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A Detailed Review on Flexible Pressure Sensor using Strain Gauge

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Abstract : Strain is the amount of deformation of a body due to an applied force. More specifically, strain (ε) is defined as the fractional change in length. Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in.or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as microstrain (με), which is ε × 10–6. When a bar is strained with a uniaxial force, a phenomenon known as Poisson Strain causes the girth of the bar, to contract in the transverse, or perpendicular, direction. The magnitude of this transverse contraction is a material property indicated by its Poisson's Ratio. This paper deals with the detailed review on strain gauge ranging from its properties, temperature effects and applications.

Index Terms **- Graphene ink, Strain gauge, Applications.**

I. Introduction

A strain gauge is a sensor whose measured electrical resistance varies with changes in strain. Strain is the deformation or displacement of material that results from an applied stress. Stress is the force applied to a material, divided by the material cross-sectional area. Load cells are designed to focus stress through beam elements where strain gauges are located [1]. Strain gauges convert the applied force, pressure, torque, etc. into an electrical signal which can be measured. Force causes strain, which is then measured with the strain gauge by way of a change in electrical resistance. Then the voltage measurement is gathered using data acquisition.

The next step when using strain gauges is getting useful data. The strain gauge must be connected to an electrical circuit that is capable of accurately responding to the minute changes in resistance associated with strain. Multiple strain gauges can be used in a divided bridge circuit to measure small changes in electrical resistance. This is called a Wheatstone bridge [2]. In a Wheatstone bridge configuration, an excitation voltage is applied across the circuit, and the output voltage is measured across two points in the middle of the bridge. When there is no load acting on the load cell, the Wheatstone bridge is balanced and there is zero output voltage. Any small change in the material under the strain gauge results in a change in the resistance of the strain gauge as it deforms with the material. This causes the bridge to be thrown out of balance, resulting in a change in the output voltage. As stated earlier, the resistance change is minute, which means that signal amplification is often needed to properly determine changes. The amplification process strengthens the strain signal changes, however, it also leads to more unwanted noise also being detected in the signal. Signal conditioning filters out the excess noise, ensuring accurate and understandable data.

II. STRAIN GAUGE CLASSIFICATION AND PRINTING

Strain gages are classified in several ways. One classification cites the purpose for which the gage is to be used, that is, for static or dynamic strain measurement. Static gages are often made up with Constantan foil (a copper-nickel alloy), which has a minimum change of resistance with temperature. Dynamic strain gages occasionally are made up with Iso-elastic foil (ironnickel- chrome alloy), which provides a greater gage factor than Constantan. Another common alloy used in strain gages is Karma, an alloy primarily of nickel and chrome. The dynamic gages, while having a much greater resistance change for a given strain than the static gages, also are much more sensitive to changes in temperature. They are used only where the phenomenon to be measured is so short in time duration that no temperature change of any consequence can occur during the time of measurement [3]. Gages also are available for the measurement of very large strains (up to 20 percent) occurring in the plastic region of the material, as distinguished from the more common gages which are used to measure elastic strains (up to 1 percent).

Mixtures of a carbon graphite particle based resistive ink (DuPont 7082) and a silver particle conductive ink (DuPont 5028) were manually screen printed onto 5 mil thick polyethylene terephthalate (PET) sheets using a Gold Print SPR-25 screen printer, 70 durometer (Shore A) squeegee blades, a printing offset of 3 mm, and an approximate printing speed of 3 cm/sec. This printing was done at room temperature (~20 °C), with a squeegee angle of ~70 degrees. The graphite based ink contains micron size graphite particles dispersed into a proprietary polymer and solvent mixture which exhibits an overall viscosity of 210 -260 Pa s, yielding printed films with sheet resistivity of ~ 400 ohm/sq/mil sheet [4] . The silver particle ink contains 5-10 µm silver particles dispersed in a polymer-solvent mixture with an overall viscosity of 15-30 Pa s, yielding printed films typically of 25 µm thickness with sheet resistivity of < 12 milliohm/sq/mil. The printed sensors had lengths, widths and line widths of 1.06, 0.80, and 0.11 centimeters, respectively with a tension of 27 Ncm. Commercial constantan (Cu-Ni) gauges, KFH-20-120-C1-11L1M2R from Omega, were used for comparison to the printed gauges and had lengths, widths and line widths of 2.007, 0.305, and 0.025 centimeters, respectively. An image of one set of four printed strain gauges and a diagram of the overall printing process is shown below in Figure 1.

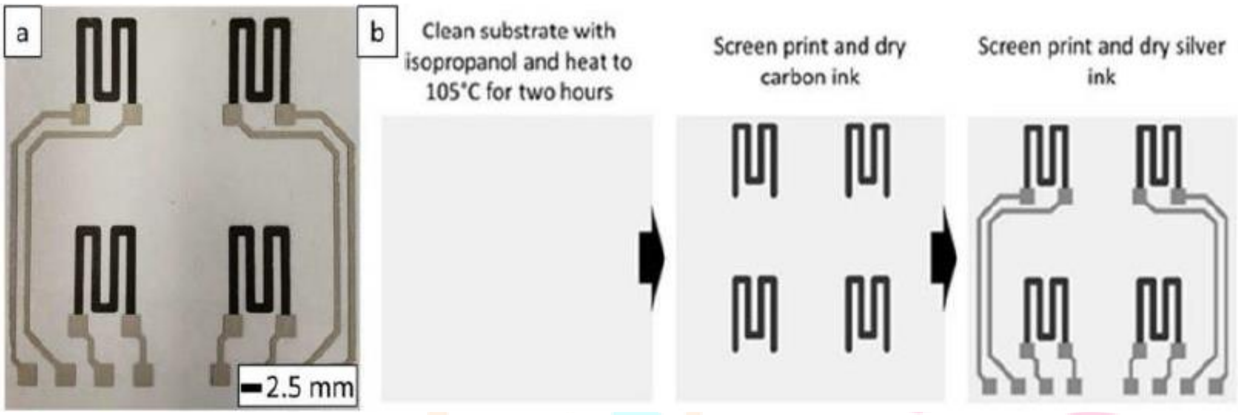

Fig. 1 (a) Set of four printed Strain gage (b) Printing Procedure

III. TEMPERATURE EFFECT OF STRAIN GAUGE

When a bonded strain gage is used in measurements, any change in resistance in the strain - gage measurement system is interpreted as resulting from a strain. If thermal expansion is not induced, then this change will result from a mechanical strain. However, if thermal expansion is induced, then there will be a change in resistance resulting from the mechanical strain, and in addition, there will be a change in resistance resulting from the response of the strain gage to changes in temperature. The strain indication which results from such a temperature effect is known as an apparent strain. [5] This effect is usually negligible in the measurement of dynamic strains, since the readout instrument associated with the strain gage usually does not respond to static or slow changes in its resistance. However, in the measurement of static strains, the effects of temperature represent the largest potential source of error and require some form of temperature compensation. It is therefore important to know the temperature at which a strain gage is used [6].

IV. APPLICATIONS OF STRAIN GAUGE

- Aerospace Applications – strain gauges are bonded to load-bearing components within air crafts to measure any strain and stress which takes place within various areas during flight. Strain gauges can monitor the wing deflection or deformation during flight to ensure it is safe. They also monitor various on-board units and power supplies [7].
- Rail applications – strain gauges can be bonded to the railway lines themselves to monitor and measure the stress the l ines are under. The readings they produce can alert personnel if the railways become under too much stress or strain. This ensures the railway line stays safe to use and allows repairs and maintenance to be carried out before any visible signs of strain or stress show.
- Use within Load Cells – strain gauges are used within load cells, the measure the strain and stress the load cell is under to determine weight and quantities. They can also be incorporated into other sensors including pressure transducers to help with pressure measuring.
- Measuring stress on circuit boards – some very small strain gauges can measure stress on electric circuit boards and other confined spaces.
- Residual Stress monitoring – this is a very broad term and can refer to monitoring stress in casting, welding and formation processes during manufacturing. This is a common application for strain gauges. They can also be used to monitor stress during high speed drilling applications.
- Strain measurement – Whenever the tested material is under high stress or load, they come under strain and that is where strain gauge is doing its job.

V. SCREEN PRINTED STRAIN SENSORS ON FLEXIBLE SUBSTRATES VIA GRAPHENE INK

It is a material composed of carbon atoms grouping that are hexagonally positioned. This arrangement results in monolayers of an atom thick. This material is part of one of the most abundant substances in nature, graphite (graphite can be found, for example, in the mines of our pencils). One millimeter of graphite contains three million layers of grapheme. Flexible electronics can be developed with a low-cost and simple fabrication process while being environmentally friendly. Conductive ink is a paint that contains silver or carbon particles. These particles are responsible for giving this ink / paint the conductive property [8].

Strain sensors are in high demand in a vast number of diverse applications ranging from structural integrity analysis in automobiles, aerospace vehicles, and civil structures to medical diagnostics with wearable equipment and monitoring systems. For resistive strain sensors, the resistance change with strain is used to quantify the amount of strain applied. The magnitude of the resistance change with strain defines its sensitivity or gauge factor and this is determined by the piezoresistivity of the sensor material along with its geometric dimensions. Commercial sensors are often made of either thin metal foil or single-crystal doped silicon. For these materials, the mechanism of resistance change with strain is quite different, leading to much different piezoresistivity properties. For metals, strain leads to small increases in resistance due to electron scattering effects whereas for semiconductors such as doped silicon, strain results in changes in the bandgap of the material leading huge influence on resistivity and thus high sensitivity [9].

VI. CONCLUSION

It can be concluded that the strain gauge sensors are in high demand in diverse areas of daily, commercial, industrial phases. As strain gage has many applications due to which it has a huge demand. Different bridges involve strain gage to be utilized in industrial sectors, although temperature has different effects on each strain gage and on each applications. Graphene has also been efficiently used to produce conductive inks which are also in turn being used to produce screen printed strain gages. In future, grapheme can be more effectively used to utilize strain gage in more and peculiar applications.

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