CHAPTER 2

LITERATURE REVIEW

2.1. Transducer

A transducer is defined as a device that receives energy from one system and transmits it to another, often in a different from. Broadly defined, the transducer is a device capable of being actuated by an energizing input from one or more transmission media and in turn generating a related signal to one or more transmission systems. It provides a usable output in response to a specified into measurand, which may be a physical or mechanical quantity, property, or conditions. The energy transmitted by these systems may be electrical, mechanical or acoustical.

The nature of electrical output from the transducer depends on the basic principle involved in the design. The output may be analog, digital or frequency modulated. Basically, there are two types of transducers, electrical, and mechanical [12].

2.1.1. Electrical Transducer

An electrical transducer is a sensing device by which the physical, mechanical or optical quantity to be measured is transformed directly by a suitable mechanism into an electrical voltage 0r current proportional to the input measurand. An electrical transducer must have the following parameters:

i. **Linearity**

The relationship between a physical parameter and resulting electrical signal must be linear.

ii. **Sensitivity**

This is defined as the electrical output per unit change in the physical parameter (for example V/°C for a temperature sensor). High sensitivity is generally desirable for a transducer.

iii. **Dynamic Range**

The operating range of transducer should be wide, to permit its use under a wide range of measurement conditions.

iv. **Repeatability**

The input or output relationship for a transducer should be predictable over a long period of time. This ensures reliability of operation.

v. **Physical Size**

The transducer must have minimal weigh and volume, so that its presence in the measurement system does not disturb the existing conditions. The main advantages of electrical transducers (conversion of physical quantity into electrical quantities) are as follows:

a. Electrical amplification and attenuation can be easily done.
b. Mass-inertia effects are minimized.
c. Effects of friction are minimized.
d. The output can be indicated are recorded remotely at a distance from the sensing medium.

e. The output can be modified to meet the requirements of the indicating or controlling units. The signal magnitude can be related in terms of the voltage current.
f. The signal can be conditioned or mixed to obtain any combination with outputs of similar transducers or control signals.
g. The electrical or electronic system can be controlled with a very small power level.
h. The electrical output can be easily used, transmitted and processed for the purpose of measurement.

2.2. Development of Barium Strontium Titanate (BST) based sensors or instruments.

Research deals with the development of Barium Strontium Titanate or simply BST based micro-sensors or instruments such at heat, optical and gas sensors or instruments.

The pyroelectric sensing capability of a Barium Strontium Titanate (BST) element is demonstrated in the form of a heat detector. Presence of an abnormal heat source triggers an alarm. The optical sensing capability of Barium Strontium Titanate (BST) element is demonstrated in the form of an optical switch. The Barium Strontium Titanate (BST) sensor detects the ambient light level. If it falls below the set threshold switches on a light.

Out future research is geared toward complex sensor by combining various sensing properties and micro-fabrication using lithography and other techniques. The obtained BST thin-film show ferroelectric, pyroelectric, piezoelectric and electro-optic properties. The oxides are chemically stable in the atmosphere. Barium Strontium Titanate (BST) thin-film was deposited on P-si (100) by spins coating technique which has advantage of simplicity and low cost. The **Figure 2.1** shows the methodology in preparation of Barium Strontium Titanate (BST) thin-film.

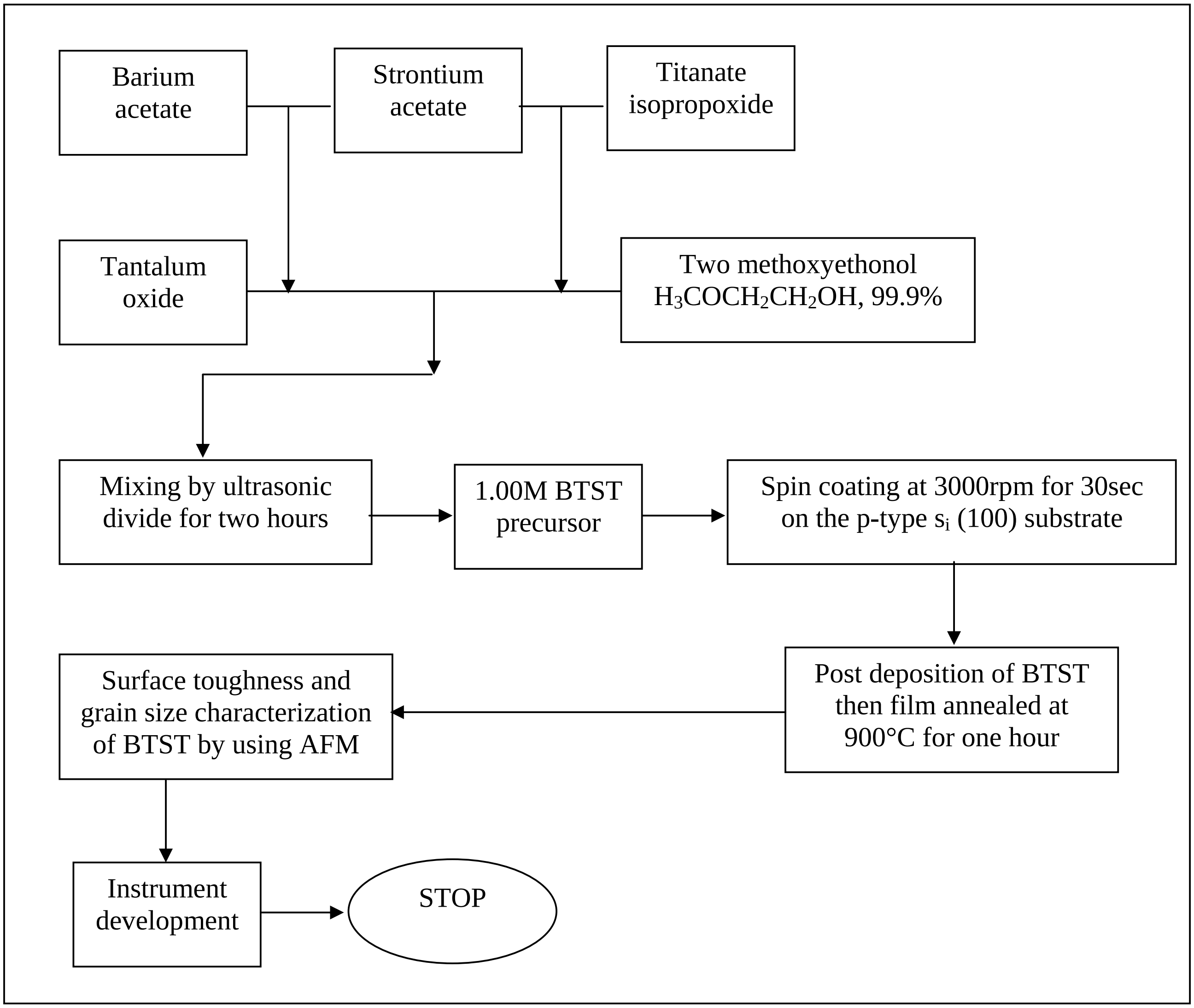

Figure 2.1: Methodology of the BST Thin-film Fabrication

2.3. Pyroelectric Sensor

An improved, selective, radiation sensing device is provided which includes a thin strip of pyroelectric material. One side of the material is coated with a continuous layer of metallic material to form an electrode while the opposite side is coated with at least a pair of electrodes and the output of the electrodes are electrically connected to a differential amplifier. A layer of energy filter material is applied over the continuous electrode. This layer is transparent to all energy outside of a desired energy frequency band to which the device is to be sensitive but absorbs and converts to heat all energy applied which is within this band. This heat is conducted quickly into the pyroelectric material which produces a voltage change in the output from the corresponding electrodes. By positioning the device at the focal point of a concave mirror, the output from the electrodes can be used to energize an alarm signal or the magnitude and frequency of the output of the device can indicate the size and movement of an energy source such as a human body. A novel method of making the device is included which facilitates the fabrication and reduces handling problems and costs[13].

2.4. Ferroelectric Sensor

In physics, the ferroelectric effect is an electrical phenomenon whereby certain materials may exhibit a spontaneous dipole moment, the direction of which can be switched between equivalent states by the application of an external electric field. The term ferroelectricity is used in analogy to ferromagnetism, in which a material exhibits a permanent magnetic moment.

There are two main types of ferroelectrics: displace and order-disorder. The effect in Barium Titanate, a typical ferroelectric of the displace type, is due to a polarization catastrophe, in which, if an ion is displaced from equilibrium slightly, the force from the local electric fields due to the ions in the crystal increase faster than the elastic-restoring forces. This leads to an asymmetrical shift in the equilibrium ion positions and hence to a permanent dipole moment. In an order-disorder ferroelectric, there is a dipole moment in each unit cell, but at high temperatures they are pointing in random directions. Upon lowering the temperature and going through the phase transition, the dipoles order, all pointing in the same direction within a domain. Ferroelectrics often have very large dielectric constants, and thus are often used as the dielectric material in capacitors. They also often have unusually large nonlinear optical coefficients [10].

2.5. Piezoelectric Sensor

Piezoelectric sensor is a device that uses the piezoelectric effect to measure pressure, acceleration, strain or force by converting them to an electrical signal. Piezoelectric sensor has proven to be versatile tools for the measurement of various processes. They are used for quality assurance, process control and process development in many different industries. Piezoelectric sensors are also seen in nature. Bones act as force sensors. Once loaded, bones produce charges proportional to the resulting internal torsion or displacement. Those charges stimulate and drive the build up of new bone material. This leads to the strengthening of structures where the internal displacements are the greatest. With time, this causes weaker structures to increase their strength and stability as material is laid down proportional to the forces affecting the bone.

The rise of piezoelectric technology is directly related to a set of inherent advantages. The high modulus of elasticity of many piezoelectric materials is comparable to that of many metals and goes up to 105 N/mm^2. Even though piezoelectric sensors are electromechanical systems that react on compression, the sensing elements show almost zero deflection. This is the reason why piezoelectric sensors are so rugged, have an extremely high natural frequency and an excellent linearity over a wide amplitude range. Additionally, piezoelectric technology is insensitive to electromagnetic fields and radiation, enabling measurements under harsh conditions. Some materials used (especially gallium phosphate or tourmaline) have an extreme stability over temperature enabling sensors to have a working range of up to 1000°C. Tourmaline shows pyroelectricity in addition to the piezoelectric effect; this is the ability to generate an electrical signal when the temperature of the crystal changes. This effect is also common to piezoceramic materials.

One disadvantage of piezoelectric sensors is that they cannot be used for true static measurements. A static force will result in a fixed amount of charges on the piezoelectric material. Working with conventional readout electronics, not perfect insulating materials, and reduction in internal sensor resistance will result in a constant loss of electrons, yielding a decreasing signal. Elevated temperatures cause an additional drop in internal resistance; therefore, at higher temperatures, only piezoelectric materials that maintain a high internal resistance can be used. Anyhow, it would be a misconception that piezoelectric sensors can only be used for very fast processes or at ambient conditions. In fact, there are numerous applications that show quasi-static measurements while there are other applications that go to temperatures far beyond 500°C.

2.5.1. Principle of Piezoelectric Sensor Operations

Depending on how a piezoelectric material is cut, three main modes of operations can be distinguished: transverse, longitudinal, and shear.

i. Transverse effect

A force is applied along a neutral axis(y) and the charges are generated along the (x) direction, perpendicular to the line of force. The amount of charge depends on the geometrical dimensions of the respective piezoelectric element. When dimensions *a*, *b*, *c* apply,

$$C_x = \frac{d_{xy} F_y b}{a} \quad \textbf{(1)}$$

Where;

a is the dimension in line with the neutral axis

b is in line with the charge generating axis

d is the corresponding piezoelectric coefficient

ii. Longitudinal effect

The amount of charge produced is strictly proportional to the applied force and is independent of size and shape of the piezoelectric element. Using several elements that are mechanically in series and electrically in parallel is the only way to increase the charge output. The resulting charge is;

$$C_x = d_{xx} F_x n \quad \textbf{(2)}$$

Where;

d_{xx} is the piezoelectric coefficient for a charge in x-direction released by forces applied along x-direction (in pC/N).

F_x is the applied Force in x-direction [N]

n is corresponds to the number of stacked elements

iii. Shear effect

Again, the charges produced are strictly proportional to the applied forces and are independent of the element's size and shape. For *n* elements mechanically in series and electrically in parallel the charge is

$$C_x = 2d_{xx}F_x n \tag{3}$$

In contrast to the longitudinal and shear effects, the transverse effect opens the possibility to fine-tune sensitivity on the force applied and the element dimension [11].

2.6. PIC16F876

This is one of the newest groups of devices from Microchip. They have flash program memory so they can be reprogrammed over and over again. Their building block is identical to the PIC16C7X family with some data memory and program memory updates. They offer 22 to 33 I/O, three timers and up to 8k of program memory. They have all the special functions PIC16C6X and PIC16C7X parts have as mentioned earlier.

All the projects in the book will be built around the PIC16F876 because it is flash reprogrammable, has A/D, and has all the other PIC features. It is also offers the option to build a boot-loader inside. A boot-loader allows me to program the part from a serial port without any special programmer circuitry [2].

2.7. Analog –to- Digital Converters (ADC’s)

An **analog-to-digital converter**, or simply ADC, is a semiconductor device that is used to convert an analog signal into a digital code. In the real world, most of the signals sensed and processed by humans are analog signals. Analog-to-digital conversion is the primary means by which analog signals are converted into digital data that can be processed by computers for various purposes.

An analog signal is a signal that may assume any value within a continuous range. Examples of analog signals commonly encountered every day are sound, light, temperature, and pressure, all of which may be represented electrically by an analog voltage or current. A device that is used to convert an analog signal into an analog voltage or current is known as a transducer. An analog-to-digital converter is used to further translate this analog voltage or current into digital codes that consist of 1's and 0's.

A typical ADC, therefore, has an analog input and a digital output, which may either be 'serial' (consisting of just one output pin that delivers the output code one bit at a time) or 'parallel' (consisting of several output pins that deliver all the bits of the output code at the same time). Analog-to-digital converters come in many forms [3].

2.8. Operational Amplifier (Op-Amp)

An operational amplifier is a dc amplifier having a high gain, of the order 10^4 – 10^8. The operational amplifier is arguably the most useful single device in analog electronic circuitry. With only a handful of external components, it can be made to perform a wide variety of analog signal processing tasks. It is also quite affordable; most general-purpose amplifiers sell for under a dollar apiece. Modern designs have been engineered with durability in mind as well: several "op-amps" are manufactured that can sustain direct short-circuits on their outputs without damage.

One key to the usefulness of these little circuits is in the engineering principle of feedback, particularly *negative* feedback, which constitutes the foundation of almost all automatic control processes. The principles presented here in operational amplifier circuits, therefore, extend well beyond the immediate scope of electronics. It is well worth the electronics student's time to learn these principles and learn them well.

The two input leads can be seen on the left-hand side of the triangular amplifier symbol, the output lead on the right-hand side, and the +V and -V power supply leads on top and bottom. As with the other example, all voltages are referenced to the circuit's ground point. Notice that one input lead is marked with a (-) and the other is marked with a (+). Because a differential amplifier amplifies the difference in voltage between the two inputs, each input influences the output voltage in opposite ways. The formula for gain and voltage output equation show below:

$$Gain = \frac{R_F}{R_{IN}} \quad (1)$$

$$V_{OUT} = A_V \left(V_{IN1} - V_{IN2} \right) \quad (2)$$

An increasingly positive voltage on the (+) input tends to drive the output voltage more positive, and an increasingly positive voltage on the (-) input tends to drive the output voltage more negative. Likewise, an increasingly negative voltage on the (+) input tends to drive the output negative as well, and an increasingly negative voltage on the (-) input does just the opposite. Because of this relationship between inputs and polarities, the (-) input is commonly referred to as the *inverting* input and the (+) as the *non-inverting* input.

Some models of op-amp come two to a package, including the popular models LM358. These are called "dual" units, and are typically housed in an 8-pin DIP package as well, with the following pin connections [1].

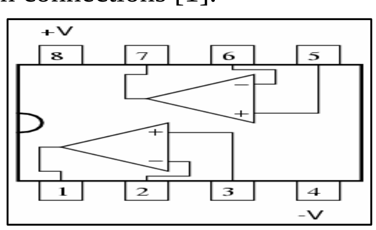

Figure 2.2: Dual Operational Amplifier LM358 in 8-packge dual [1].