"A Computational Approach for Simulating P-type Silicon Piezoresistor Using Four Point Bending Setup"

Authors: **T. H. Tan[1]**, S.J.N Mitchell[1], D.W. McNeill[1], H. Wadsworth[2], S. Strahan[2].
[1]*School of Electronics, Electrical Engineering and Computer Science,*
Queen's University Belfast, BT9 5AH, United Kingdom.
[2]*Schrader Electronics Ltd., Antrim BT41 1QS, United Kingdom.*

Queen's University Belfast

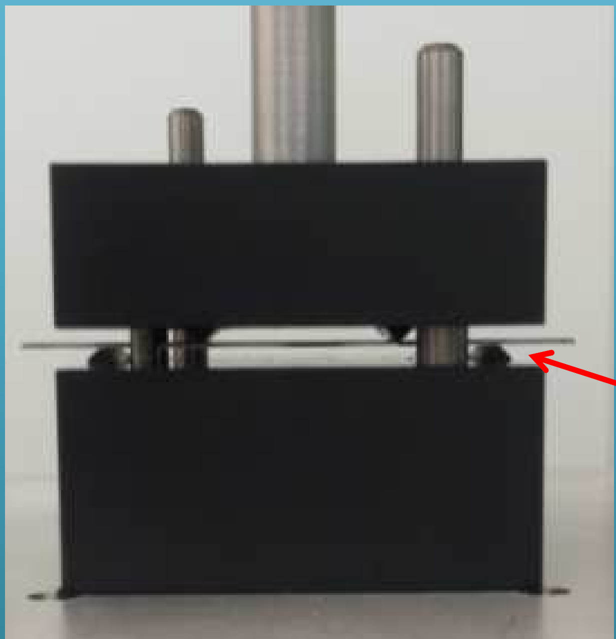
COMSOL CONFERENCE ROTTERDAM 2013

Introduction

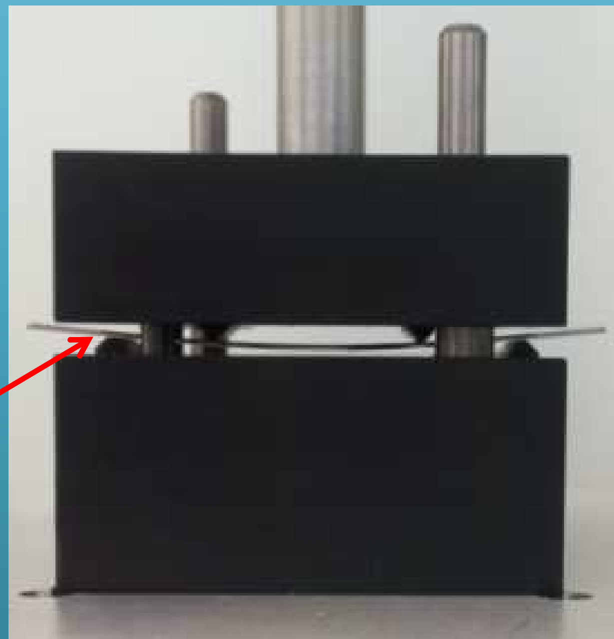
- Silicon piezoresistive pressure sensors are widely used in MEMS sensing applications.
- Piezoresistance effect is defined as change in resistance due to applied stress.
- COMSOL Multiphysics 4.3 released new user interface model – piezoresistivity modelling.
- Aim of this work:
  - ✓ Using COMSOL Multiphysics to model four point bending.
  - ✓ Using COMSOL Multiphysics to simulate piezoresistance effect in silicon.
  - ✓ Compare and verify simulation with experimental results.

Practical setup – four point bending fixture

- Designed and fabricated to analyse the piezoresistance effect in *p*-type silicon.
- Used to apply uniform and uniaxial stress along the <110> crystal direction
- Investigate the piezoresistive characteristic of *p*-type resistors as a function of doping concentrations.
- Stress uniformity verified using COMSOL Multiphysics.



Silicon beam



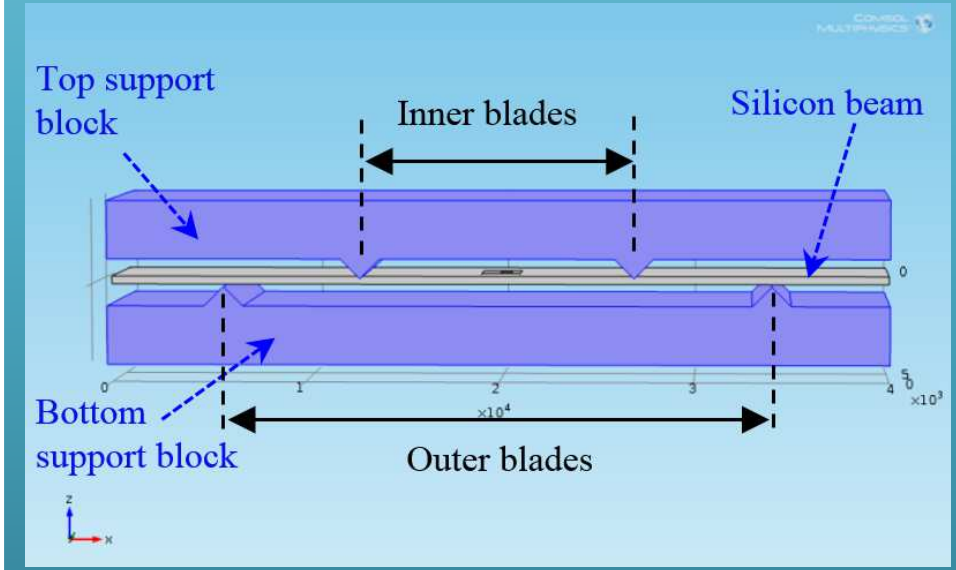
Pressure

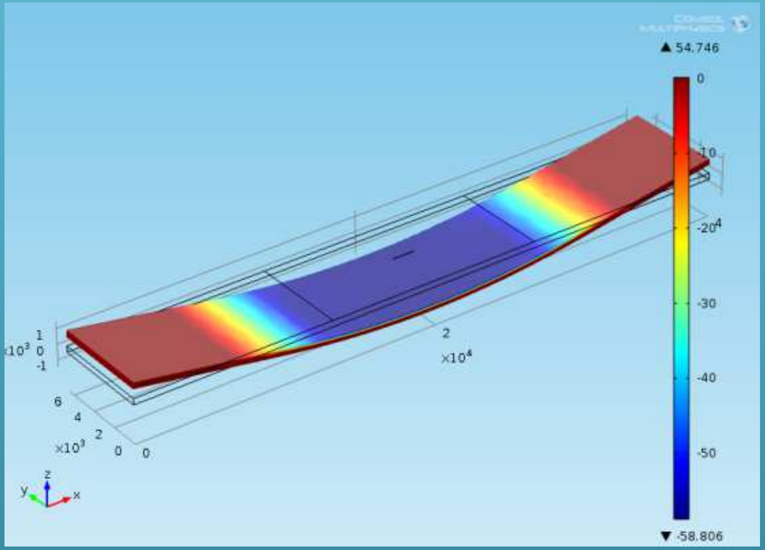
Queen's University Belfast

COMSOL CONFERENCE ROTTERDAM 2013

Four point bending COMSOL model:

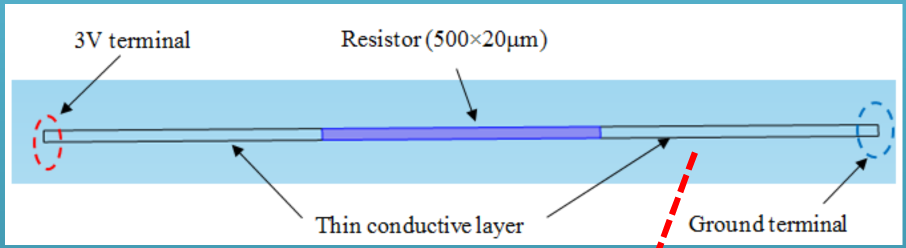
- 3D geometry comprises three main components.
- Silicon bar is 40mm long, 6mm wide and 400µm thick.
- Two inner blades and outer blades with separation of 14mm and 28mm
- Apply downwards loading forces to the silicon beam (convert to stress using COMSOL).

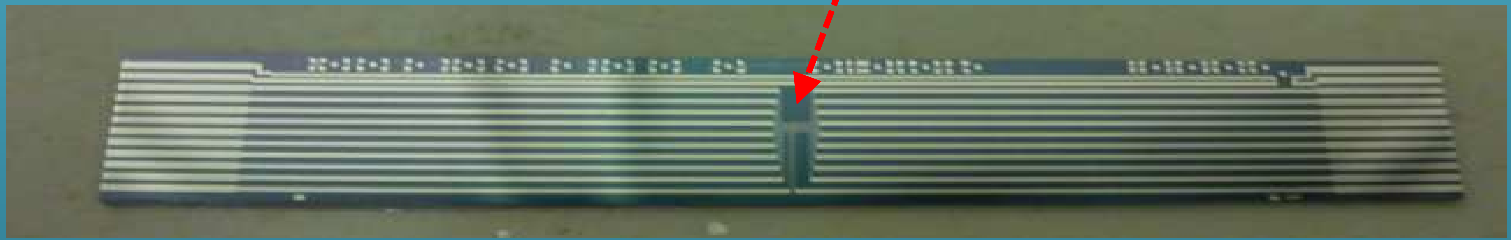




Details of piezoresistor:

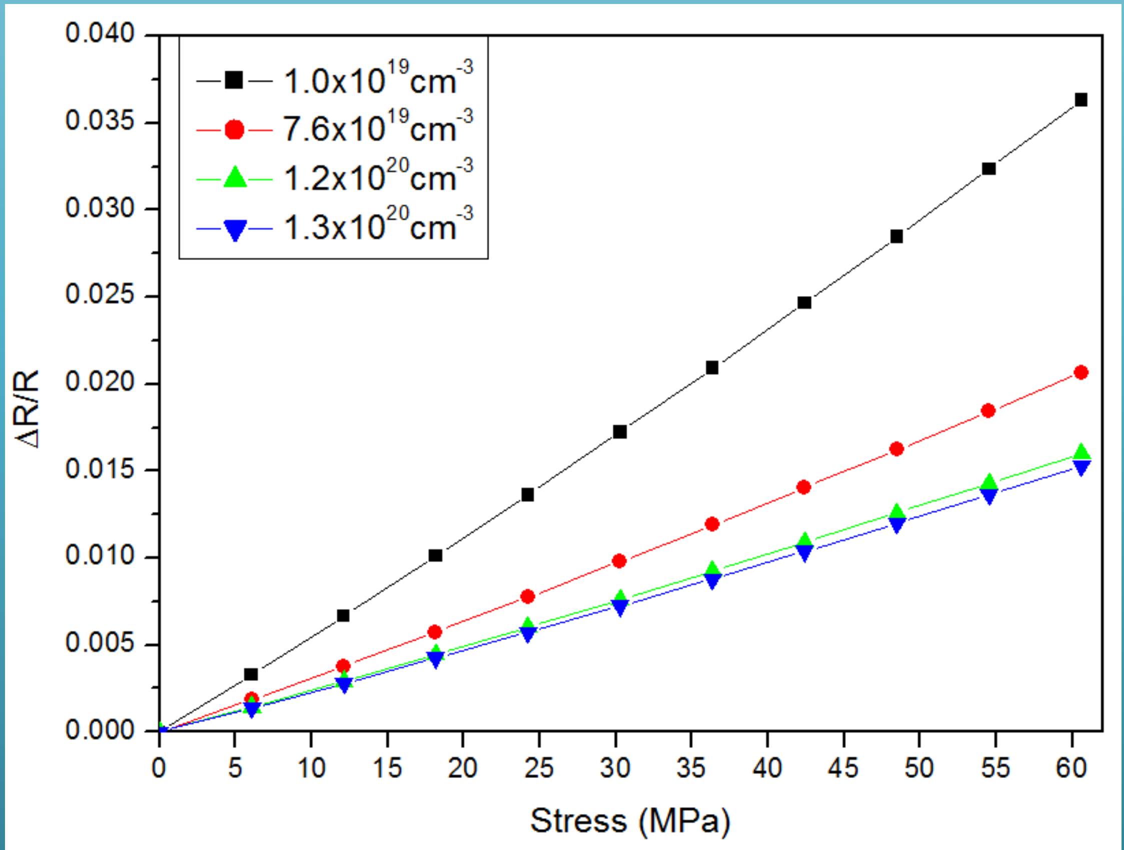
- Two terminal piezoresistor including the two contact pads with similar dimensions.
- Four doping concentration values ranges from $1.0 \times 10^{19}cm^{-3}$ to $1.3 \times 10^{20}cm^{-3}$.
- Higher doping concentrations are investigated due to less temperature dependence.
- It has been found that inclusion of a "thin conductive layer" is important to observe the effect of doping concentration on piezoresistor.
- Keeping the "thin conductive layer" the same size as the resistor gives the best agreement with published / measured results.





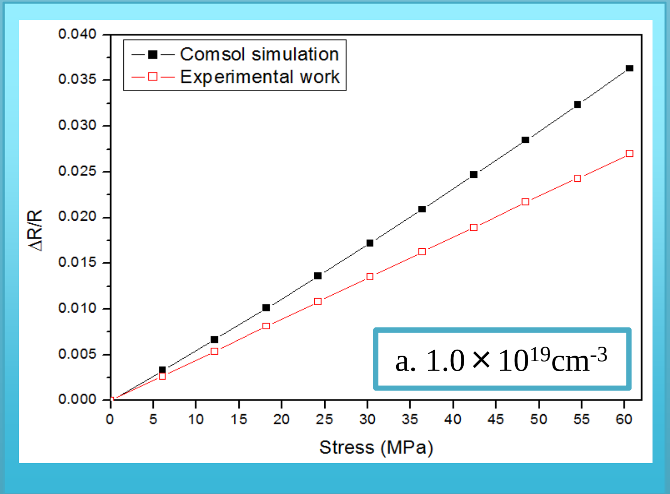
COMSOL simulation results:

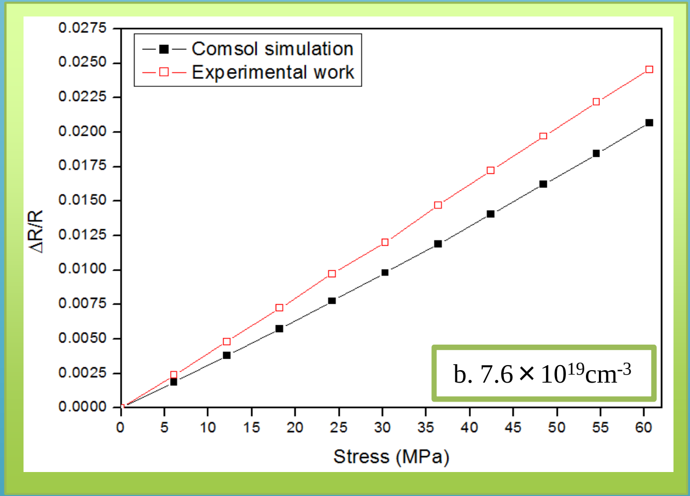
- Resistance change is linearly proportional to applied stress.
- Stress up to 60MPa
- Piezoresistance effect ⇩ as doping concentration ⇧ .

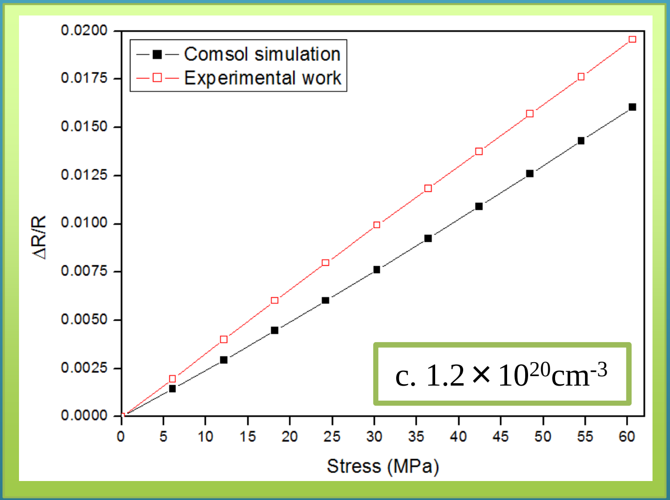


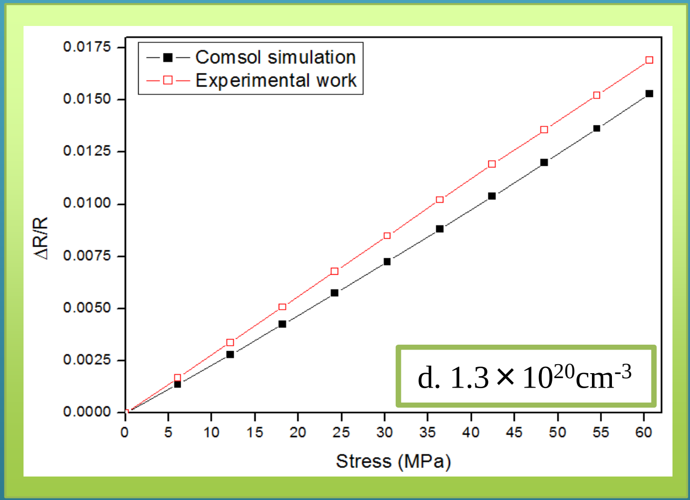
Comparison between COMSOL simulation and experimental work:

- Using COMSOL default parameters.
- Discrepancies are generally small (< 30%).









Conclusions:

- COMSOL Multiphysics was employed
  - Simulate four point bending model
  - Investigate piezoresistive effect in *p*-type silicon for a range of doping concentrations.
- Four point bending force application method produced uniform and uniaxial stress.
- Piezoresistance effect decreases as the doping concentration increases.
- Simulation results demonstrate a similar trend to experimental results.
- It was found out that inclusion of a “thin conductivity layer” with identical size with piezoresistor is essential to give good representation in relation to measured/ published data.

THANK YOU

Queen's University Belfast

COMSOL CONFERENCE ROTTERDAM 2013