School of Materials Science & Engineering

materials.unsw.edu.au

UNSW SYDNEY

Who I am:

Scarlet Kong

Community and Current Student Engagement Officer
PhD Student
Bachelor of Engineering - Materials Science and Engineering / Chemical Engineering

Did my HSC in 2012 ~88 ATAR

What I will talk about today

1. Fundamentals of materials science and engineering
2. Mechanical properties
3. Examples of materials characterisation and property measurements
4. Other resources to help with your study
5. Materials Science and Engineering at UNSW
6. Q&A – Ask anything about Materials or going to Uni and I'll try to answer the best I can

Understanding Materials

WHY AND HOW MATERIALS BEHAVE THE WAY THEY DO

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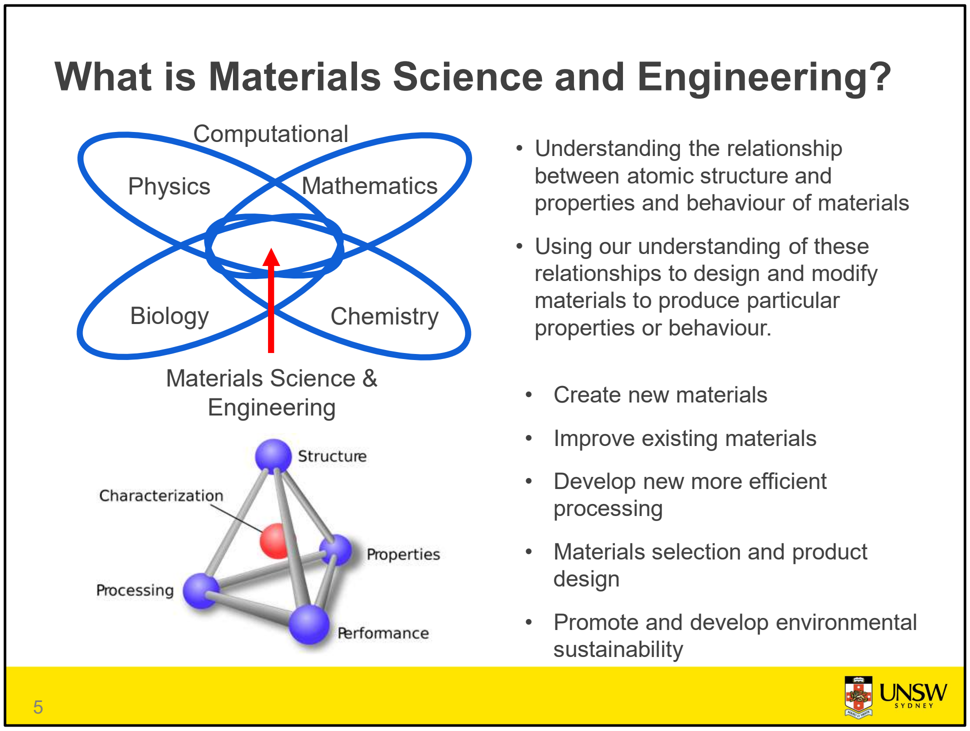
Materials are everywhere. Everything we touch and hold is made from one or more materials. And materials have be specifically designed for its individual application.

Organic and inorganic materials

Materials science and engineering focusing on inorganic materials. How we can design them for specific applications

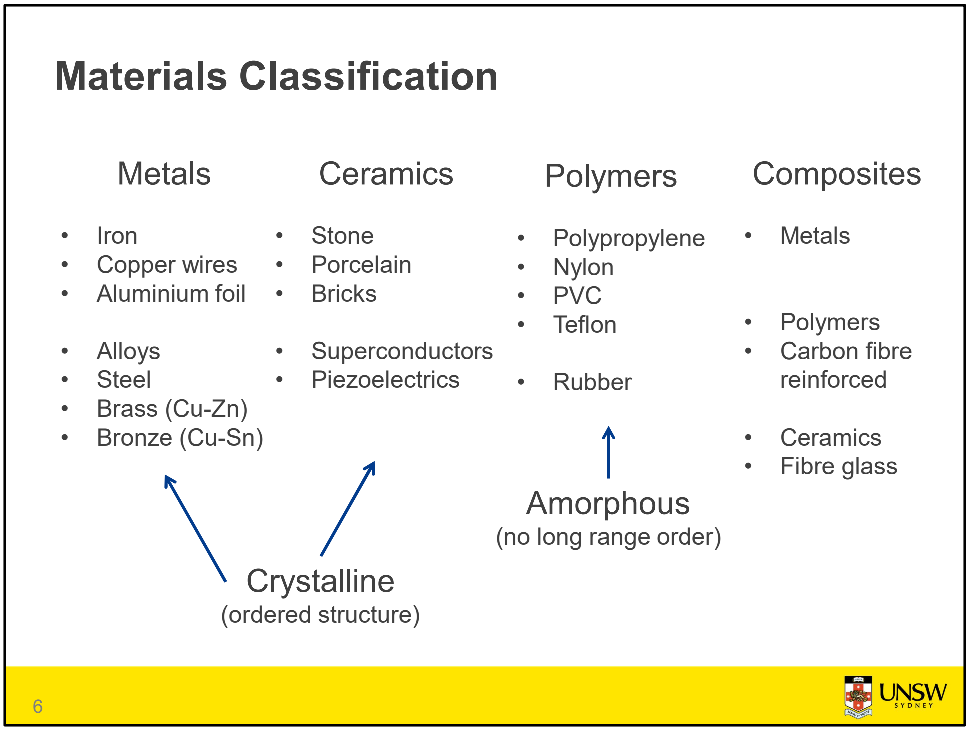


All technology starts with materials - Engineering innovative materials for our changing world

The field of materials science and engineering is looking at understanding how changes at the atomic level impact the physical behaviour of materials. We then use this knowledge to improve existing materials, create new materials, improve materials fabrication and processing.

Sustainability and recycling is a hot topic in materials research right now – such as phasing out the use of lead in chemical mixtures, recycling and reusing of plastic (SMART centre)

The work we do in materials extends everywhere. From the phone / computer we are all using for today's workshop, to the chinaware in your cupboards and many more.



There are 4 major groups: Metals, ceramics, polymers and composites.

Metals are iron, aluminium, copper, steel etc.

Ceramics, bricks, ceramic plates, but also more hi-tech ceramics such as superconductors and piezoelectrics

Metals and ceramics are what we call crystalline materials. I'll explain this in detail in the next slide but for now, imagine a nicely laid out brick wall, the atoms are mostly arranged nicely with a specific repeating pattern.

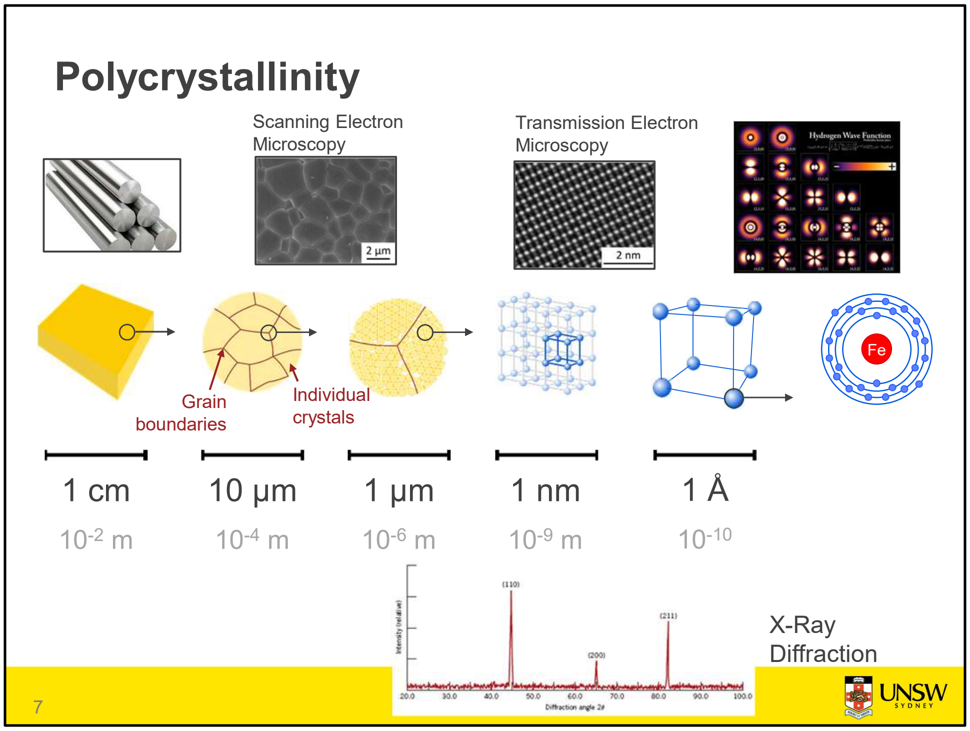
Polymers – commonly known as plastic, such as polypropylene, nylon etc. Rubber as well. They are not crystalline. It's amorphous. Atomically, they are made up of tangled up polymer chains

CH3 H

-C- C –

H H

Composites are made up of 2 or more materials with very different mechanical properties – steel reinforced concrete, fibre glass resin boats



Back to crystalline materials – metals and ceramics. Lets look at them in-depth

1. A block of iron
2. Most materials in this world is polycrystalline. This means it made up of billions and billons of micron sized crystals which we call grains.
3. All these grains have the largely the same chemical composition. We have grain boundaries between individual grains – this is because each grain has a different orientation – e.g. one grain is facing up, the neighbour is facing right.
4. The orientation comes from the atomic lattices.
5. Lattices are made up of repeating unit cells
6. And the atoms make up the unit cell.
7. At this stage, we can go even further, starting to dive into quantum mechanics and look at how electron clouds between neighbouring atoms interact – and really it's at this level that we can explain why certain materials are magnetic, their electrical properties and their chemistry as well.

For a pure metal, like iron, its simple – on the lattice we only have iron atoms.

For alloys, it gets more complicated. How are the atoms arranged on the lattice – more complex – some elements tend to segregate and cluster together. We can more secondary phases and more – and sometimes they move towards the grain boundaries etc.

Mechanical Properties

Elasticity
- Deformation that is recovered upon release of load

Youngs Modulus
- This is the stiffness of a materials. How much force is required to elastically deform a material by a given amount.
  – Rubber has a very low elastic modulus
  – Metals and ceramics have very high elastic modulus

Strength
- How much stress is required to go plastically deform the material - go beyond the elastic limit of the material (sometimes how much to break)

Toughness
- The amount of energy the material absorbs per unit volume before breaking

Ductility
- How much a material will plastically deform before failure. Related to brittleness/toughness

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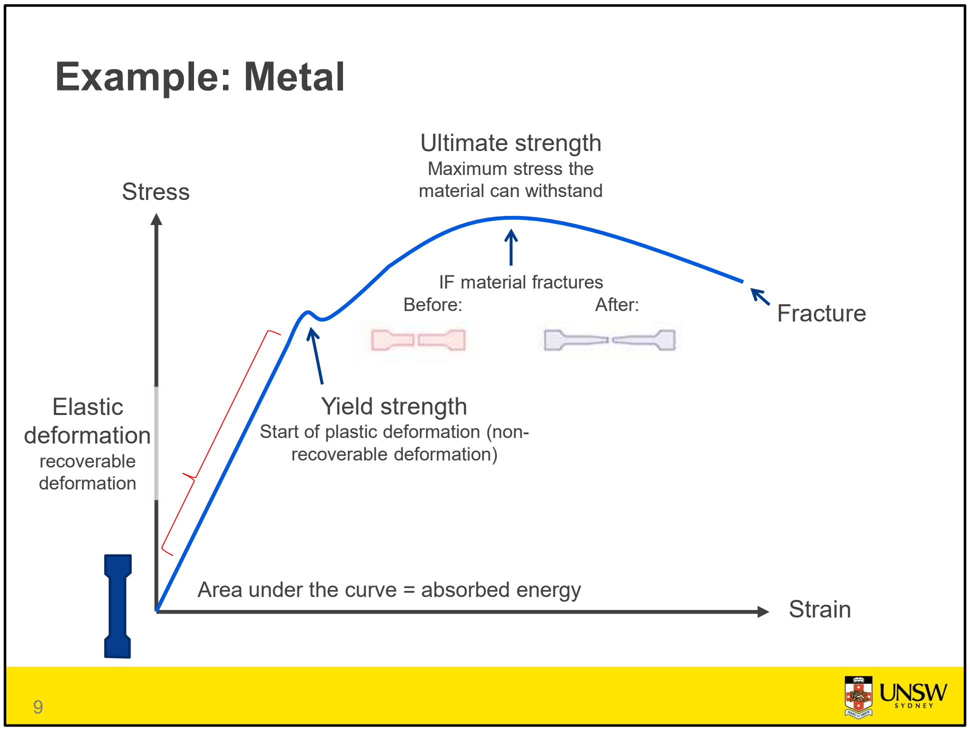
A few terminologies that we use to describe material properties



Here is a stress strain curve – tells us the material's relationship between stress and strain. We measure this by gradually applying a load (tension or compression) and measuring the deformation (change in length)

Elastic deformation

Yield strength

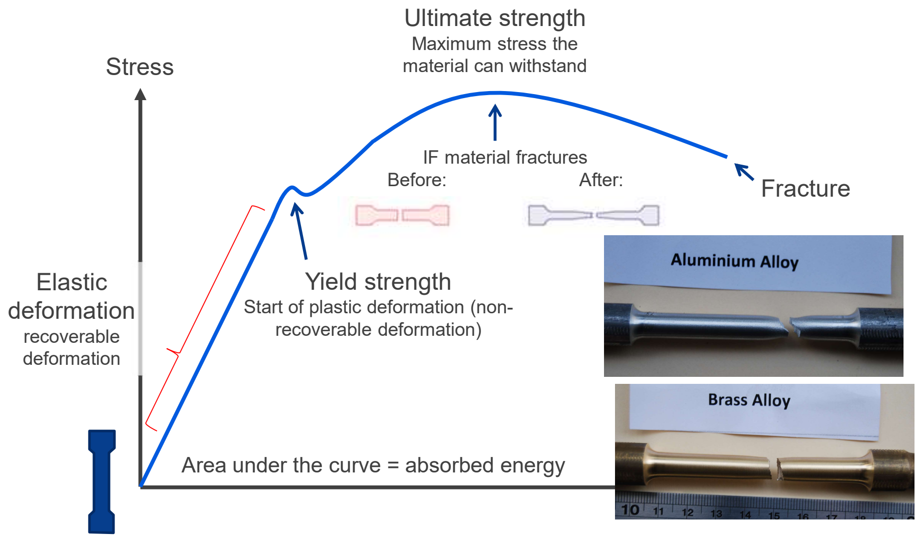
Ultimate tensile strength

Fracture

Necking

Ductile and brittle

Example: Metal



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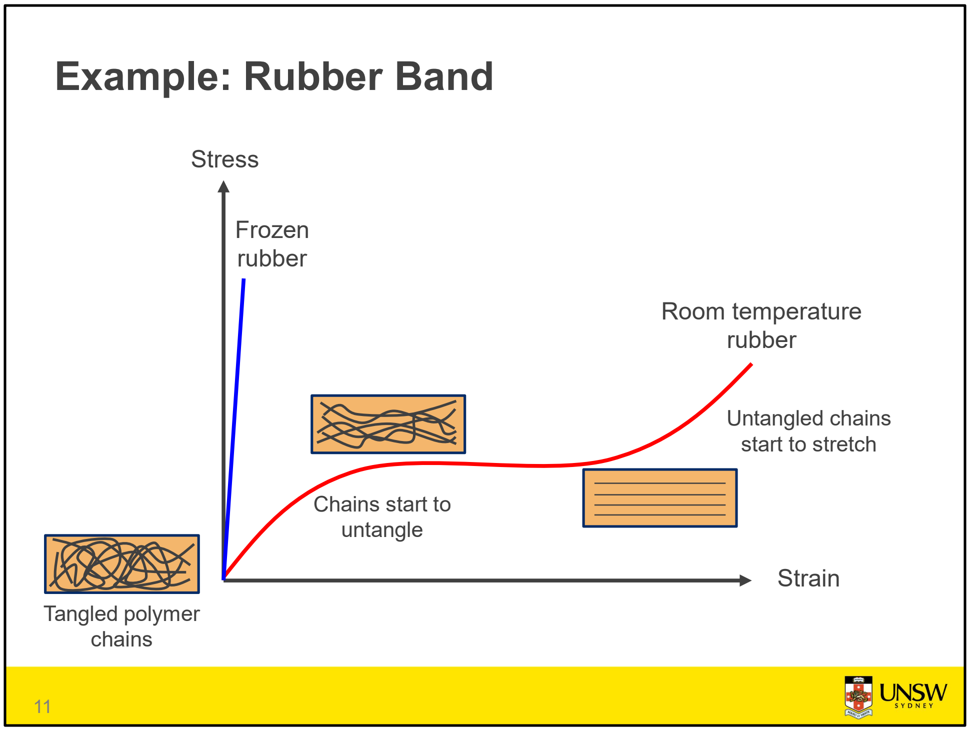
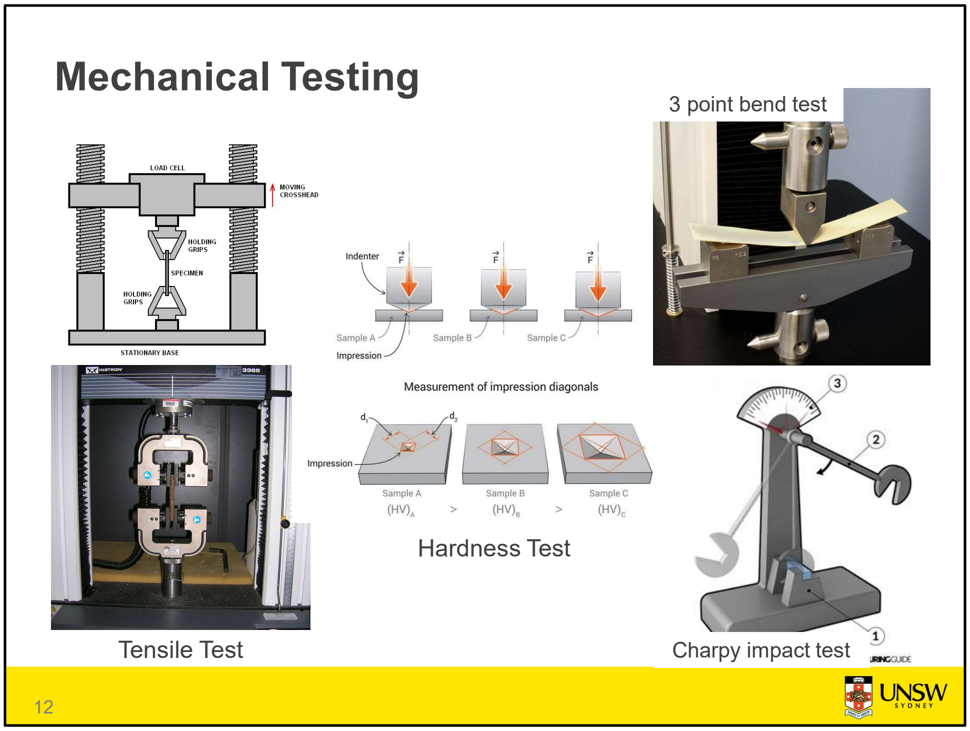


https://www.tf.uni-kiel.de/matwis/amat/iss/kap_3/backbone/r3_1_2.html

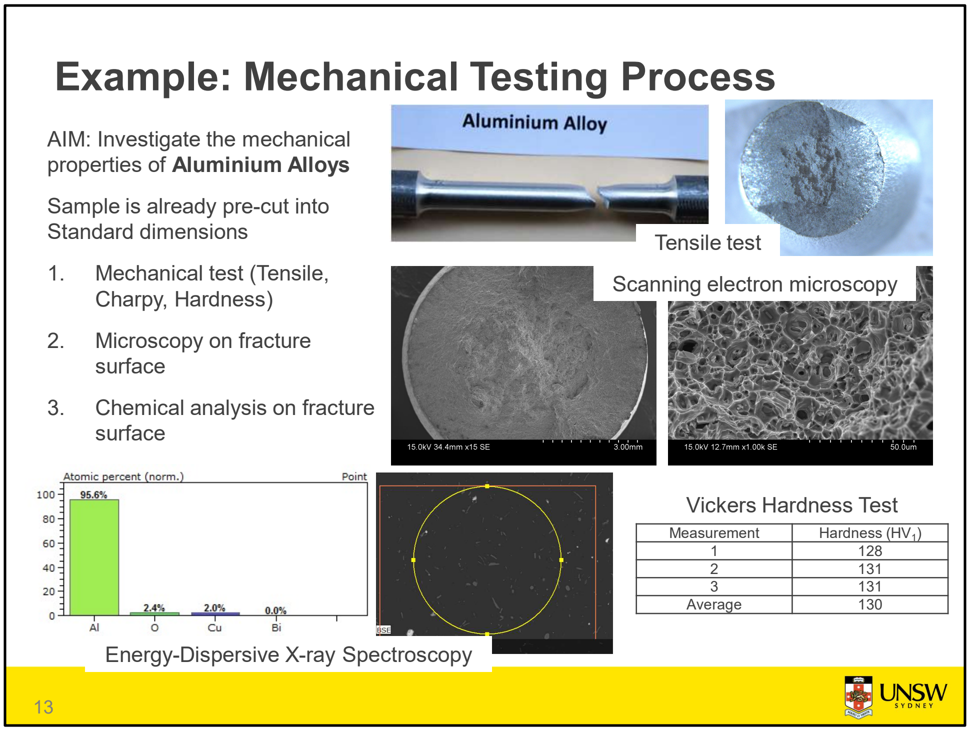


Tensile testing is a common testing technique used to understand the stress and strain relationship in a material. The sample is pulled in uniaxial tension until failure. The properties that can be directly measured are ultimate tensile strength, fracture stress, maximum elongation and reduction in area. These properties can be used to determine the Young's modulus, Poisson's ratio, yield strength and strain hardening of the material.

Hardness testing determines how resistant a material is to deformation. Many different forms of hardness testing exist – where the indentation formed on the material, the depth, diagonal length or area of indentation can be used to compare the hardness between different materials. These tests can be performed on a macroscopic or microscopic scale. Different hardness testing techniques have different units. There is no correlation between different hardness testers. Individual hardness values means nothing

The **three-point bending test** is used to determine the flexibility of materials, providing values for the bending modulus and flexural stress and flexural strain. This testing technique uses either 3 points or 4 points of contact on the material. The main advantage of a three-point flexural test is the ease of the specimen preparation and testing. However, this method has also some disadvantages: the results of the testing method are sensitive to specimen and loading geometry and strain rate.

The **Charpy impact test** is used to determine the amount of energy absorbed by the material during fracture. This technique uses high strain rate to fracture the material. Absorbed energy is a measure of the material's toughness.



Tensile test –

Necking was present, cup and cone and rough fracture surface is indicative of ductile failure.

SEM –

Rough fracture surface under high magnification shows dimples – indicating that micro voids long the grain boundaries formed while the material was under tension

Dimples result from the formation and coalescence of microvoids, signifying plastic fracture and ductile failure.

EDS –

The different contrast – the lighter particles are secondary phases in the alloy.

The particles are scattered sparsely in a matrix of aluminium and are comprised of oxygen (1.37 wt.%), copper (4.54 wt.%) and bismuth (0.36 wt.%)

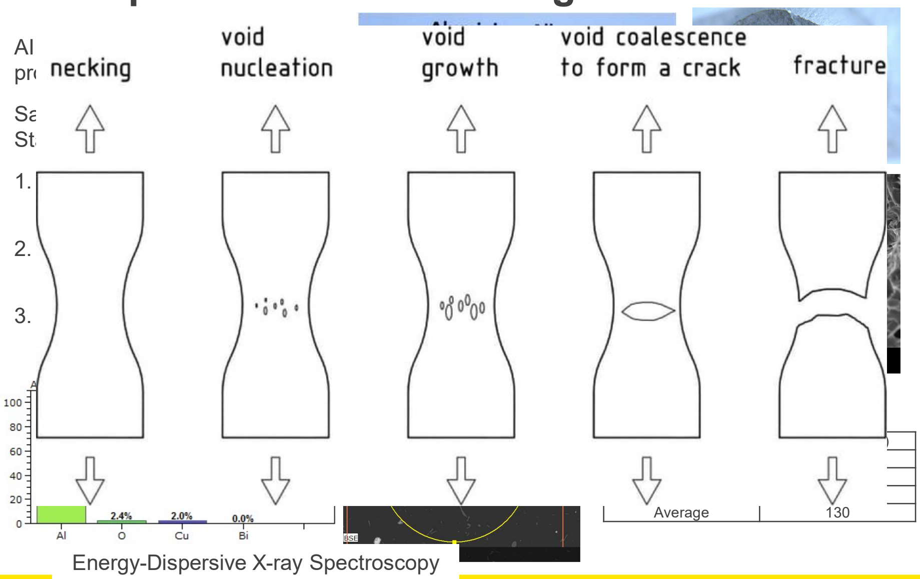
Hardness testing –

Again the number here is useless until we compare it with another material.

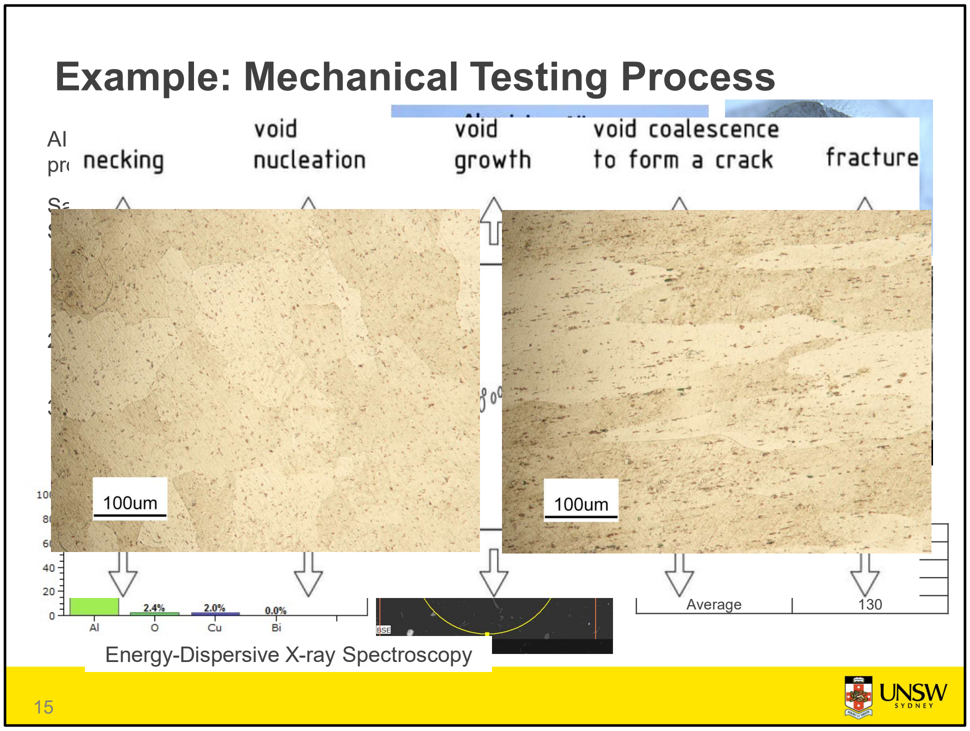
Diamond is 10,000 HV

Vickers Hardness considers the applied load and the length of the diagonals.

Example: Mechanical Testing Process

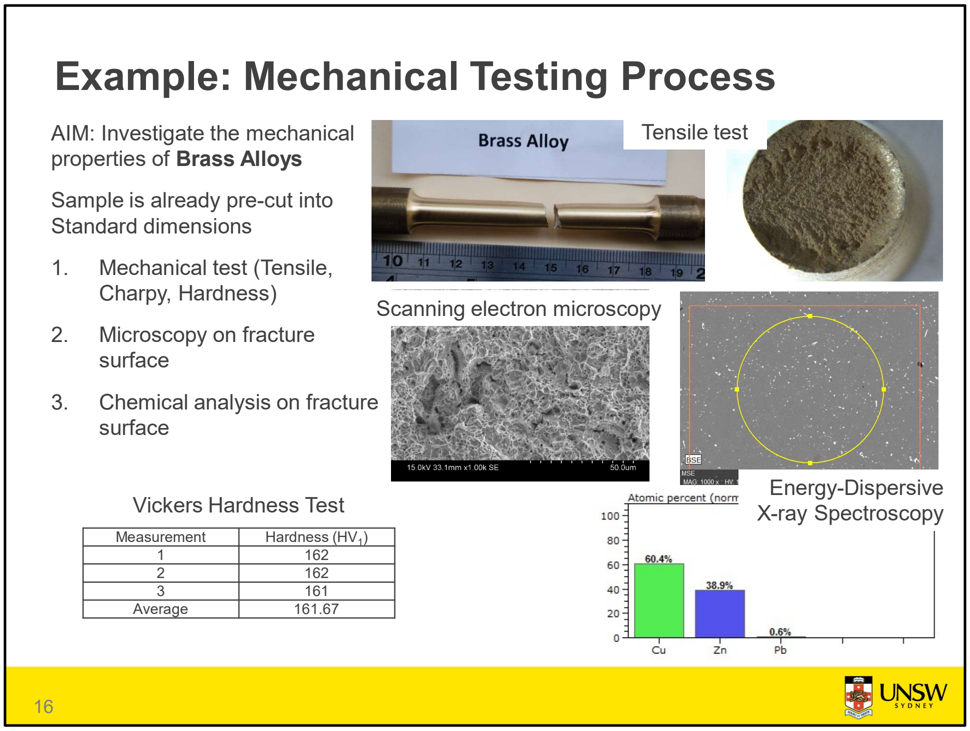


Energy-Dispersive X-ray Spectroscopy



Optical microscope – grain are elongated along the tension direction

Left: perpendicular to tension Right: parallel to tension



Tensile test –

Necking was present, cup and cone and rough fracture surface is indicative of ductile failure. MUCH less than Aluminium alloy

SEM –

Rough fracture surface under high magnification shows dimples – indicating that micro voids long the grain boundaries formed while the material was under tension

Dimples result from the formation and coalescence of microvoids, signifying plastic fracture and ductile failure.

EDS –

The different contrast – the lighter particles are secondary phases in the alloy.

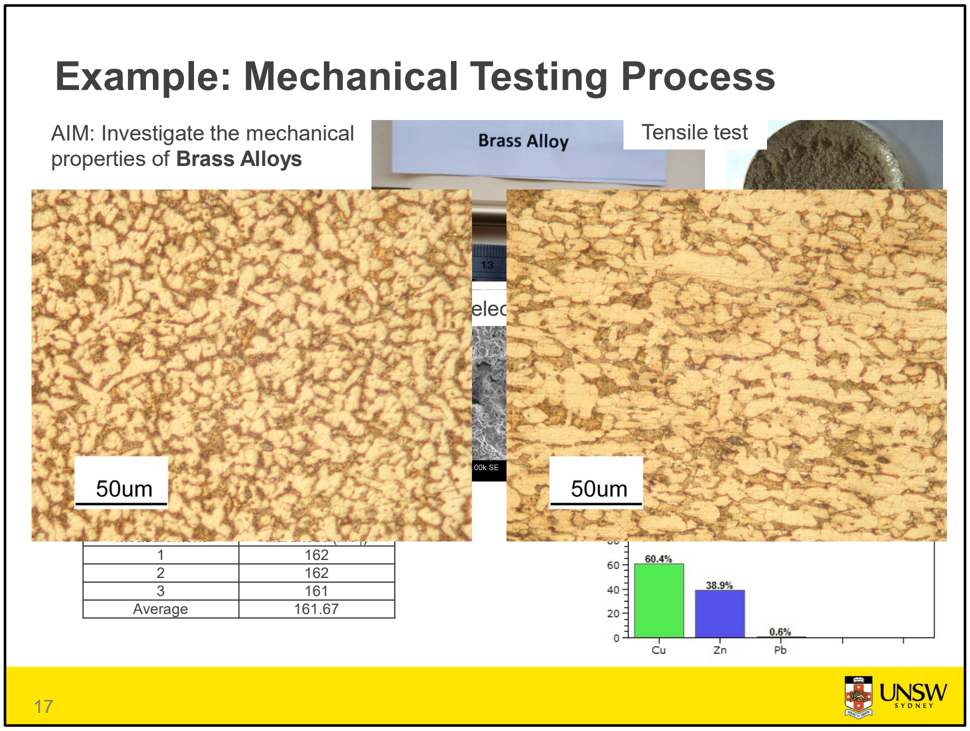
The overall EDS analysis shows the heterogeneity of the brass specimen, clearly indicating where the secondary phase particles are. The composition of the specimen is 58.95 wt.% copper, 39.09 wt.% zinc and 1.97 wt.% lead *(figure 26)*. The EDS point analysis of particles show large concentrations of copper and zinc on the fracture surface.

Hardness testing –

Much harder than Aluminium alloy

Diamond is 10,000 HV

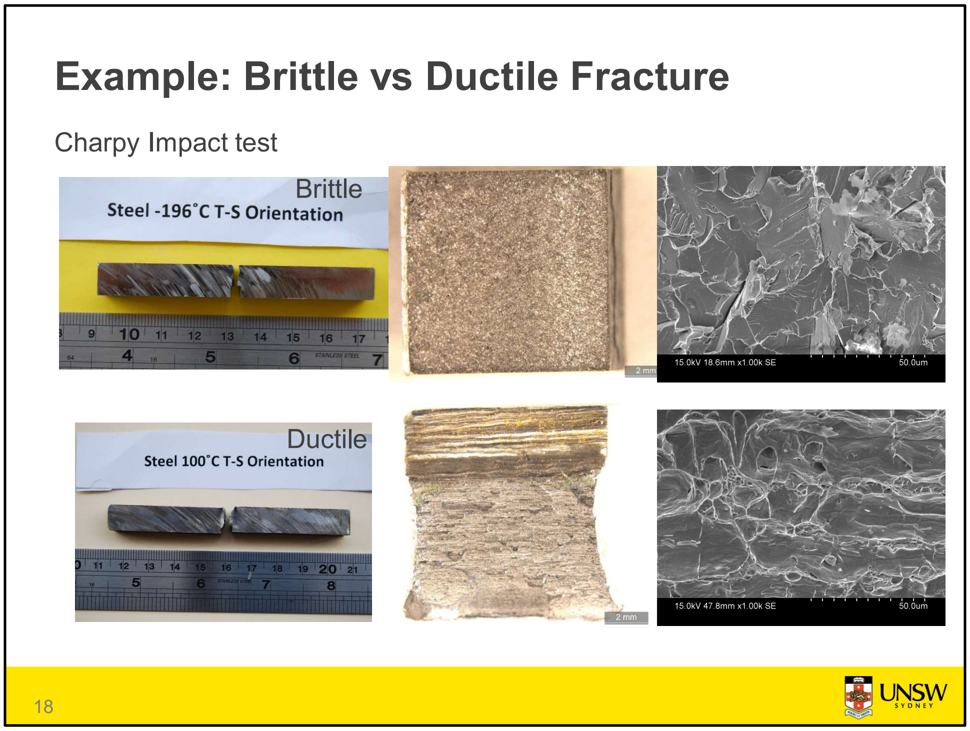
Vickers Hardness considers the applied load and the length of the diagonals.



Optical microscope – grain are elongated along the tension direction

Left: perpendicular to tension Right: parallel to tension

It can be seen that the α-phase is precipitating out of the β-phase and that there is a greater amount of α than β.



High temperature:

The side compression is clearly seen, where the sides appear pushed in. These are in accordance with the Poisson effect of contraction, characteristic of ductile fracture.

The fracture is transgranular, and the surface is rough and dull, further confirming of ductile fracture. - fracture through the grains

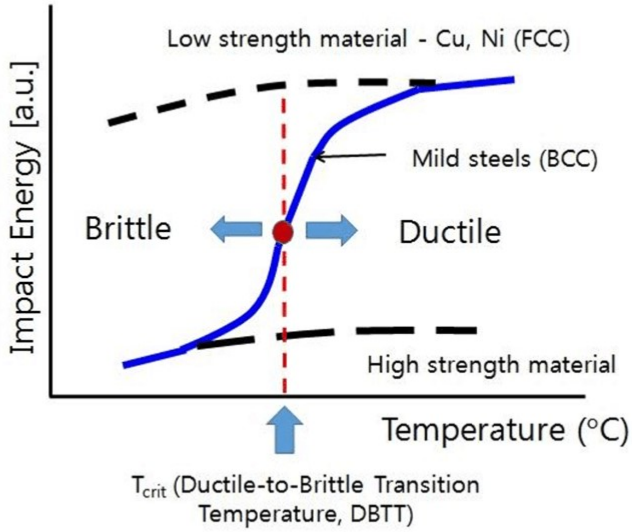
The 1000x magnification SEM image of the steel specimen shows the presence of dimples on the facture surface and secondary phase particles resting in the dimples. The overall EDS analysis of the specimen shows a homogenous composition with 97.12 wt.% iron, 2.39 wt.% carbon and 0.50 wt.% manganese. The low percentage of carbon in the specimen is in accordance with the classification of the specimen. No EDS analysis was obtained for the particles but it was advised that the steel contained elongated MnS particles (stringers) running in the longitudinal direction of the plate.

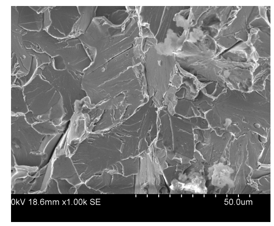
Low temperature:

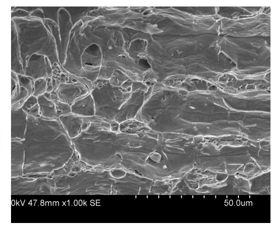
No plastic deformation. The fracture surface is flat and shiny, indicative of brittle fracture. At 200x magnification in the SEM image, cleavage fracture can be seen, with some microscopic tearing on the fracture surface.

Due to the low temperature conditions of testing, the crack orientation respective to grain directions become insignificant, and has little effect on crack propagation,

Example: Brittle vs Ductile Fracture







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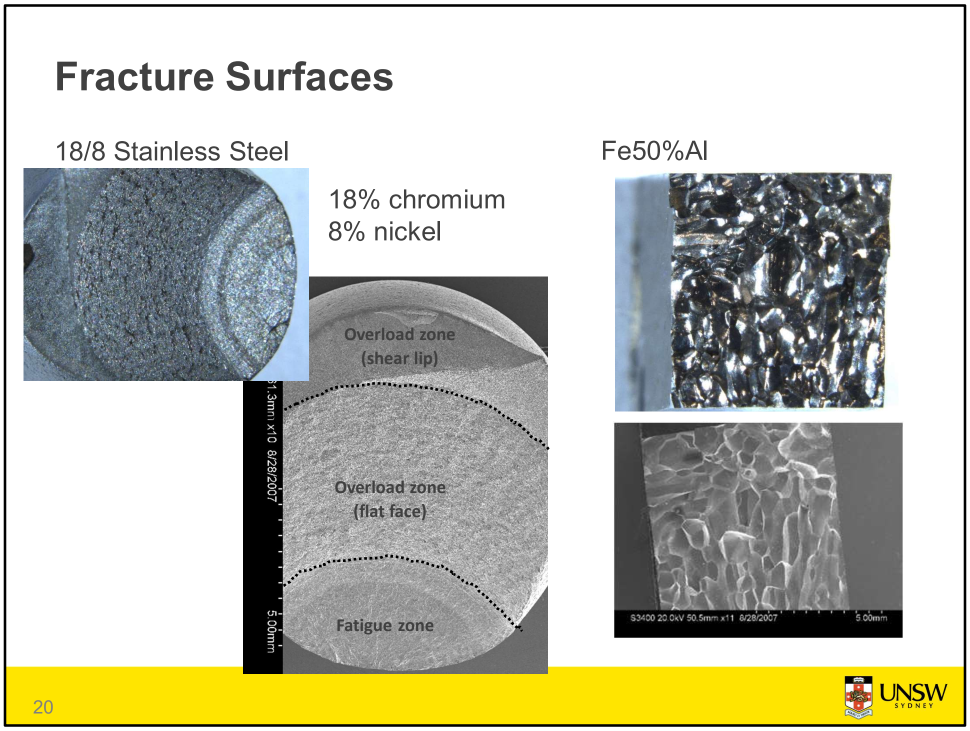

Left Image:

Beach marks can be seen on the fracture surface on the stereo microscope image. This is indicative of cyclic loading and fatigue failure. The fatigue zone, as shown in SEM image, occupies approximately only one quarter of the fracture surface and appears shiny, signifying brittle failure in this region. The overload region, comprised of the flat face and shear lip appears dull and rough , thus the overload region is ductile.

In the SEM image, the point of crack initiation can be seen, right side of the image, as well as the directionality of crack propagation. At 500x magnification, crack propagation by cleavage fracture and striations formed by cyclic loading are seen. Dimples on the fracture surface can be seen in the flat faced overload region, further characterising the ductile failure. On the shear lip, the dimples are directional and particles can be seen at the base of the dimples.

Right Image:

Macroscopic analysis of this specimen shows no signs of plastic deformation or ductility. The shiny and smooth rock candy-like structure of the fracture surface can be attributed to intergranular brittle fracture . The grains in this specimen are large, approximately 5 mm wide, unlike the grains in the previous samples. In the 100x magnification SEM image, microscopic particles can be seen protruding out of the smooth grain surfaces. Due to the unique nature of this failure, the grain boundaries of this specimen can be clearly seen.

Useful Resources

Past HSC exam answers

"Feedback on written examination”

- use correct terminology
- outline several advantages/similarities and how each was an advantage
- using accepted standard conventions of representing microstructures
- identifying and responding to what the question is asking, that is, ‘how’ the process…

https://educationstandards.nsw.edu.au/wps/portal/nesa/resource-finder/hsc-exam-papers/2019/engineering-studies-2019-hsc-exam-pack

External Materials

Google “Materials Science and Engineering Tutorials”

https://www.doitpoms.ac.uk/tlplib/index.php

https://www.materials.unsw.edu.au/study-us/high-school-students-and-teachers/online-tutorials

https://textbooks.elsevier.com/manualsprotectedtextbooks/9780750663809/static/index.htm

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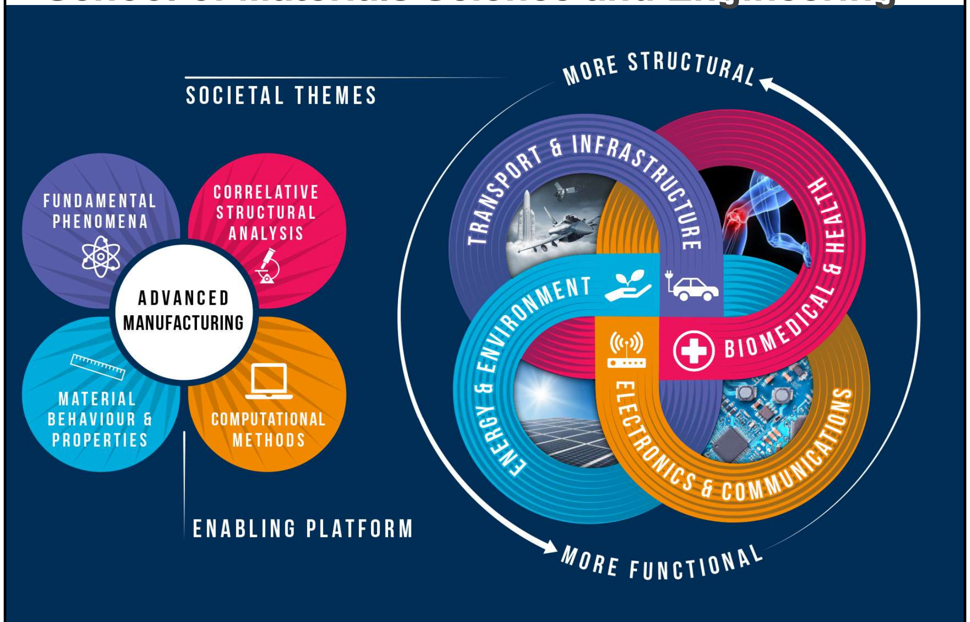

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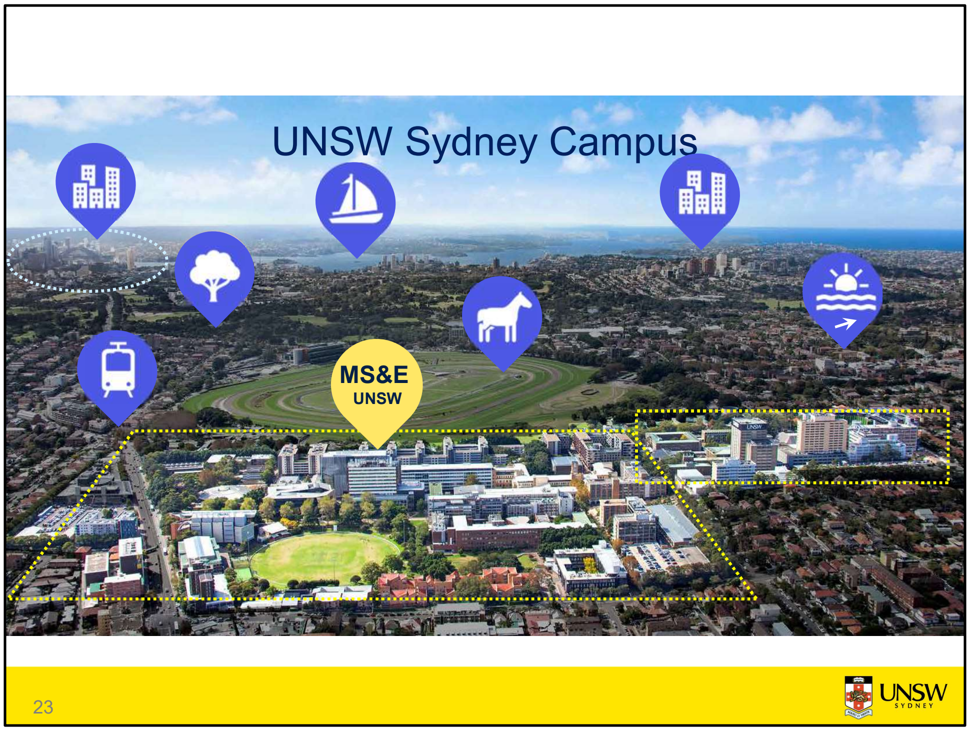
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UNSW FACTS & FIGURES

1949 ESTABLISHED

1 University College
UNSW Canberra
at the Australian Defence Force Academy

59,000+ Total Students

20,000+ International Students

35,000+ Undergraduate Students

18,000+ Postgraduate Students

300,000+ Alumni

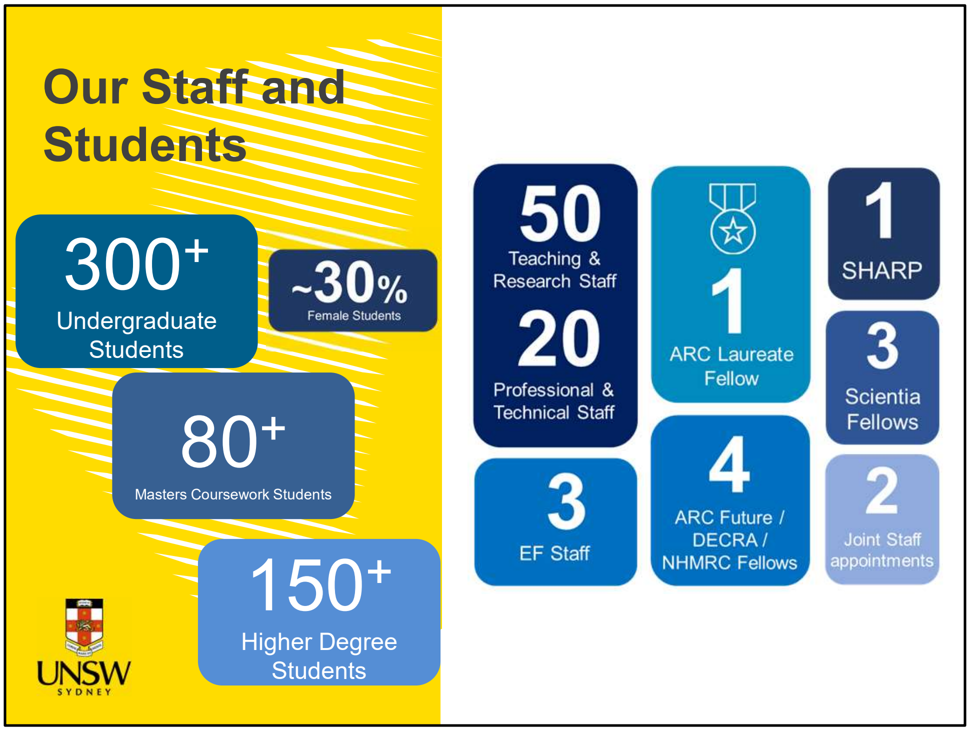
6 Faculties

Arts, Design & Architecture
Business
Engineering
Law & Justice
Medicine & Health
Science

45
Schools

125
Centres and Institutes

18
Colleges and student accommodation


Our Staff and Students
300+ Undergraduate Students
~30% Female Students
80+ Masters Coursework Students
150+ Higher Degree Students
UNSW SYDNEY
50 Teaching & Research Staff
20 Professional & Technical Staff
3 EF Staff
1 ARC Laureate Fellow
4 ARC Future / DECRA / NHMRC Fellows
1 SHARP
3 Scientia Fellows
2 Joint Staff appointments

Our Main Undergraduate Programs

- BE (Materials Science & Eng)
- BE (Materials) / B Eng. Sci. (Chemical Engineering)
- BE (Materials) / M Biomedical Engineering
- BE (Materials) / B Commerce
- BSc (Materials Science)

Majors:

Materials Engineering | Ceramic Engineering | Functional Materials | Physical Metallurgy | Process Metallurgy

STANDARD UNDERGRADUATE PROGRAM STRUCTURE

	TERM 1			TERM 2			TERM 3		
YEAR 1	Design & Application of Materials	Engineering Chemistry 1A	Computing Core	Mathematics 1A	Physics 1A		Intro to Engineering Design & Innovation	Mathematics 1B	Engineering Elective
YEAR 2	Physical Properties of Materials	Materials Characterisation	Engineering Mathematics 2E	Mechanical Behaviour of Materials	Fluid Flow and Heat Transfer	Thermodynamics & Phase Equilibria	Diffusion and Kinetics	Sustainable Materials Processing	General Education
YEAR 3	Mechanical Behaviour of Metals	Fundamentals of Ceramic Processing	Numerical Methods & Statistics	Polymer Science and Engineering 1	Design & Application of Materials 3	Materials Industry Management	Professional Elective	General Education	
YEAR 4	Materials Engineering Project	Stream Professional Elective	Professional Elective	Materials Engineering Project	Stream Professional Elective	General Education	Materials Engineering Project	Professional Elective	

Note: This degree example is indicative only and subject to change at any time without prior notice.
For the latest degree information visit the relevant UNSW Handbook page at www.handbook.unsw.edu.au.

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Year 1: Enabling Fundamentals

Year 2: Basic Materials Tools Thermodynamics, crystallography, mechanical behaviour, kinetics etc.

Year 3: Detailed Knowledge Advanced courses in strengthening, phase transformations, management, ceramics, polymers etc.

Year 4: Advanced Electives & Research Project Specialisations

Area of Employment for Our Graduates

- Extraction, refining, recycling
- Processing, fabrication, quality control
- Design, materials selection
- Education, training
- Business development and marketing
- Research and development
- Entrepreneurship & Innovation

Questions?

Thank you!

For more information, visit us at

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