DEVELOPMENTS

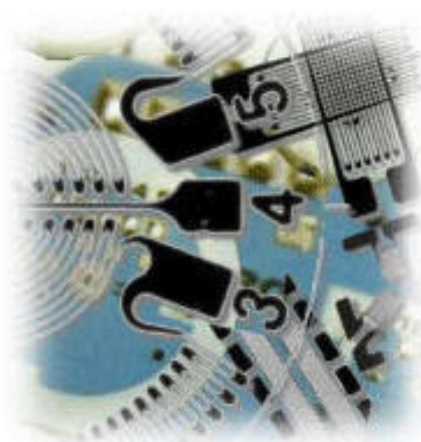
IN

SEMICONDUCTOR STRAIN

GAUGES

Albert Ellison

esi
technology



Ellison Sensors

esi

Pressure Transducers & Transmitters, Ranges from 0-500mbar to 0-4,000bar

TSM

TSM

Strain Gauge Manufacture & Supply , In-house or On-site Installation Service

SIGTEL

SIGTEL

Radio Telemetry Systems Wireless systems for Strain Gauge Sensors

STRESS & STRAIN

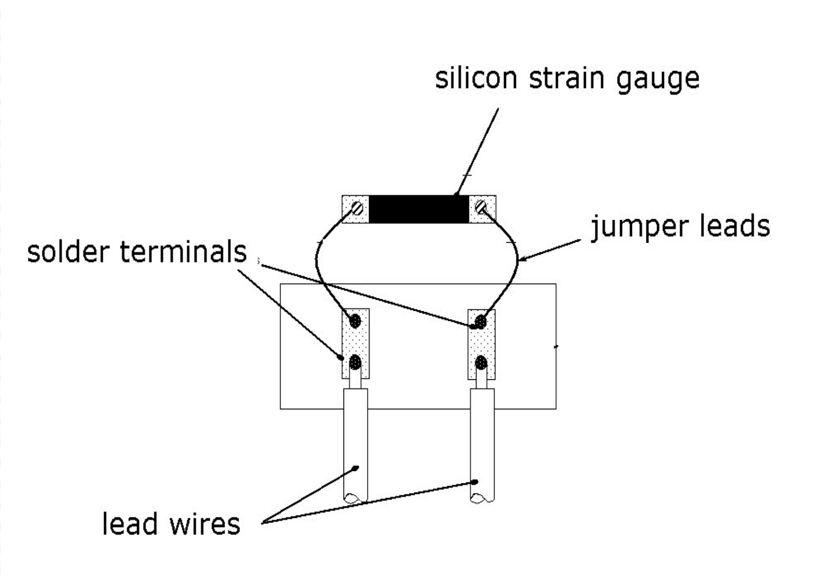
- External forces applied to stationary object , results are stress & strain
- Stress is the object's internal resisting forces = F/A
- Strain is the amount of deformation per unit length =(△L)/L
- Strain is expressed in micro-strain = strain x 10^{-6}
- Strain may be compressive or tensile and is typically measured by strain gauges.

DEVELOPMENT OF THE STRAIN GAUGE

- 1850's Lord Kelvin reported metallic conductors when strained exhibit a change in resistance.
- 1930's First bonded wire wound strain gauge followed by metallic foil strain gauge.
- 1959 TSM start manufacture of foil strain gauges
- 1950's Bell Laboratories discovered the piezoresistive characteristics of silicon.
- 1970's first semiconductor silicon strain gauge developed.

BONDED SEMICONDUCTOR STRAIN GAUGE

- Resistance element diffused into substrate of silicon
- Strain gauge element usually not backed.
- Strain gauge bonded to surface with care.



DIFFUSED SEMICONDUCTOR STRAIN GAUGE

- Further development in strain gauge technology.
- Eliminates the need for bonding agent.
- Errors due to creep and hysteresis reduced.
- Uses photolithography & solid state diffusion of boron to produce resistors and track.
- Limited to moderate temperature applications requires temperature compensation .

SILICON-ON-INSULATOR (SOI) SEMICONDUCTOR STRAIN GAUGE

- Next significant development in semiconductor strain gauge technology.
- The resistors and interconnecting track are built on islands of silicon fabricated on an insulating substrate.
- The insulating layer provides isolation between strain gauges and connecting track.
- Silicon-on-Sapphire the first and still the most successful of the silicon-on-insulator technologies.

SILICON-ON-SAPPHIRE (SOS) SEMICONDUCTOR STRAIN GAUGE

- SOS formed by depositing a thin layer of silicon onto a sapphire wafer at high temperature.

- Strain gauges and interconnecting track formed in silicon layer by photolithography & etching techniques.

- Outstanding insulation properties of sapphire substrate.

- Sapphire highly elastic exhibiting no measurable hysteresis , excellent choice for sensors .

APPLICATION OF SILICON-ON-SAPPHIRE (SOS) SEMICONDUCTOR STRAIN GAUGE TECHNOLOGY

What is Sapphire ?

- Sapphire is from the word Greek : *sappherios* refers to naturally occurring gem of the mineral aluminium oxide Al_2O_3 .

- Single crystal sapphire is purest form of aluminium oxide and is synthetically produced.

APPLICATION OF SILICON-ON-SAPPHIRE (SOS) SEMICONDUCTOR STRAIN GAUGE TECHNOLOGY

- Aluminium oxide (Al_2O_3) powder is heated in a controlled furnace to 2000ºC then slowly cooled.

- The result is a sapphire ingot of with a uniform grain structure.

Sapphire ingot

- Czochralski process , Verneuil process

- The ingot is then cut and ground into a wafer.

APPLICATION OF SILICON-ON-SAPPHIRE (SOS) SEMICONDUCTOR STRAIN GAUGE TECHNOLOGY

- C-plane cut perpendicular to the crystal axis (0001) and is used for the production of blue LED and laser diodes.

- A-plane cut 90º to C-plane (1120) provides uniform dielectric constant and high insulation for hybrid microelectronic applications.

- R-plane cut 57º to C plane used for epitaxial deposition of silicon for strain gauge sensors and microelectronics

APPLICATION OF SILICON-ON-SAPPHIRE (SOS) SEMICONDUCTOR STRAIN GAUGE TECHNOLOGY

- R-plane of cut sapphire has oxygen atoms spaced at a distance close to the spacing of atoms in the (100)plane of silicon .
- This feature enables successful growth of silicon on he sapphire wafer.
- The process is known as epitaxial growth

APPLICATION OF SILICON-ON-SAPPHIRE (SOS) SEMICONDUCTOR STRAIN GAUGE TECHNOLOGY

- Epitaxy is the method of depositing a monocrystaline film on to a monocrystaline substrate.

- The term epitaxy comes from the Greek epi meaning ‘above’, and taxis meaning ‘in ordered manner’

- The compatibility between the (1102) plane of sapphire and the (100) plane of silicon enables SOS technology.

COMPARISON OF MECHANICAL PROPERTIES OF SAPPHIRE

	units	Diamond	Sapphire R plane	Spring steel	17-4PH , H900
Compressive Strength	MPa	6000	3000	1800	1000
Young's Modulus	GPa	1100	345	200	197
Hardness HV1	GPa	90	25	5	4
Poisson's Ratio	MPa	0.1 - 0.29	0.29	0.27	0.27

Electrical properties of sapphire

Dielectric strength 4.8 x 104 KVmm-1

Bulk resistivity 1 x 1014 ohm-cm

APPLICATION OF SILICON-ON-SAPPHIRE (SOS) STRAIN GAUGE TECHNOLOGY IN THE MANUFACTURE OF PRESSURE SENSORS

SILICON-ON-SAPPHIRE (SOS) STRAIN GAUGE TECHNOLOGY APPLIED TO PRESSURE SENSORS

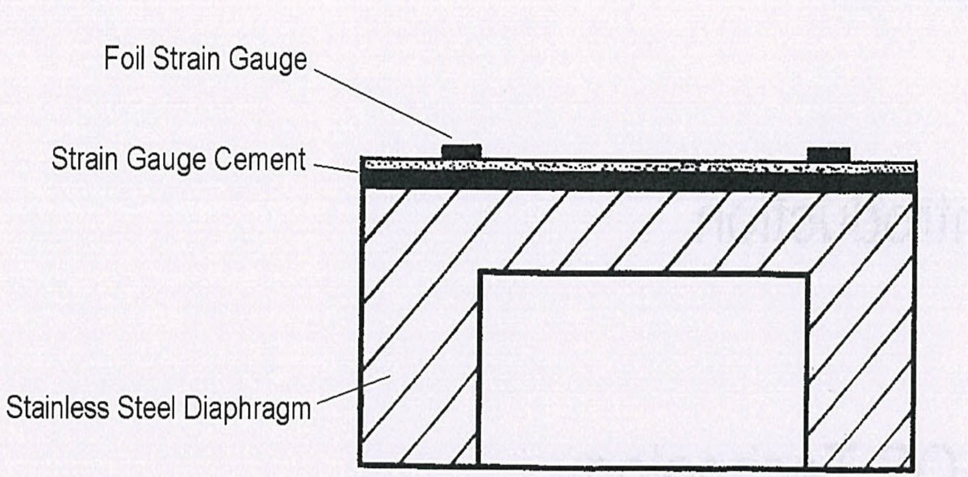
- Resistive strain gauge pressure measurement most popular sensing technique used in the manufacture of pressure sensors.

- Applied pressure causes the deformation of a diaphragm , the deformation is translated into a proportional electrical signal by means of a strain gauge attached to the diaphragm.

SILICON-ON-SAPPHIRE (SOS) STRAIN GAUGE TECHNOLOGY APPLIED TO PRESSURE SENSORS

- Strain gauge initially cemented to the pressure diaphragm

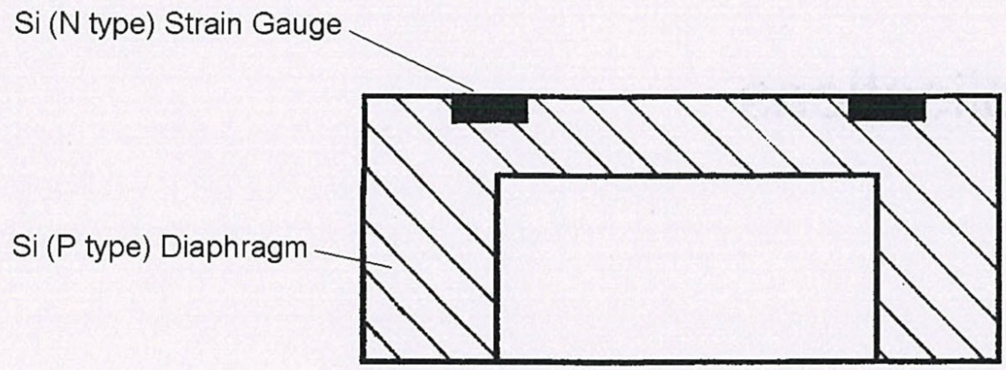
- 3 component system gage-cement-diaphragm suffers creep and hysteresis



Bonded Foil Strain Gauge Sensor

SILICON-ON-SAPPHIRE (SOS) STRAIN GAUGE TECHNOLOGY APPLIED TO PRESSURE SENSORS

- Demand in industry was for more stable and repeatable sensors.
- Introduction of solid state piezoresistive pressure sensors .



Solid State Diffused Silicon Sensor

SILICON-ON-SAPPHIRE (SOS) STRAIN GAUGE TECHNOLOGY APPLIED TO PRESSURE SENSORS

- Solid state silicon piezoresistive pressure sensors offered some improvement over bonded strain gauge type.

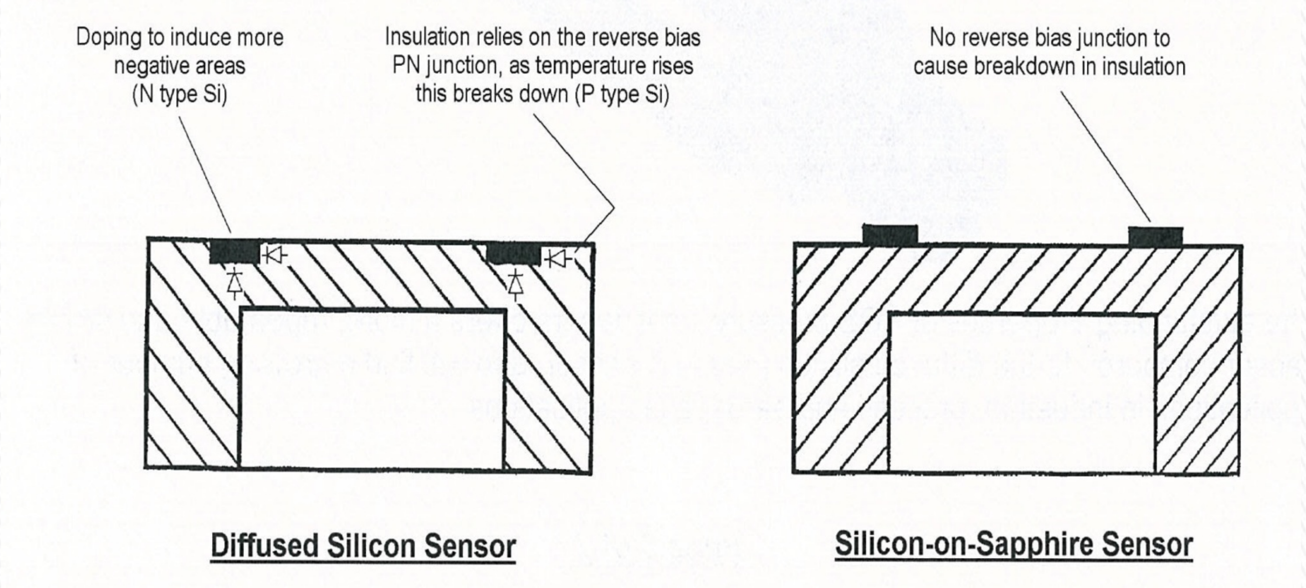
- Improved sensitivity and repeatability

- Techniques for production of solid state pressure sensors same as those used for integrated circuits.

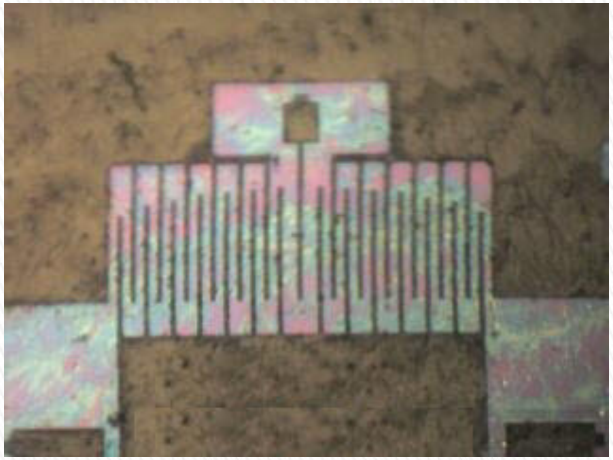
SILICON-ON-SAPPHIRE (SOS) STRAIN GAUGE TECHNOLOGY APPLIED TO PRESSURE SENSORS

- Silicon proven to be one of the most desirable pressure sensing elements .

- Sapphire outstanding elasticity and insulating properties.



SILICON-ON-SAPPHIRE (SOS) STRAIN GAUGE TECHNOLOGY APPLIED TO PRESSURE SENSORS



- Strain gauges etched in doped silicon epi layer .
- Individual strain gauges are electrically isolated from one another by the outstanding insulating properties of the sapphire substrate.
- Excellent performance at temperatures up to 350ºC .
- Excellent repeatability of sapphire diaphragm.

APPLICATIONS OF
SILICON-ON-SAPPHIRE (SOS) PRESSURE TRANSDUCERS

Oil Gas & Offshore

Pressure Transducers & Transmitters

- High temperature operation
- Outstanding long term stability
- Superior SOS sensing technology
- Land, Offshore & Subsea applications
- Down hole Wellhead & Control valve sensors

SOS semiconductor strain gauge technology

Silicon-on-Sapphire

Pressure Transducers & Transmitters

Superior sensing technology

High temperature operation

Outstanding long term stability

Ranges 0-500mbar to 0-4000bar

Digital Signal Processing with active digital compensation