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A Review on Various Types of Sensors and Their Applications

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Abstract- A brief overview of sensors physics, materials, types and applications is presented in this paper. Emphasis is placed mainly on acoustic sensors and optical sensors with their respective advantages and their specific applications in industry.

***Keywords*- Acoustic Wave (AW); Inter Digital Transducer(IDT); Fiber Optic Sensor(FOS); Fiber Bragg gratings (FBGs).**

I. INTRODUCTION

In recent years there is a growing demand of sensors over a wide range of applications which are currently used as resonators, filters, sensors and actuators. The AW family of devices include thickness shear mode (TSM) devices, shear horizontal acoustic plate mode (SH APM), the surface acoustic wave (SAW), shear horizontal surface acoustic wave (SH SAW). The major types of Optical sensors included microbending sensors, FBGs, optical fiber interferometers and polarization modulated fiber optic sensors.
Some of their applications include automotive applications, medical applications and industrial and commercial applications.

II. SENSOR

A sensor is a device which receives and responds to a signal when touched. In our daily life, we are surrounded by sensors like microphone, touch screen tablet. There are also innumerable applications for sensors of which most people are unaware.

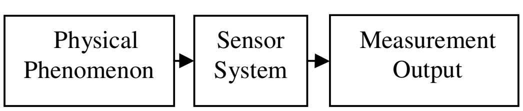

Fig1. Block Diagram of Sensor

Applications include cars, machines, aerospace, medicine, manufacturing and robotics.

III. SENSORS MATERIALS

Acoustic Sensors are made up of piezoelectric substrate materials [1]. The most common are quartz (SiO) and lithium tantalate (LiTaO), and to a lesser degree, lithium niobate (LiNbO). Each material has specific advantages and disadvantages, which include cost, temperature dependence, attenuation, and propagation velocity.

An interesting property of quartz is that it is possible to select the temperature dependence of the material by the cut angle and the wave propagation direction. With proper selection, the first-order temperature effect can be minimized. Other materials that have commercial potential include gallium arsenide (GaAs), silicon carbide (SiC), langasite (LGS), zinc oxide (ZnO), aluminum nitride (AlN), lead zirconium titanate (PZT), and polyvinylidene flouride (PVDF).
Glass optical fibers are almost always made from silica. Other crystalline materials like sapphire can be used for longer-wavelength infrared. Silica exhibits good optical transmission over a wide range of wavelengths. Silica can have extremely low absorption and scattering losses. Fusion splicing and cleaving of silica fibers is relatively effective. Silica fiber also has high mechanical strength against both pulling and even bending, provided that the fiber is not too thick and that the surfaces have been well prepared during processing. Even simple cleaving of the ends of the fiber can provide nicely flat surfaces with acceptable optical quality. Silica is also relatively chemically inert. In particular, it is not hygroscopic.

IV. OPERATING PRINCIPLES

Piezoelectricity [2] refers to the production of electrical charges by the imposition of mechanical stress. The phenomenon is reciprocal. Applying an appropriate electrical field to a piezoelectric material creates a mechanical stress. Conversely, by applying an appropriate mechanical stress, an electric field will be created. Piezoelectric acoustic wave sensors apply an oscillating electric field to create a mechanical wave, which propagates through the substrate and is then converted back to an electric field for measurement.

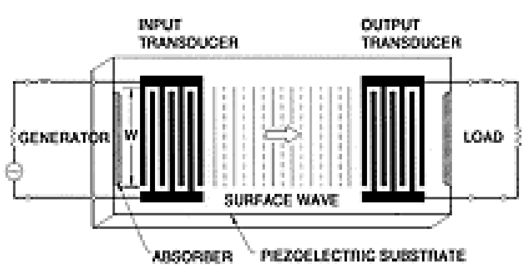

Fig2. IDT converts electric-field energy into mechanical wave energy and vice-versa.

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An Electro-Optic effect is a change in the optical properties of a material in response to an electric field that varies slowly compared with the frequency of light. The operation of an optical fiber is based on the principle of total internal reflection [3].

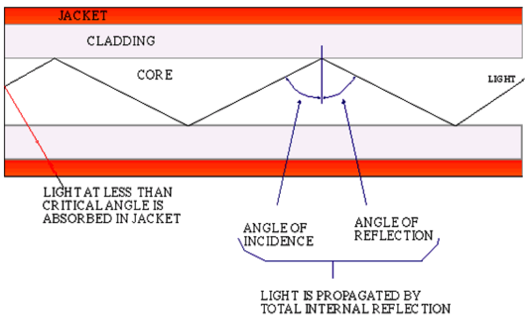

Fig3. Total internal reflection in an optical fiber.

Light reflects (bounces back) or refracts (alters its direction while penetrating a different medium), depending on the angle at which it strikes a surface. Controlling the angle at which the light waves are transmitted makes it possible to control how efficiently they reach their destination. Light waves are guided through the core of the optical fiber in much the same way that radio frequency (RF) signals are guided through coaxial cable. The light waves are guided to the other end of the fiber by being reflected within the core.

V. SENSORS FABRICATION

The acoustic sensors are made by photolithography process [4]. The manufacturing process begins by carefully polishing and cleaning the piezoelectric substrate [See Fig. 4(a)]. Metal, usually aluminum, is then deposited uniformly onto the substrate. The device is then coated with a photo-resist, which is spun on and then baked to harden it. The coated device is then exposed to UV light through a mask [see Fig. 4(b)]. The mask contains opaque areas, which correspond to the areas to be metalized on the final device. The exposed areas undergoes chemical change, allowing them to be removed using a developing solution [see Fig. 4(c)]. This exposes areas of metal, which are chemically etched away. The remainingphoto-resist is then removed, leaving the final device, as shown in Fig. 4(d).The pattern of metal that remains on the device is called an interdigital transducer (IDT).

VI. FIBER OPTIC SENSORS

Fiber optic sensors- can be classified as- Based on the sensing location, a fiber optic sensor can be classified as extrinsic or intrinsic [5].

Based on the operating principle or modulation and demodulation process, a fiber optic sensor can be classified as intensity, a phase, a frequency, or a polarization sensor [6].

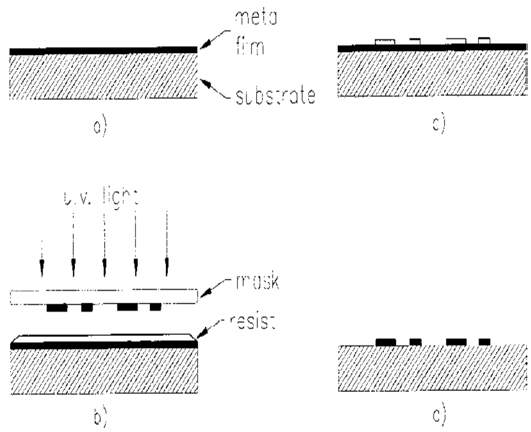

Fig4. Sensors are manufactured using the photolithography process.

6.1 Based on sensing location

Extrinsic FOS are basically optical sensor where we deliver (and collect) light signal by optical fiber, while the modulation of the light signal occurs outside optical fiber. Typical examples are fiberized versions of Doppler anemometers and non-contact vibration measurements systems. Their major advantage is that the flexible and dielectric link provided by the fiber allows the instruments to be used where access is difficult or prohibitive by means of electrical signals.
In Intrinsic fiber optic sensor, Perturbations act on the fiber and the fiber in turn changes some characteristic of the light inside the fiber .Intrinsic FOS are "true" fiber optic sensors, meaning that the modulation of light takes place inside fiber in accordance to measured parameter.

6.2 Based on operating Principle

a) Intensity Based Fiber Optic Sensors
In intensity modulated FOS, measured parameter induces light intensity change at the detector. The intensity-based sensor requires more light and therefore usually uses multimode large core fibers. There are a variety of mechanisms such as microbending loss, attenuation, and evanescent fields that can produce a measurand-induced change in the optical intensity propagated by an optical fiber. One of the intensity-based sensors is the microbend sensor, which is based on the principle that mechanical periodic micro bends can cause the energy of the guided modes to be coupled to the radiation modes and consequently resulting in attenuation of the transmitted light.

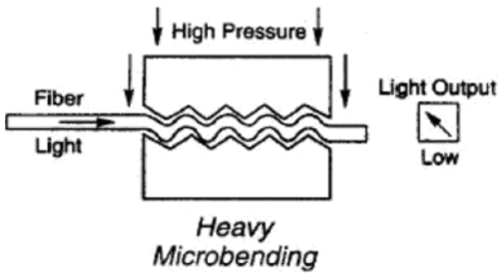

Fig5. Microbend FOS

b) Wavelength Modulated Sensors

Wavelength modulated sensors use changes in the wavelength of light for detection. Fluorescence sensors, black body sensors, and the Bragg grating sensor are examples of wavelength-modulated sensors. Fiber Bragg gratings are formed by constructing periodic changes in index of refraction in the core of a single mode optical fiber. This periodic change in index of refraction is normally created by exposing the fiber core to an intense interference pattern of UV energy. The variation in refractive index so produced, forms an interference pattern which acts as a grating. The Bragg grating sensor operation is shown in Fig6.

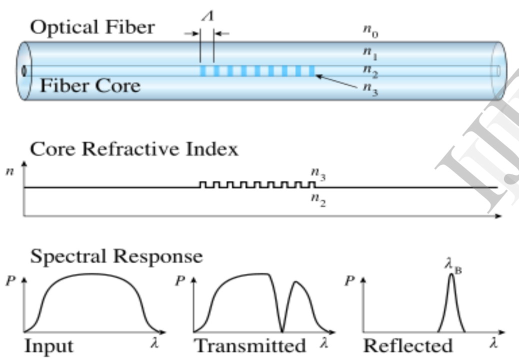

Fig6. Fiber Bragg gratings (FBGs)

c) Phase Modulated Fiber Optic Sensors

Phase modulated sensors use changes in the phase of light for detection. The optical phase of the light passing through the fiber is modulated by the field to be detected. This phase modulation is then detected interferometerically, by comparing the phase of the light in the signal fiber to that in a reference fiber. In an EFPI sensor, the Fabry- Perot cavity is outside the fiber. Fiber guides the incident light into to the FFPI sensor and then collects and the reflected light signal from the sensor. Figure 7 shows a typical EFPI sensor [7] based on capillary tube.

VII. ACOUSTIC WAVES SENSORS

Acoustic waves sensors [8] include thickness shear mode (TSM) devices, shear horizontal acoustic plate mode (SH APM), the surface acoustic wave (SAW), shear horizontal surface acoustic wave (SH SAW).

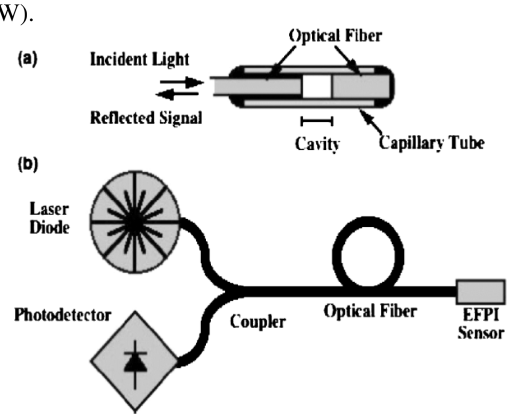

Fig7. Capillary tube based EFPI sensor.

7.1 Bulk Wave Sensors—TSM Resonator

The TSM [9] referred as a quartz crystal microbalance (QCM), is the oldest and simplest acoustic wave device. TSM consists of a thin disk of AT-cut quartz with parallel circular electrodes patterned on both sides. The application of a voltage between these electrodes results in a shear deformation of the crystal. The device is known as a resonator because the crystal resonates as electromechanical standing waves are created. The displacement is maximized at the crystal faces, making the device sensitive to surface interactions. The TSM resonator was originally used as a deposition sensor to measure metal deposition rates in vacuum systems. The sensor is typically used in an oscillator circuit, where the oscillation frequency tracks the crystal resonance and indicates mass accumulation on the device surface. Later, the TSM resonator operates as a vapor sensor. Recent work has been done to form high-frequency TSM resonators utilizing piezoelectric films and bulk silicon micromachining techniques.

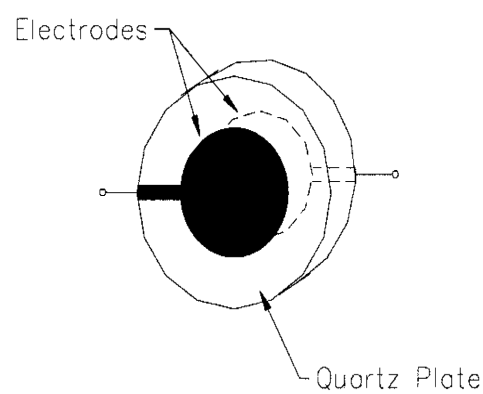

Fig 8. TSM resonator is useful for measuring metal deposition rates.

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7.2 Bulk Wave Sensors—SH-APM Sensor

SH-APM (Shear-horizontal acoustic plate mode) sensors utilize a thin piezoelectric substrate, or plate, that serves as an acoustic waveguide, confining the energy between the upper and lower surfaces of the plate. As a result, both surfaces undergo displacement, thus, detection can occur on either side. This is an important advantage, as one side contains the IDTs that must be isolated from conducting fluids or gases, while the other side can be used as the sensor. SH-APM sensors are quartz plates with thickness of a few wavelengths, where SH waves are generated by means of two IDTs positioned on one surface of the plate SH waves have particle displacement predominantly parallel to the plate surface and perpendicular to the propagation direction along the separation path between the two IDTs and hence are suited for operation in contact with liquid. APMs are a series of plate modes with slightly different frequencies. The difference between these frequencies decreases with decreasing plate thickness. To select a dominant SH mode, material and crystal cut, IDT design and oscillator electronics must be optimized. APMs have antinodes on both device surfaces so that each of them can be used as a sensing surface. In particular, the electrode-free face can be made chemically active and analysis in solution can be performed with a complete separation between the electric side and the liquid side.

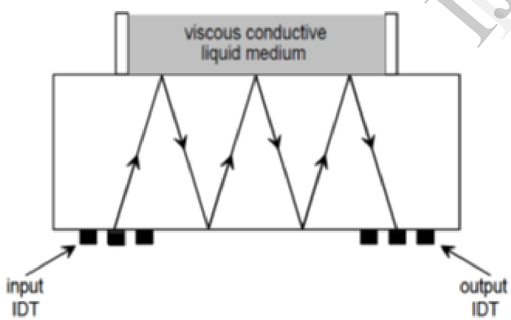

Fig 9. Structure of APM

7.3 Surface Wave Sensors- SAW Sensor

Surface acoustic wave (SAW) sensors are made by a thick plate of piezoelectric material, where Rayleigh waves propagate along the upper surface. Surface wave generation is efficiently accomplished by interdigital transducer (IDT). An IDT is formed by two identical comb-like structures whose respective fingers are arranged on the surface in an interleaved alternating pattern. This happens at the characteristic or synchronous frequency $fo = v/d$, where v is the SAW velocity in the material. The IDT of each sensor provides the electric field necessary to displace the substrate to form an acoustic wave.

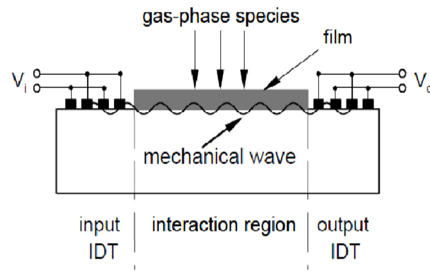

Fig10. Structure of saw sensor

The wave propagates through the substrate, where it is converted back to an electric field at the other IDT.

VIII. CONCLUSION

An overview of fiber optics sensors and Acoustic Sensor is presented along with their applications. Besides greater penetration in the automotive, medical, and industrial arenas, sensor manufacturers also anticipate a multitude of applications in wireless communications and consumer electronics. Most of these sensors will be of the MEMS and MST type. In fact, Motorola and Analog Devices propose the use of inertial sensing modular clusters to manage the vast number of sensing functions that will be required for vehicle dynamics, navigation, safety, and steer-by-wire applications.

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