Why Strained Semiconductors are like Crinkle Cut Crisps

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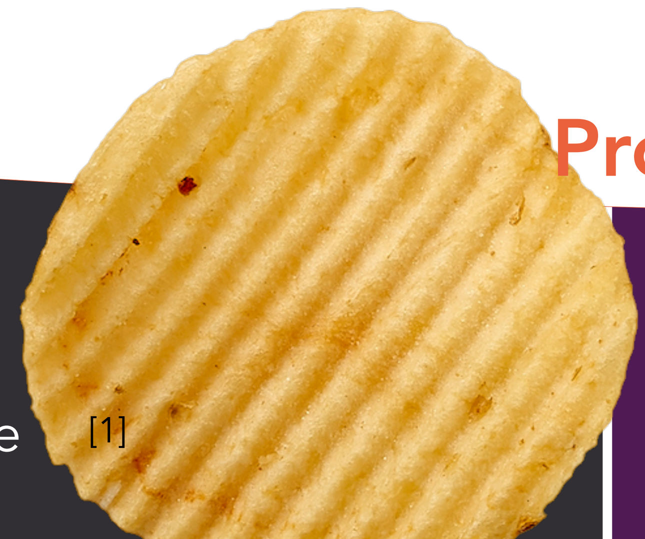
INTRODUCTION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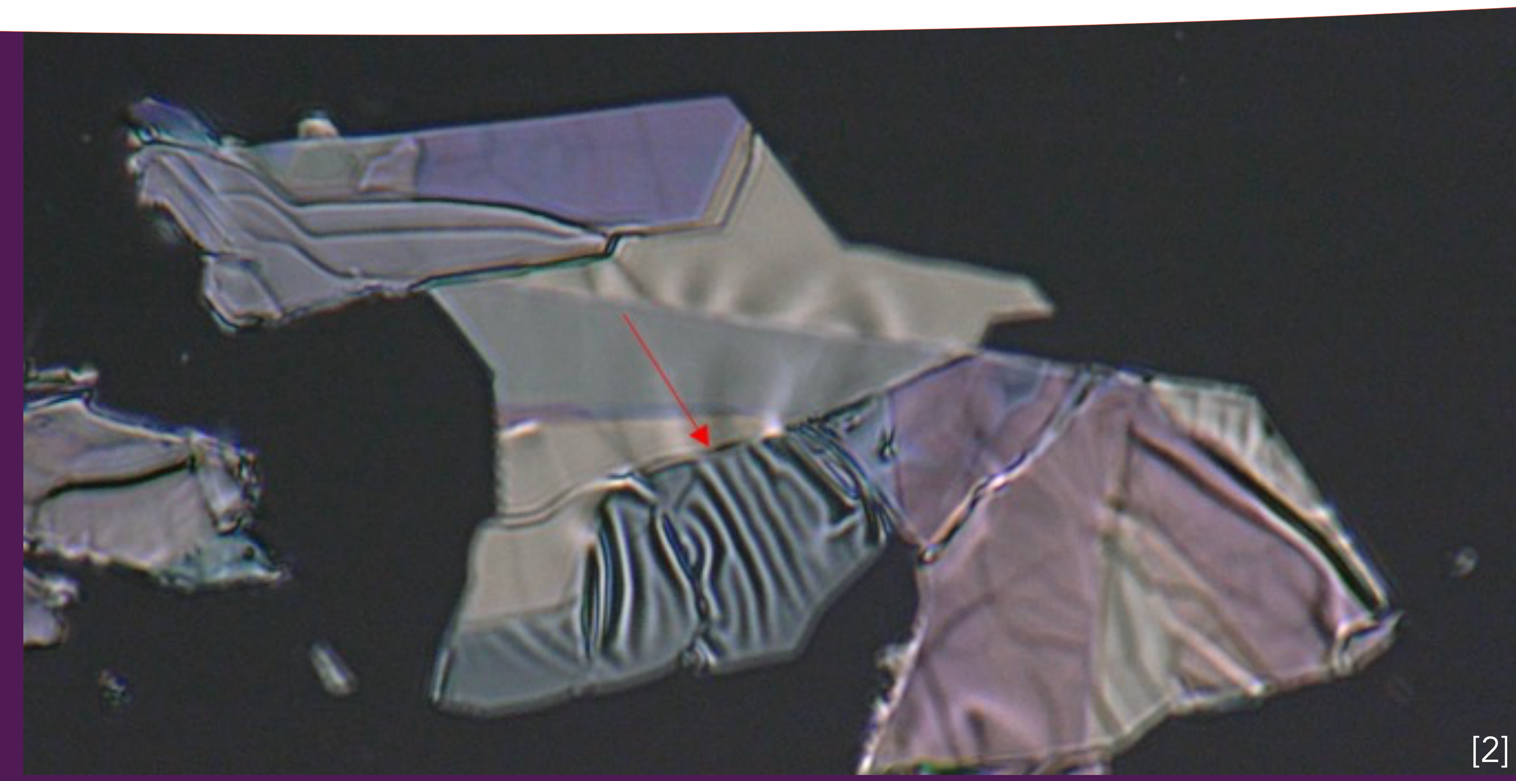
The way in which electrons act varies depending on the material, of which there are 3 different categories:

1) Insulators – where the electrons stay with their own nuclei and cannot move around the material.
2) Conductors – where the electrons can leave their atoms and move freely through the material.
3) Semiconductors – the materials in the middle. Under certain conditions, semiconductors act like insulators and under others the electrons can move freely, like in conductors.

If you stretch a semiconductor (or as we say, "apply tensile strain"), the distance between the atoms increases and so the forces holding the electrons to their nuclei get weaker. This makes it easier to free the electrons from their atoms (**decreasing the bandgap**) which, in turn, makes the semiconductor act more like a conductor. If you do the opposite and squash a semiconductor, the bond strength increases and so the atoms can hold on to their electrons better, **increasing the bandgap**.

Crinkle cut crisps taste better because they hold more salt.
Crinkle cut semiconductors insulate better because they hold more electrons.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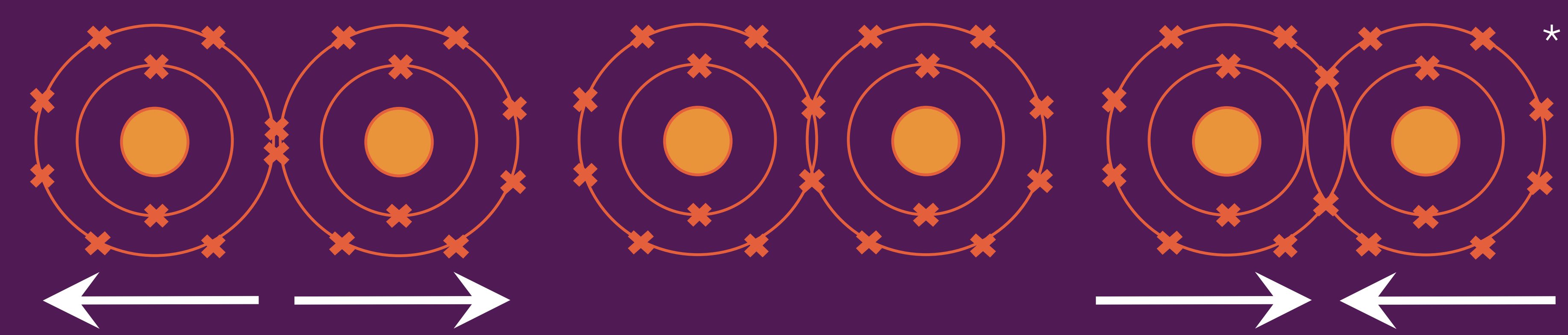
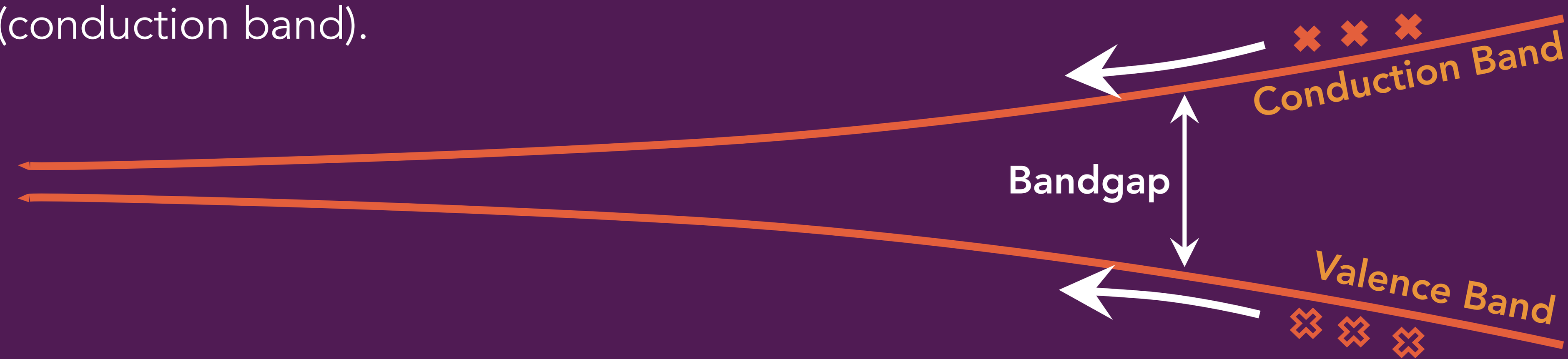


Bandgap: the energy difference between the furthest energy level attached to the atom (valence band) and the sea of delocalised (free) electrons in a material (conduction band).



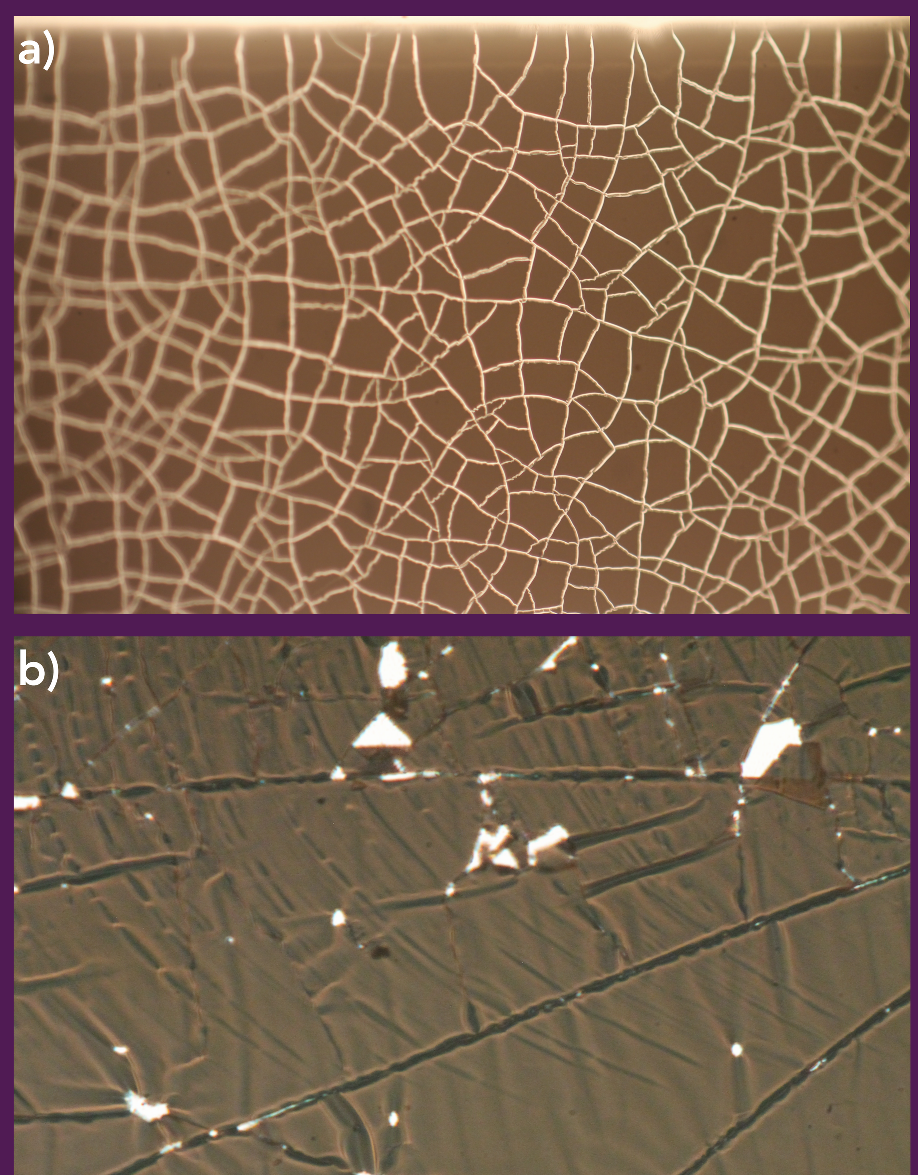
This logic can then be applied to new technologies, such as touchscreens. Where the user interacts with the screen will experience varying typed of compressive and tensile strain.

This will change the semiconductor bandgap, as explained here*.

This change in bandgap will funnel the charges through the material in a unique way and, by characterising this change in current, the data can be triangulated to work out where on the touchscreen has been pressed.

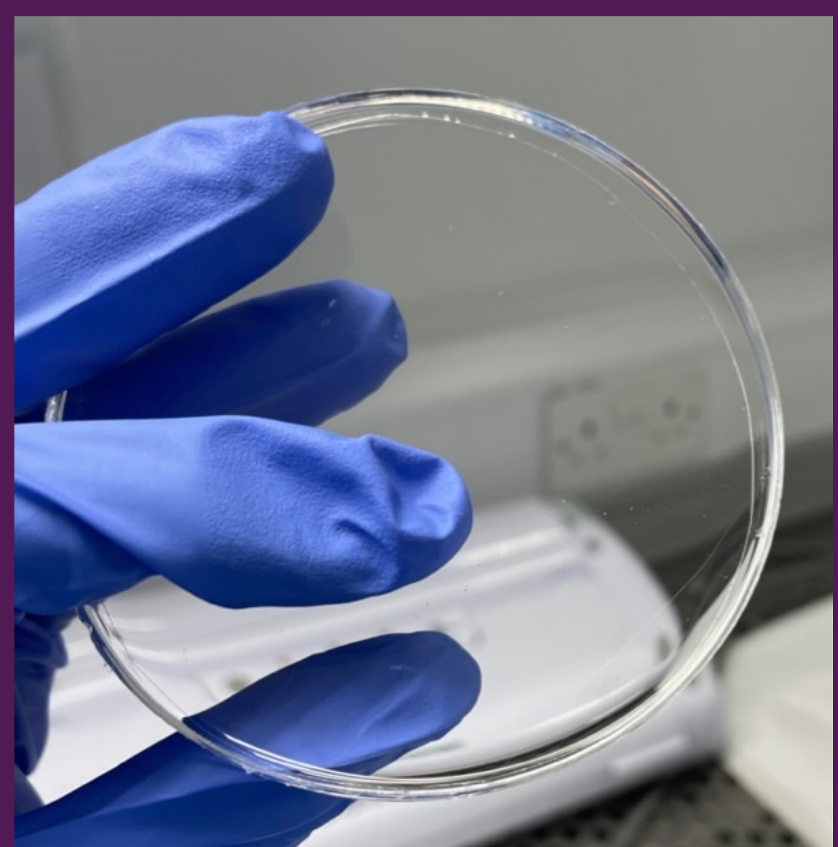
The main methods of characterisation to be used are:

- Scanning Microwave Impedance Microscopy (SMIM), to characterise the reactive behaviour of the sample
- Atomic Force Microscopy (AFM), to characterise the surface morphology
- Kelvin Probe Force Microscopy (KPFM), to measure the localised work function.



An optical microscope image showing the crinkling and cracking experienced by the evaporated chrome (a) and sputtered gold (b) electrodes.

METHODOLOGY



- Mix PDMS with curing agent in a 10:1 weight ratio and cure at 150°C for 10 minutes under 10e-6 bar vacuum. Glass Petri dishes are currently used as moulds.

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- Evaporate 50 nm of gold onto PDMS substrate using a shadow mask.

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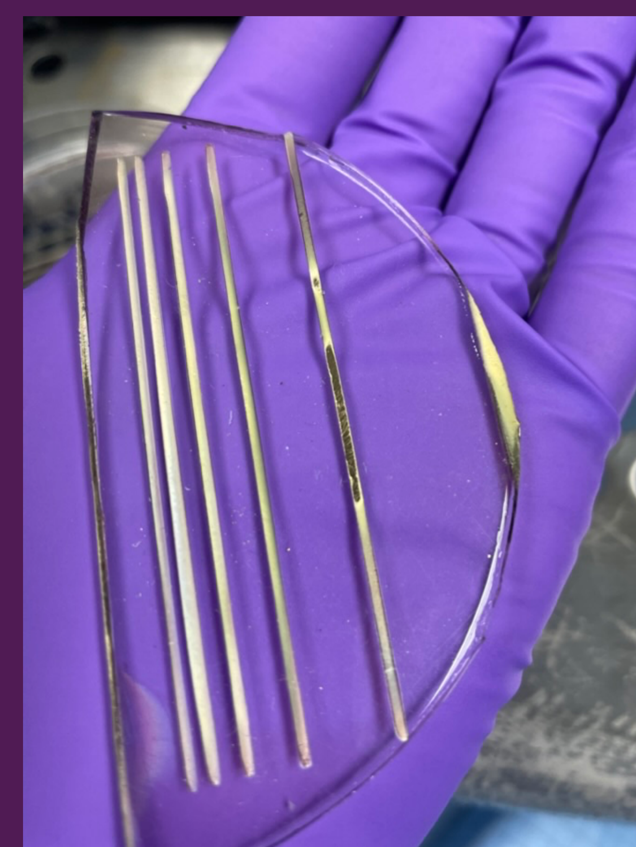

- Attach wires using silver paint and experiment to see how the resistance changes with strain.

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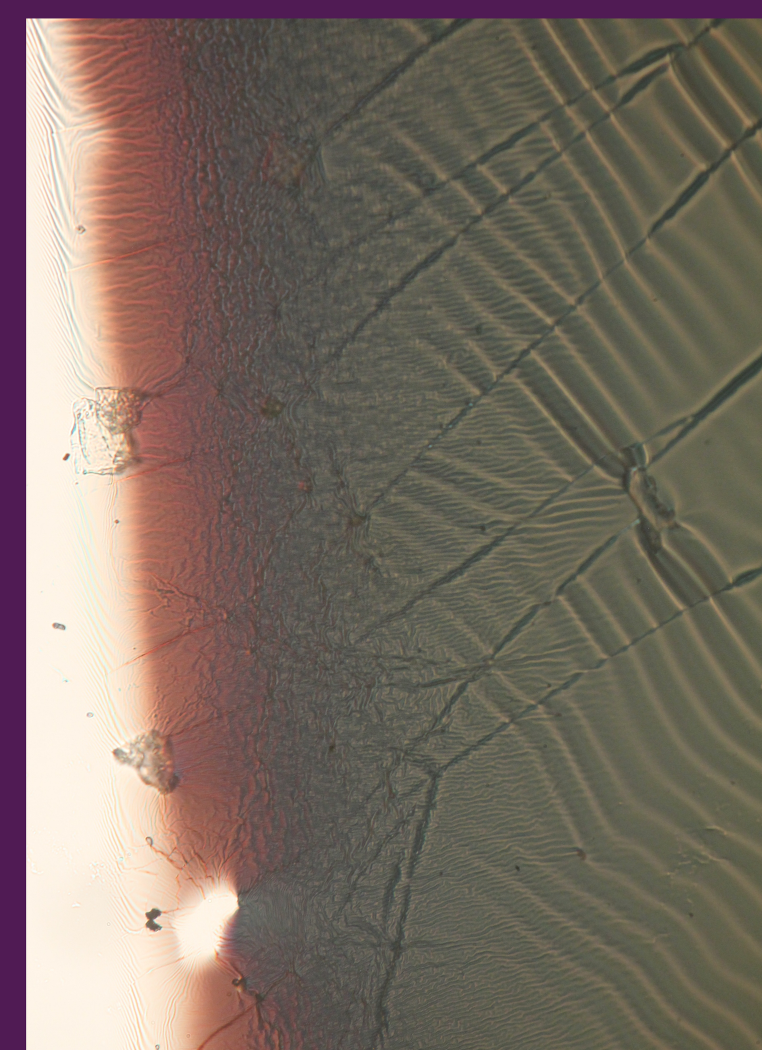

An optical microscope image of the gold after compressive strain has been applied.

- After the electrodes have been successfully and robustly produced, the semiconductor MoS_2 can be deposited and analysed under strain.

Any questions, please contact emilia.russell@durham.ac.uk

[1]: https://www.europesnacks.com/crinkled-crisps/
[2]: Y. Jahn, Ben Gurion, University of the Negev

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