BTP REPORT 2020(5TH SEMESTER)

- Title: **Fabrication of Thermal Sensor**
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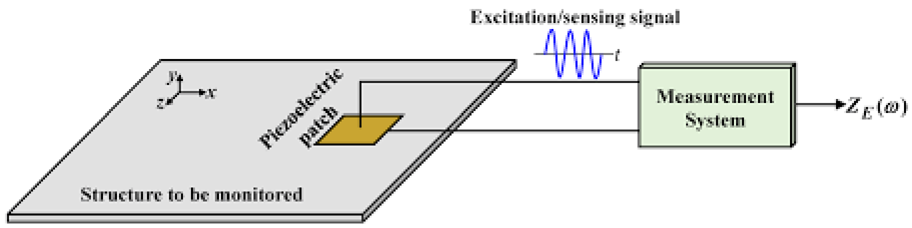
Introduction

Thermal Sensors measure the amount of Heat energy/Coldness that is generated by an object or a system, allowing us to accurately detect any physical change to that temperature producing either an analogue or digital output.

Mainly used to check the temperature, thermal sensors have some other applications too, in particular, preventative reliability is a core application of thermal sensors.

According to the need of temperature sensing, we have different kinds of thermal sensors available. The differences include what is being measured (air, mass, liquid), the range of temperature and where it is being measured. The most commonly used temperature sensors in modern day electronics: Thermocouples, Thermistors, RTDs (Resistance temperature detectors) etc.

This project is particularly focused on Piezoelectric Thermal sensor and its fabrication, the piezoelectric effect is the ability to produce electric charge in response to applied mechanical stress. The most commonly used piezoelectric materials are quartz(SiO_2) and Lithium Tantalate($LiTaiO_3$).Piezoelectric sensing is of increasing interest for high-temperature applications in aerospace, automotive, power plants and material processing due to its low cost, compact sensor size and simple signal conditioning, in comparison with other high-temperature sensing, G. techniques **(Hunter W et al., 2006)**.



Literature Review

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 (SiO2), lithium niobate (LiNbO3, LN), gallium orthophosphate (GaPO4), langasite and aluminium nitride, (**Damjanovic et al., 1998**).

Quartz, the most popular HT piezoelectric material, possesses high electrical resistivity (>1017 Ω at room temperature), high mechanical quality factor, and excellent high-temperature stability. Nevertheless, its low electromechanical and piezoelectric coefficients, high losses above 350 °C, and α to β phase transition temperature at 573 °C limit the use of quartz for high-temperature applications. The Curie temperature of LiNbO3 has been reported to be about 1,150 °C with high electromechanical coefficients. (**Schulz, M et al. 2009**)

Kim et al. (2012), have 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. Thickness mode YCOB crystals (15 × 7 × 2 mm) with the (XYlw)-15°/45° cut were prepared and used for piezoelectric sensing crystals. Inconel and high purity alumina were mainly used for the materials of HT sensor assembly and a platinum foil was used for electrical connection.

Working Principal

The middle part of a piezo disc (two metal plates with piezoelectric material in between them) is coated with a layer of piezo electric material called Lead Zirconate. The crystals in this material are capable of dis-orientation and re-orientation when it is subjected to mechanical, electrical and heat stress

(**Hribsek,M.F et al., 2010**). The Direct Piezo electric property of the piezoelectric crystals is the ability to generate electric signals when the crystals dis-orient and re-orient following a stress. This property is used here to sense temperature.

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.

Material Selection

A new piezoelectric material (PZT-PZNM) with a high Curie temperature (260 °C) is soldered onto a direct bonded copper substrate. When the power module is operating at a high temperature, the substrate deflects and induces thermal stress, which is converted into an electric voltage via a piezoelectric mechanism. Three main groups of materials are used for piezoelectric sensors: piezoelectric ceramics, single crystal materials and thin film piezoelectric materials. The ceramic materials (such as PZT ceramic) have a piezoelectric constant/sensitivity that is roughly two orders of magnitude higher than those of the natural single crystal materials and can be produced by inexpensive sintering processes. The piezoeffect in piezoceramics is "trained", so their high sensitivity degrades over time. This degradation is highly correlated with increased temperature.

The less-sensitive, natural, single-crystal materials (gallium phosphate, quartz, tourmaline) have a higher – when carefully handled, almost unlimited – long term stability. There are also new single-crystal materials commercially available such as Lead Magnesium Niobate-Lead Titanate (PMN-PT). These materials offer improved sensitivity over PZT but have a lower maximum operating temperature and are currently more complicated to manufacture due to four compound vs. three compound material PZT**.**

Applications of PZT Thermal Sensor

The huge potential market for wireless sensors that run on power derived from mechanical energy source is set to significantly boost the demand for piezoelectric sensors over the next few years. Furthermore, these sensors are gaining momentum due to rising power densities and higher feasibility for practical applications.

Piezoelectric materials that can function at high temperatures without failure are desired for structural health monitoring and/or nondestructive evaluation of the next generation turbines, more efficient jet engines, steam, and nuclear/electrical power plants. In automotive combustion systems, HT sensors are essential for recording engine temperature, pressure, and vibration to improve the efficiency and reliability of internal combustion engines (**Fleming et al. 2001**).

For an instance, in space-crafts high temperature sensors are used to monitor propulsion component conditions and the incoming data is analyzed to optimize propulsion system operations under temperatures of 500–1,000 °C, and with lifetimes up to 100,000 hours, conventional day to day or even most of the industrial thermal sensors are not built to function at such high temperatures and have such reliable life(**Turner, R et al. 1994**).Piezoelectric thermal sensors are useful in such scenarios which can function at temperatures as high as 700 °C, and it is under constant research and development to increase its functional range even higher.

Objectives of the project

1. **Detailed Literature review of PZT thermal sensor.**
2. **Simulation of a 3D model in ANSYS and fabrication of 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.**

Work Plan for Upcoming Semesters

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

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