Nano-Porous silicon for Microelectromechanical systems (MEMS) sensors research

Why Porous Silicon: Nano-porous silicon can be produced by the electrochemical reaction (anodization) of silicon wafers (put more simply, by applying current to silicon in an acid bath). The resulting material contains a network of nanopores (tiny air holes in silicon) as indicated in the figure. The number of pores in the silicon is defined as the porosity. For example, 0% porosity has no pores, 100% porosity is all air (no silicon). The porosity modifies the film’s properties such as refractive index, Young’s modulus, electrical conductivity and thermal conductivity. More importantly the pores create a huge surface-to-volume ratio (200-800 m²/cm³), which allows the material to work well for sensors based on surface attachment of a small analyte (species to be detected). The large area increases the chance that a species (drugs, explosives, gases etc..) can be detected, providing a method to make very sensitive detectors.

The team: The group has been developing MEMS microspectrometers for the last 10 years in our state-of-the-art cleanroom and measurement laboratories at UWA. We have a wealth of experience in surface and material characterization, optical, electrical and mechanical design (modeling) and characterization, as well as experimental design. The team is well versed in the use of (to name a few) laser Doppler vibrometers, optical profilometry, SEM, AFM and TEM material characterisation, X-ray diffraction, XPS, carrier transport (Hall effect) studies, reflection spectroscopy, ellipsometry and electrical noise characterization.

The Projects: The focus of our research is in using this novel material to make advanced sensors and micromachined (MEMS) devices. This is very challenging as the material sensing characteristics are best when the porosity if high, however the mechanical properties (such as Young’s
modulus) are very poor at high porosities. Our goal is to produce sensors that have extremely high sensitivity using combinations of optical, mechanical and electrical sensing mechanisms.

Types of sensors being investigated include:

**Microelectromechanical systems (MEMS) microcantilever sensors** – these sensors bend (deflect) or change their resonant frequency in response to an analyte being adsorbed on the surface. The ability to tailor the mechanical properties such as Young’s modulus through porosity control provides the freedom to design sensors with unique properties.

**Nano-Porous silicon ultra-sensitive optical sensors** – optical sensors include diffraction gratings, waveguides and plasmonic structures. The ability to tailor the refractive index in these devices provides enormous potential to create novel devices with exceptional sensitivities.

**Low noise performance** – The ability to electrically measure a change in conductivity provides a simple method to build a highly sensitive device using porous silicon, allowing the technology to integrate with CMOS microfabrication technologies. However the large surface area which gives rise to high sensitivity also leads to high noise including $1/f$ noise which needs to be well studied.

**Control of Thermal properties** – The porosity of porous silicon can be used to alter the thermal conductivity of the films. This allows the design and fabrication of devices such as MEMS micro-hotplates which are well isolated from the substrate to which they are attached.

**Integrated MEMS technologies** – MEMS are traditionally built using mechanically strong structural materials. Our aim is to build novel MEMS sensors which leverage the unique ability to tailor the porosity to control the mechanical, optical, electrical and thermal properties of the films, requiring an understanding of how all these properties inter-relate.

PhD students are welcomed in areas such as the following:
1. Electrical noise characterization including $1/f$ noise
2. Mechanical design, fabrication and test of novel MEMS devices
3. Material characterisation and surface state studies of nanoporous silicon to enhance sensing capabilities
4. Optical design, fabrication and characterisation of optical MEMS sensors
5. Thermal characterisation of porous films

Students will develop skills in multi-physics modelling using ANSYS or Conventorware simulation packages (industry standard), design and fabricate devices in the state-of-the-art cleanroom at UWA and undertake experimental characterisation of their devices in the electrical and optical laboratories at UWA.

Contact: Adrian.Keating (AT) uwa.edu.au