular patch has 4.5mm of ZnO with 0.25mm each of Cu at the ends.
3. The ZnO here acts as the piezoelectric element and the Cu acts as an isotropic element.
4. While Meshing both 3D piezoelectric element and 3D elastic element were selected to reflect the desired properties
5. Axial loading of various magnitude was applied and graphs were plotted for Load vs Electric Discharge and Load vs Electric Potential.



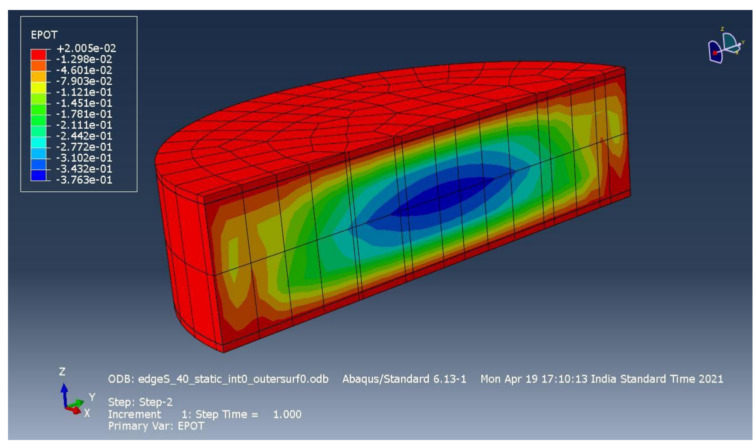
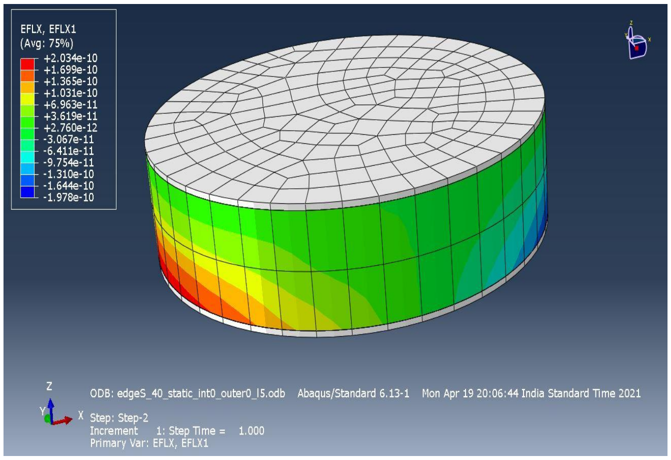


Fig. The load on the plate is **1N** in both the pictures.(left)Electrical Discharge distribution inside the circular plate.(right)Electrical Potential distribution inside the circular plate.



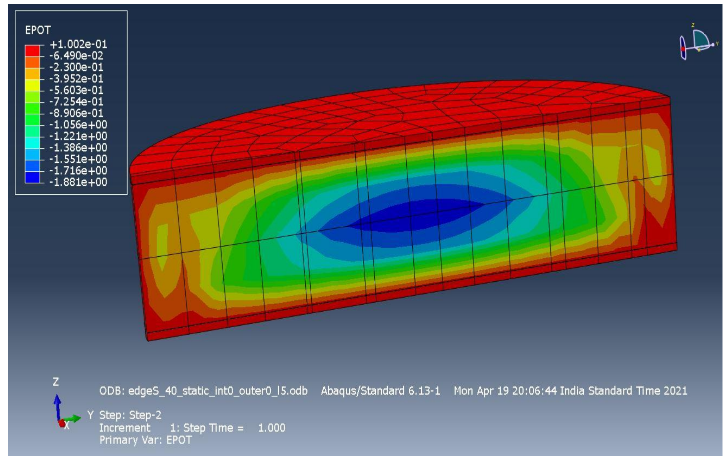
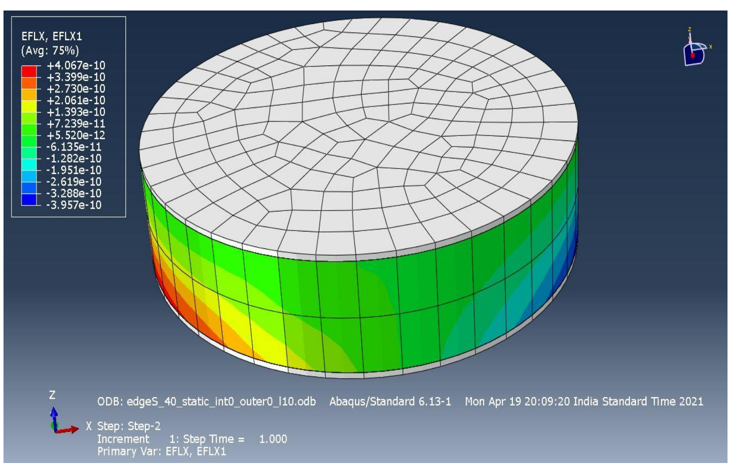


Fig.The load on the plate is **5N** in both the pictures.(left)Electrical Discharge distribution inside the circular plate.(right)Electrical Potential distribution inside the circular plate.



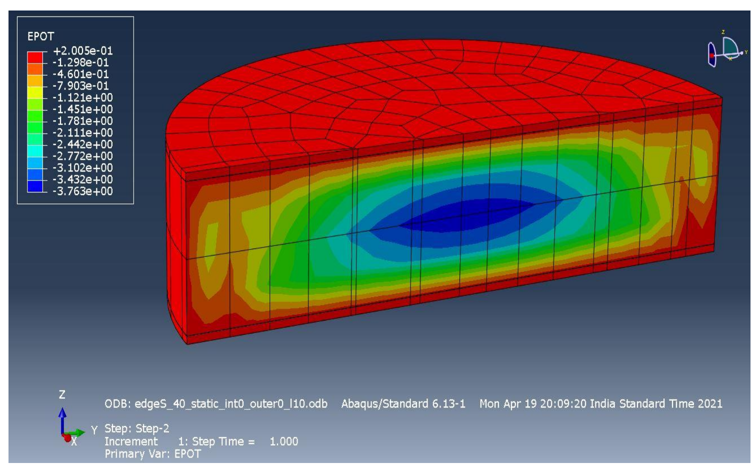
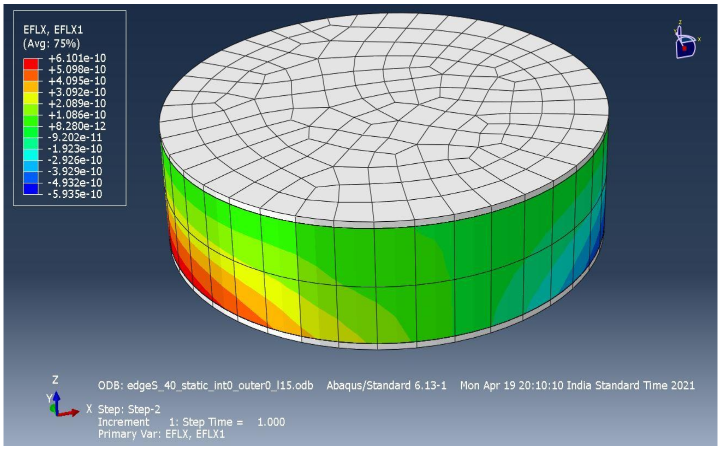


Fig.The load on the plate is **10N** in both the pictures.(left)Electrical Discharge distribution inside the circular plate.(right)Electrical Potential distribution inside the circular plate.



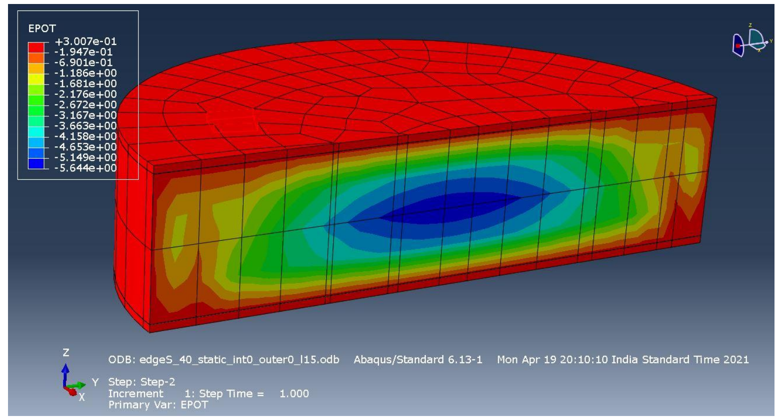
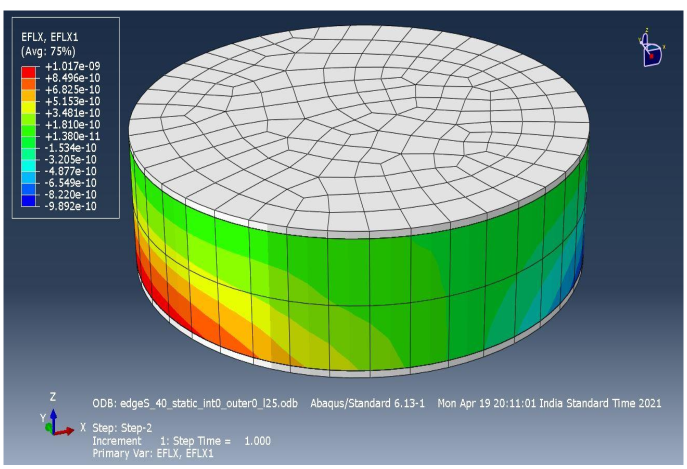


Fig.The load on the plate is **15N** in both the pictures.(left)Electrical Discharge distribution inside the circular plate.(right)Electrical Potential distribution inside the circular plate.



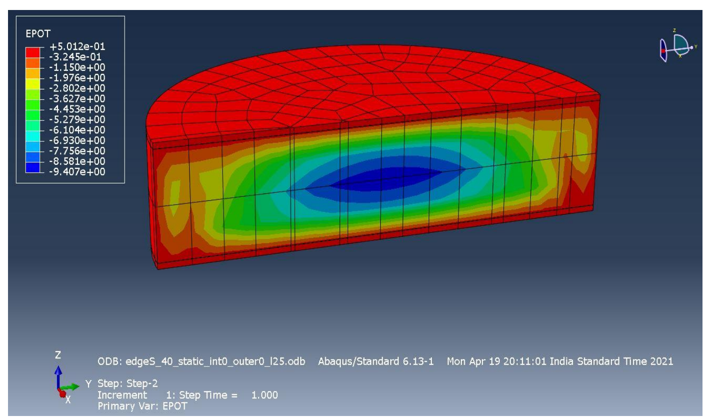
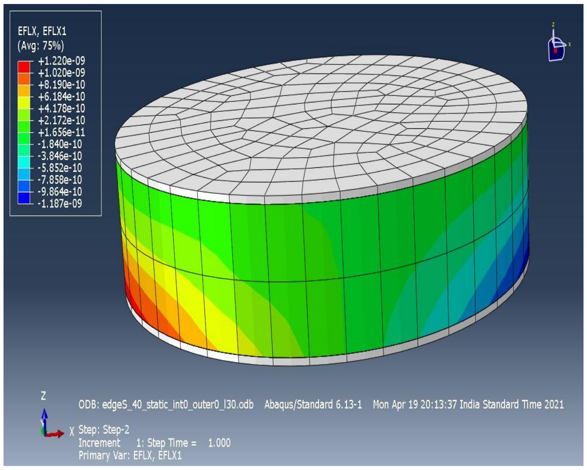


Fig. The load on the plate is **25N** in both the pictures.(left)Electrical Discharge distribution inside the circular plate.(right)Electrical Potential distribution inside the circular plate.



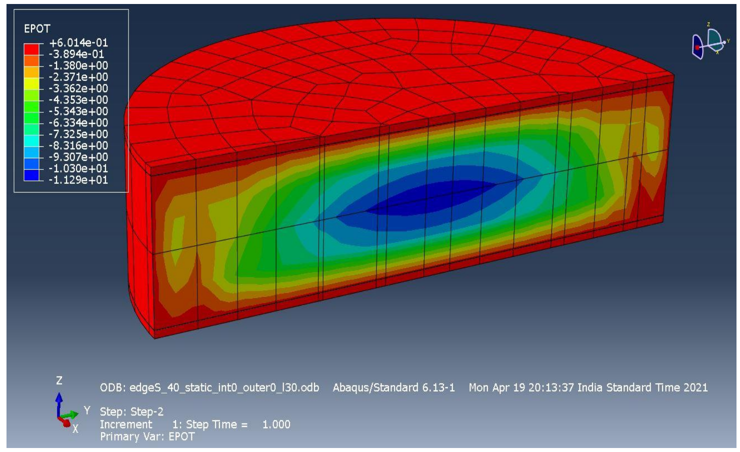
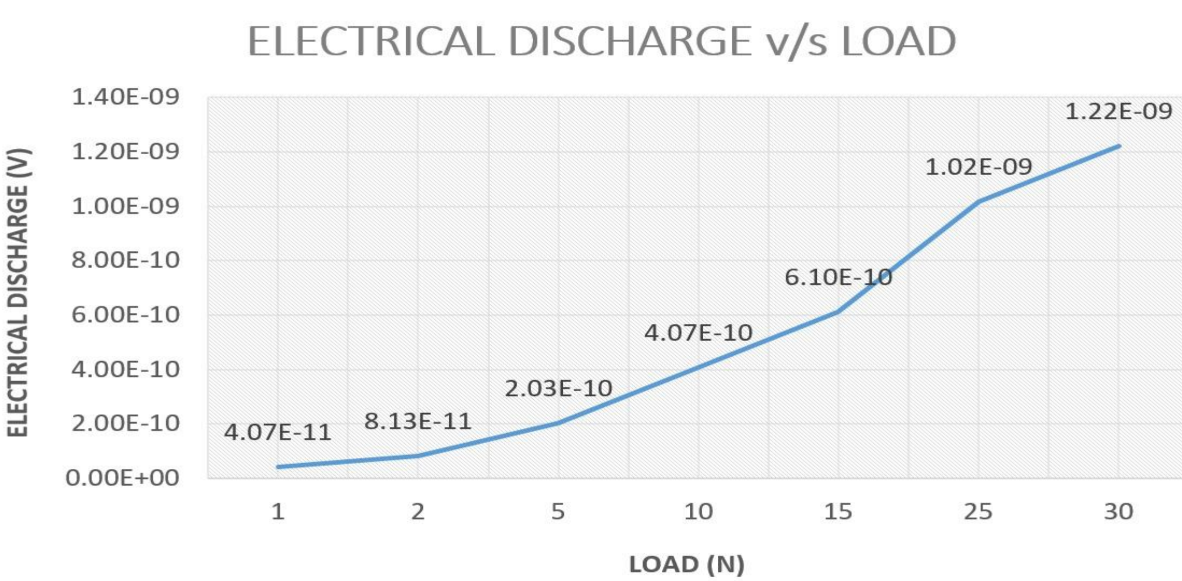


Fig. The load on the plate is **30N** in both the pictures.(left)Electrical Discharge distribution inside the circular plate.(right)Electrical Potential distribution inside the circular plate.

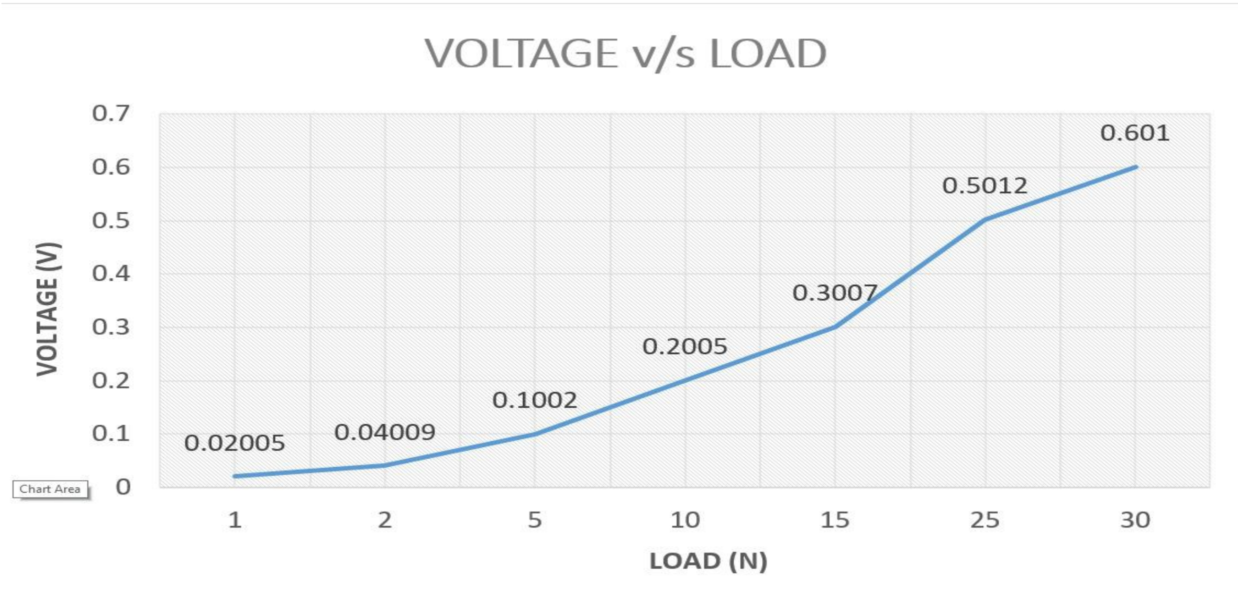
In all the above pictures the red box at the top left shows the value of the electric discharge and potential respectively.Plotting these points against the load will give us the desired graph.

GRAPHS:

The graph below shows electrical discharge v/s load :



The Graph below shows electrical potential v/s load:



CONCLUSION

A thin film of the piezoelectric plate was successfully generated in ANSYS and analysis was performed to generate electrical discharge and voltage under an applied load to it. The theoretical results had also been calculated and compared with that of the results from ANSYS analysis.

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Work Plan For Upcoming Semesters

	Sem 5	Sem 6	Sem 7	Sem 8
Detailed Literature review on PZT thermal sensor				
Simulation of PZT based Sensor				
Fabrication of PZT thermal sensor				
Circuit Development and Designing the sensor				
Calibration and Testing the performance				