Post-processing of sensors

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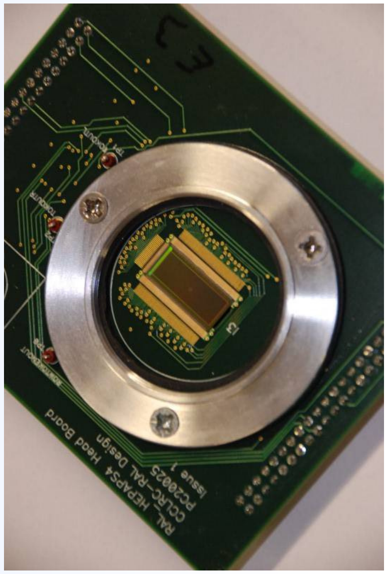
Outline

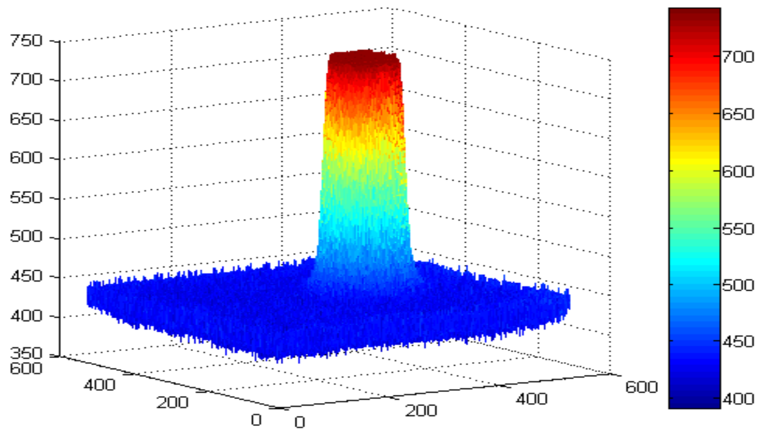
- Detector development in Glasgow
  - Current and past activities in related fields
  - Facilities and areas of expertise
- Post-processing of silicon sensors
  - Problems to address
  - Technological possibilities
- Examples of applications

University of Glasgow

Present APS activities in Glasgow

- Glasgow active in the **HEPAPS** project and the **MI³** collaboration
- Characterisation of APS devices
  - DAQ/control: firmware, control & analysis software
  - Optical measurements: PTC, spectral response, …
  - Charge particle response: Source test, beam test
  - Neutron detection
- What a new RD collaboration could give in this area
  - Close link between users and designers
  - Forum to define test procedures and exchange results
  - Common test beam (beam time, telescope, …)

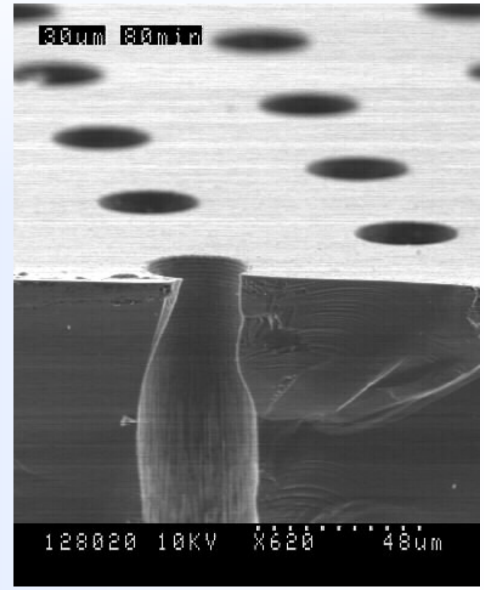




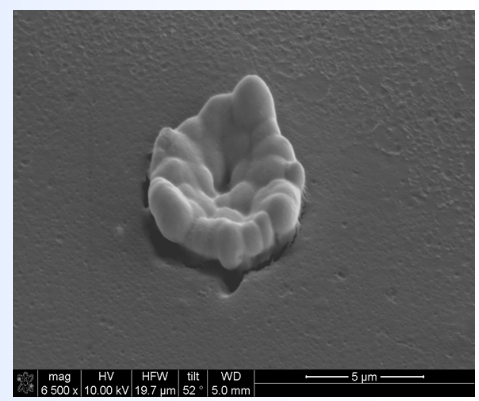
Response of APS illuminated with monochromatic light via an optical fibre

Facilities and expertise – where do we come from?

- Production site for ATLAS SCT modules and performed burn-in of LHCb Velo modules
  - Probe station, bonder, pick-and-place, lab instruments, …
  - Expertise and equipment can be applied to new fields
- Experience in sensor fabrication and processing
  - In-house equipment: Wafer saw, wafer polisher, SEM, clean room facilities, …
  - 3D sensors: early in-house prototyping, currently working with CNM in RD50
  - Electrode arrays for biological applications
  - Experience in back-thinned and edgeless devices.
  - MCM_D for interconnects and integration of electronics
  - … and …



Etched hole for 3D prototype sensor

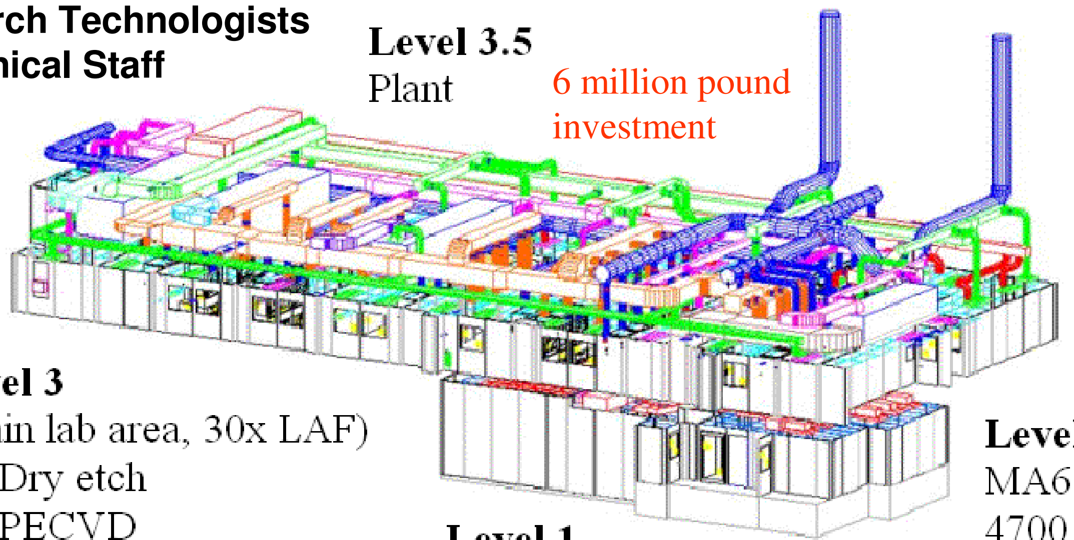


Bio-compatible electrode

James Watt Nano-fabrication Centre

- Lithography
  - Mask aligner
  - e-beam writer
- Etching
  - Wet/dry
- Deposition
  - Sputters
  - CVD
- Doping
  - Implantation
  - Annealing

5 Research Technologists
15 Technical Staff



Part of Electrical Engineering department in Glasgow, but the Particle Physics group has full access

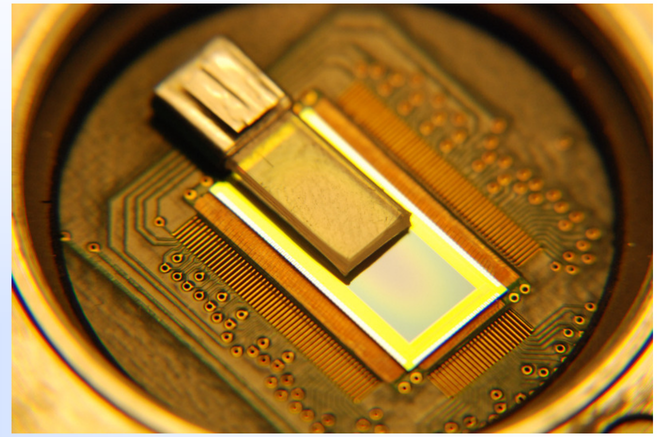
Some examples presented here are produced in the JWNC, other together with industrial partners

Proposed area of activity: post-processing of sensors

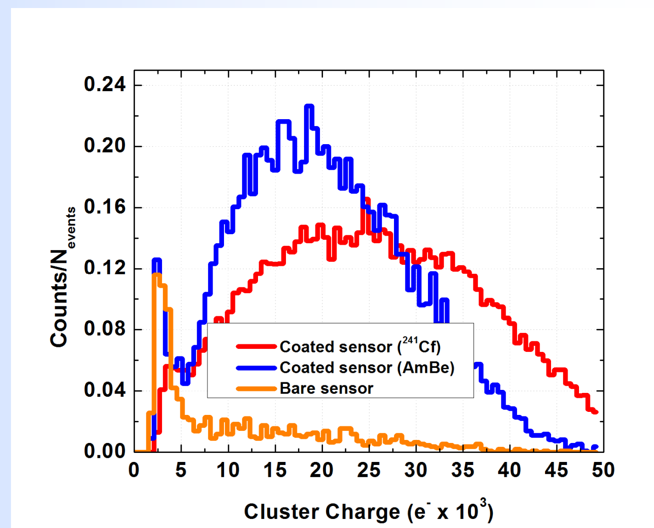
- Post processing of monolithic devices would add value and extend the range of applications
- Structure of RD collaboration still to be defined
  - Presumably organised in working groups or areas of interest?
  - Based on sensor type, activity type, application, … ?
- Suggest one area of activity: **post-processing**
- Beneficial to bring together expertise on
  - Applications
  - Sensor design
  - Processing
  - Characterisation
- To illustrate what is intended examples will follow
  - Not intended to show results or to present fully worked out concepts

Example: neutron detection

- Fast neutron detection
  - Polyethylene converter
- Slow neutron detection
  - ^{6}LiF converter ($^{6}Li + n \rightarrow \alpha + {}^{3}H$)
- First results look promising
  - Results presented at IEEE (Dresden)
- Scope for improvements
  - Deposition of converters
  - Back-thinning
  - Etching trenches
- Possible applications
  - Neutron imaging
  - Spallation neutron sources
  - Dosimetry (a lá Medipix)



PE converter glued to APS sensor



Cluster charge for two different fast neutron sources

Example: coupling to scintillators

- Photons with high energy has very large penetration depth in Si
  - E > ~ 4 keV very low interaction probability in the epi-layer
- Scintillators extend the useful range of Si sensors
  - Can be tailored to the photon energy
- Is post-processing a too fancy name for this?
  - Interface between scintillator and sensor is crucial, so how it is applied matters
  - Good detection efficiency requires 'thick', uniform and pure layers
  - Diffusion of light reduce achievable resolution
  - Compartmentalisation is a possibility

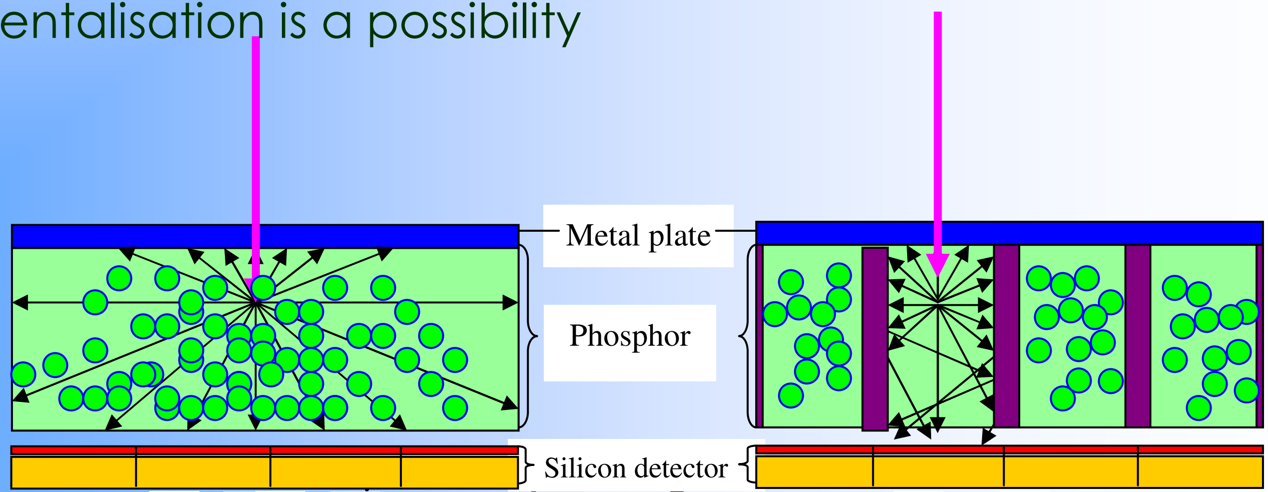
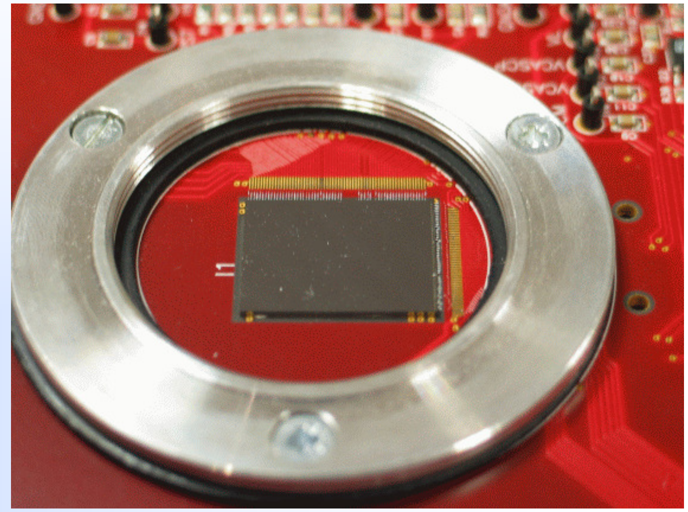


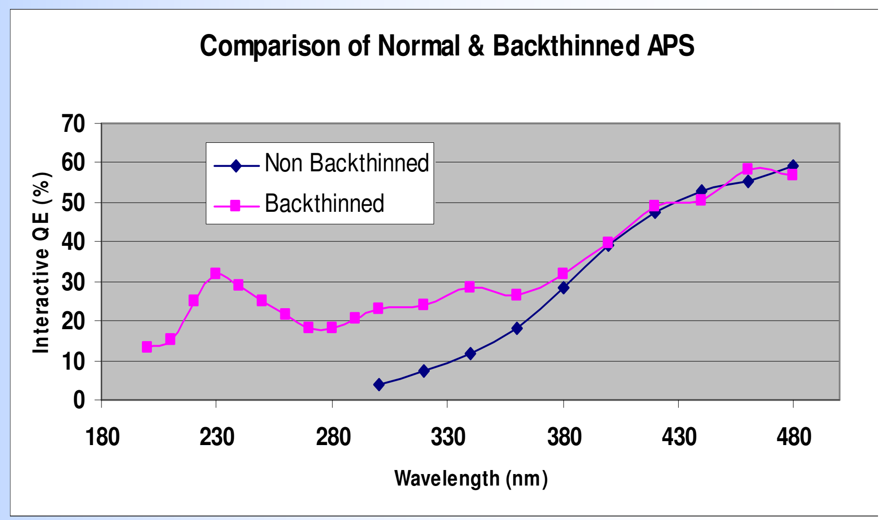
Illustration from Applied Scintillation Technologies Ltd

Example: Back-thinning of devices

- Why back-thin?
  - Reduce material
  - Visible light: reflected in metal layers
  - UV & soft x-rays: absorption in the processed layers
  - Alpha, tritium and low energy protons: short penetration depth
- Variety of methods
  - Polishing, wet/dry etch.
  - Thin the whole device, etch widow, etch trenches, etch holes, …
- Applications:
  - Bare device
  - Couple to converter or scintillator
  - Fill the windows, trenches, holes with converter or scintillator

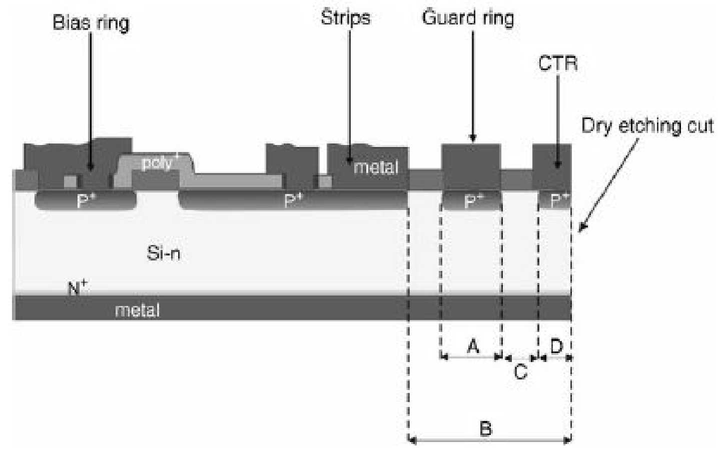


Back-thinned vanilla sensor

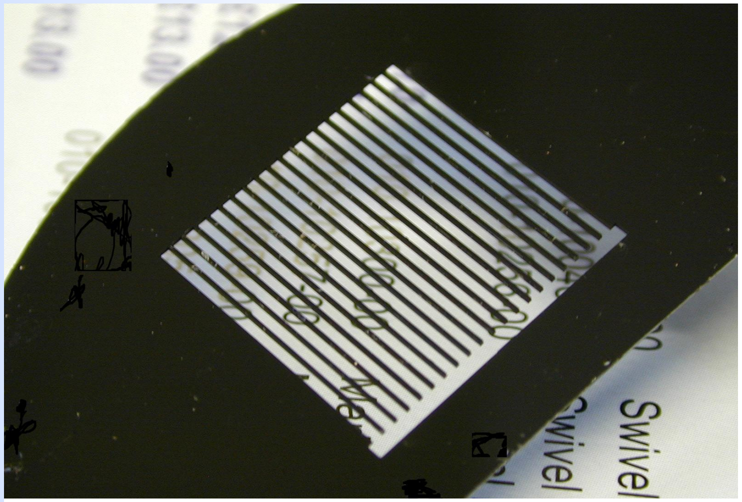


Example: edgeless/active edges

- Standard Si sensors normally have a large insensitive area at the edge
- Guard rings and similar structures to control the edge current
  - Mainly a problem for biased devices
- Etching to dice the device
  - Minimises defects on the 'cut' surface
  - Can be done with 'lithographic precision'
  - Integrated in the Si fabrication process
- Active edges
  - Etched cuts can be doped to generate the appropriate field configuration at the edge
- Can these techniques be applied to monolithic devices?



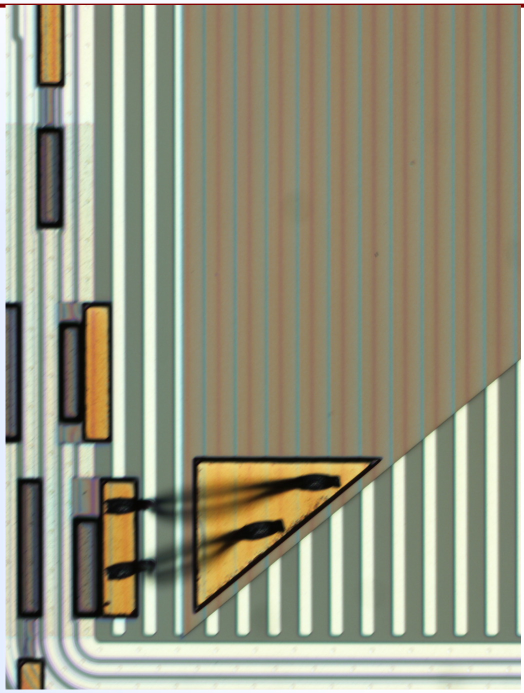
Example of etched edgeless structure

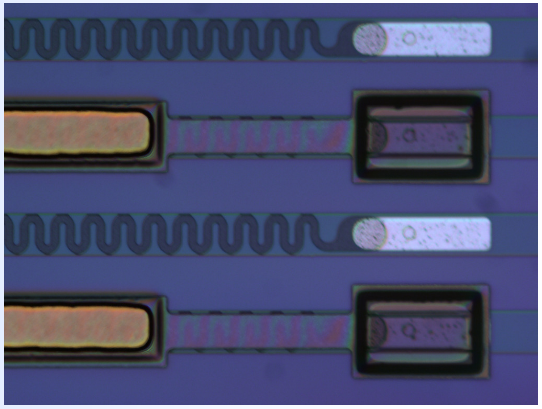


Trenches etched through a silicon wafer

Connectivity and integration: MCMD

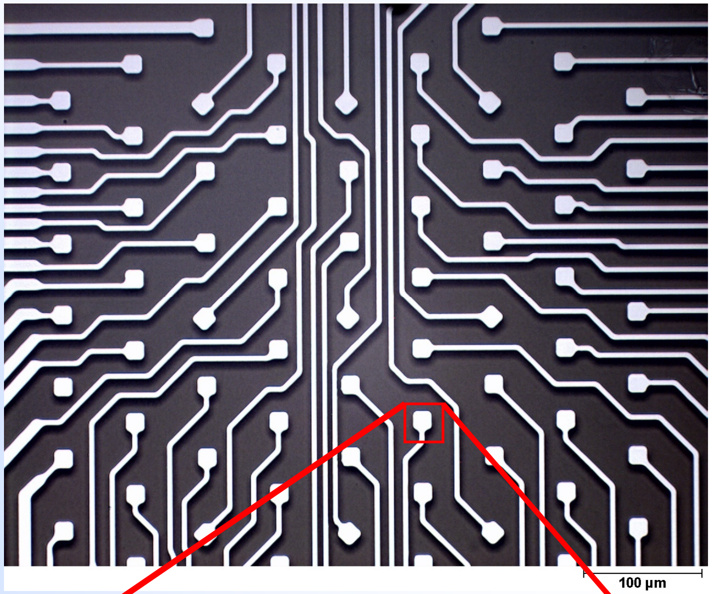
- MCM – D: Multi-chip module – deposited
  - Building dielectric and metal layers with deposition and lithographic techniques
  - Can be used to build PCB-like structures directly on the sensor
- Via connections to metal pads on the sensor
- Currently evaluated in the context of the ATLAS upgrade to possibly replace the hybrid
- Similarities with vertical integration
  - Different materials used
- Possible applications
  - Connectivity: replace pitch adaptors, etc.
  - Integration: passive components, connectors, integrated circuits, …

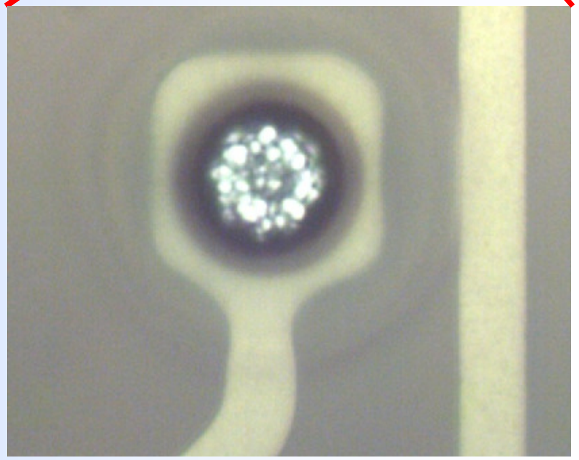


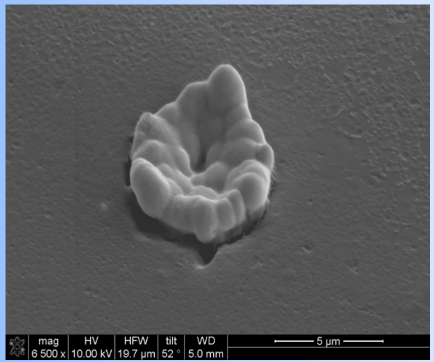


Example: Electrode arrays

- Bio-compatible electrode arrays fabricated in Glasgow for retinal experiments
- Rigid substrates
  - 30 μm electrode pitch and 1 μm line/spacing
- Flexible substrates
  - 60 μm electrode pitch and 6 μm line/spacing
- These electrode arrays are 'hybrid' devices
  - Array coupled to separate RO chip
- Research in other groups on integrating high-density electrode arrays directly on CMOS chips
- Extends the use of monolithic devices into areas outwith physics







Summary

- Glasgow's previous experience: Characterisation of devices and in-house expertise in processing
  - Hence we suggest an area of activity for this new RD collaboration
- Post-processing of sensors (monolithic, vertically integrated or even plain sensors)
- Not intended to show results or fully worked out concepts here, but rather
  - Highlight the interest and potential of this area
- Fruitful to collaborate from start on this topic
  - Application
  - Sensor design
  - Post-processing
  - Characterisation