Then and Now

Silicon Microengineered Sensors (SME)

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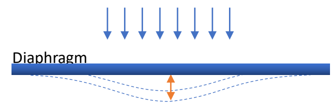
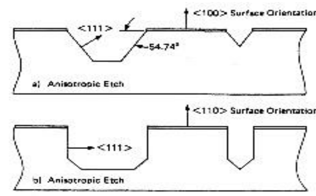
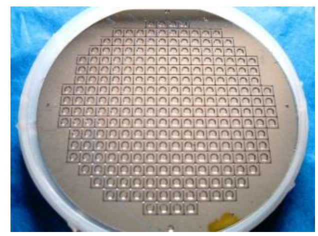
Silicon pressure sensors

- Silicon pressure sensors were pioneered in the late 1960's and early 1970's by Kulite in the USA and Druck in the UK. Druck was founded in 1972.
- Conventional pressure sensors consist of 2 elements, a structure to convert differential pressure into deflection, generally a diaphragm, and a means of measuring the deflection, typically by attaching strain gauges to the back of the diaphragm.
- Silicon has two principal advantages
  1. It can fulfil both of these functions in a single component and whole wafer of sensors can be made at once using standard semiconductor processing techniques including anisotropic etching
  2. The sensors are much smaller with less internal volume resulting in a much higher frequency response
- The first commercial application of STL SME technology was a pressure sensor for ITT Barton Industries (City of Industry, California). A multiple array of diaphragms was etched in a silicon wafer after strain gauges were formed on the reverse side of the wafer







Array of diaphragms etched in a silicon wafer

Silicon pressure sensors were pioneered in the late 1960's and early 1970's by Kulite in the USA and Druck in the UK. Druck was founded in 1972. Conventional pressure sensors consist of 2 elements, a structure to convert pressure into deflection, generally a diaphragm, and a means of measuring the deflection, typically by attaching strain gauges to the back of the diaphragm. Silicon has 2 principal advantages over this approach.

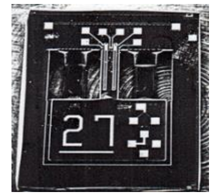
1. Silicon can fulfil both of these functions in a single component, the diaphragm is formed by thinning the silicon wafer by etching, and the strain gauges are formed in the diaphragm itself by ion implantation. So a whole wafer of sensors can be made at once using standard semiconductor processing techniques
2. Silicon has a gauge factor of about 150, compared with 2 for foil gauges, resulting in a much bigger output from a small deflection. This means that the sensors are much smaller with less internal volume resulting in a much higher frequency response

However, the sensors are still analogue piezoresistive devices and exhibit zero drift as the dopants in the gauges migrate with time.

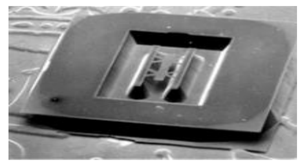
The STL Resonant pressure sensor

- The boron etch-stop was invented at STL by John Greenwood, who designed various etched mechanical structures.
- The most successful structure John developed was a resonant pressure sensor with an etched butterfly-type structure. The etched pit is about 1.8mm by 2.5mm.
- The structure was processed at STL by the SME Team in its custom-built clean room.
- Prototype pressure sensors were developed, and interest was shown by Druck Ltd.
- Nortel showed no interest in the exploitation of SME, so STL licensed the resonant pressure technology to Druck Ltd, of Leicester in 1990.
- The STL team, including John Greenwood, moved to Druck.

Rugged piezoelectric accelerometer



Resonant cantilever accelerometer



Resonant pressure sensor

Prototype pressure sensor

Work on silicon sensors started at the labs in the early 1970s in TM (Jackie) Jackson's dept, with John Greenwood working on the basic etching process.

John invented the boron etch-stop, a huge breakthrough whereby he realised that analogue strain gauges could be replaced with a mechanical resonator formed in the silicon as part of the diaphragm giving a frequency output which varies with strain in much the same way as the frequency of a guitar string changes with tension. This was an etched butterfly-type structure with an etched pit of approximately 1.8mm by 2.5mm.

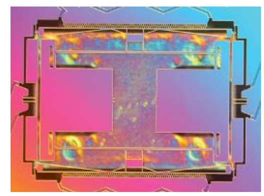
This structure gave the order of magnitude improvement in stability over existing devices.

The structure was processed at STL by the SME Team in its custom-built clean room in K Corridor for etching and wafer processing under Pete Graves' management who had taken over when Jackie Jackson retired in 1975. At this time work was in hand to develop an etched piezoresistive diaphragm sensor for ITT Barton Industries in California. Barton were part of ITT Industrial Products Group - about 20% of ITT sales were in this area and about 25% in telecoms (the rest was in hotels, baking, Avis etc). Other experimental work was looking at other applications for etched sensor structures.

The group regularly supplied 4" processed wafers to Barton for their pressure measuring equipment. STL also had MoD contracts to develop John Greenwood's designs of resonating pressure sensor and accelerometer for RARDE Fort Halstead. The plan was to use the device in 'intelligent' artillery shells, and tests were made on Salisbury Plain, shooting a dummy shell containing an STL Si accelerometer to 60,000 feet and then digging it up from being buried 10 feet in the ground. It survived!

Transfer of STL SME resonant pressure technology to Druck

- STL resonant pressure sensor offered an order of magnitude improvement in stability over Druck's piezoresistive device and significant cot saving over the bought-in Solartron resonant sensor but was difficult to manufacture and yields variable
- Druck's first product based on the resonant pressure sensor was the DPI 141 in 1993
- This was superseded in 2002 by the DPI 142, which remains today the UK standard barometer at NPL
- In 2001 Druck began a project to update the design and manufacturing process to produce a new resonant sensor TERPS (Trench Etched Resonant Pressure Sensor) which is the current production part



Nortel showed no interest in the exploitation of SME, so STL licensed the resonant pressure technology to Druck Ltd, of Leicester. The STL team, including John Greenwood, moved to Druck.

STL's resonant pressure sensor offered an order of magnitude improvement in stability and a cost saving over Druck's piezoresistive device. However, it was difficult to manufacture and yields were variable.

Druck's first product based on the resonant pressure sensor was the DPI 141 in 1993

In 2001 Druck began a project to update the design and manufacturing process to achieve a more consistent yield. They invested in a deep reactive ion etcher and a wafer bonder to replace the previous manual processes with automated wafer-scale processes. John Greenwood was heavily involved in the design. The instruments were also redesigned with modern VGA screens.

The DPI 141 was superseded in 2002 by the DPI 142, which remains today the UK standard barometer at NPL.