Bring microstructure to life

Materials 2, Thursday week 3

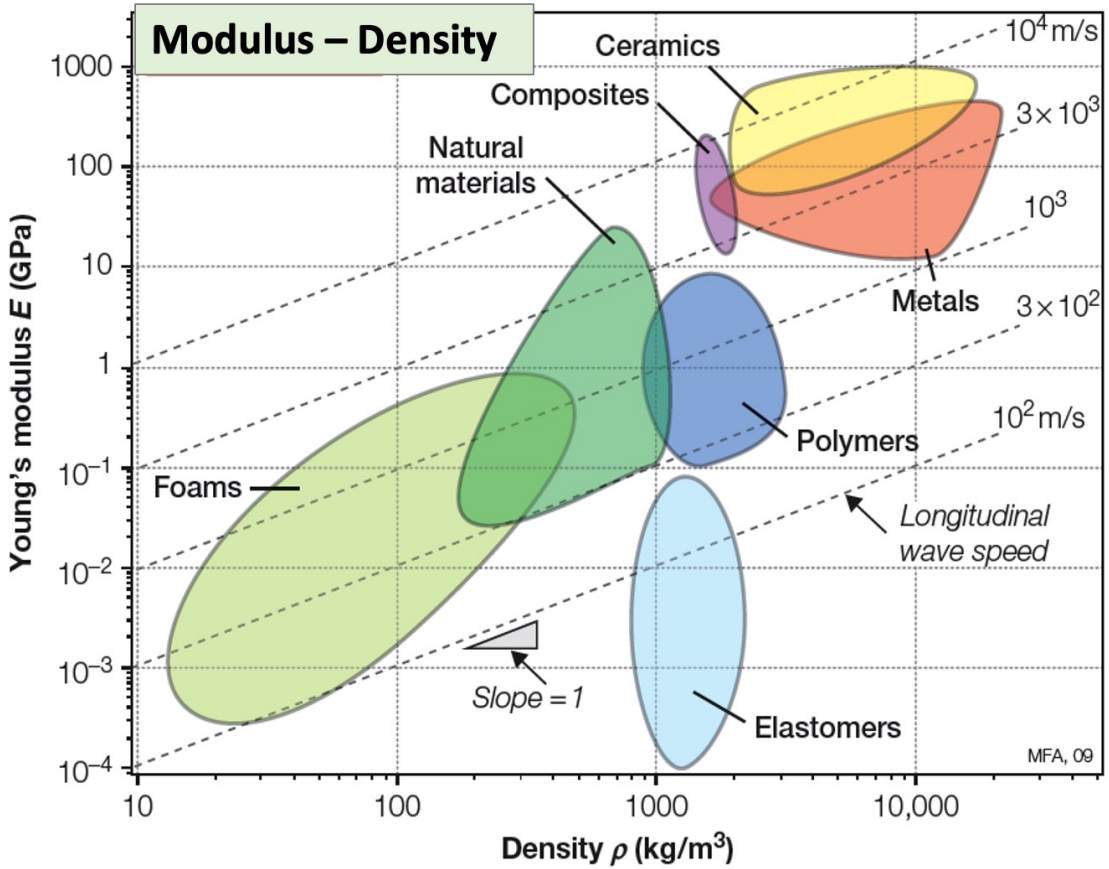
For information

Thursday 10am sessions, in Weeks 1-5 no additional information is given, everything we cover is in other material on Learn

core

Materials selection charts show properties

knowing the small scale structure gives us a basis for understanding them



For example we will see material classes cluster into bubbles because of their atoms and bonding

Materials 2 Questions set 2
Materials Properties

1. Define density and state its SI units.
Note: when you define properties of materials give the defining equation and state what the symbols mean.

2. Define stress, strain, Young's modulus, and Poisson's ratio and state the units where applicable.

3. Why do we use density, Young's modulus and stress when we define material properties rather than mass, stiffness and force?

4. Define thermal expansion and thermal conductivity and state the units where applicable.

5. Consider the following materials:
aluminium, brick, iron, polyethylene, silicon carbide (SiC), steel
(a) State which classification these materials belong to: metals, ceramics, and polymers.
(b) For each material, state the reference source you use to find the data, for the following properties: density, strength, Poisson's ratio, thermal expansion, thermal conductivity, temperature of use. *Advice on which reference sources to use: data sheets, or pdf of video slides*.
(c) For consideration in the seminars: what can you sense of feel kinaesthetically in a metal, ceramic, and polymer in relation to these properties?

in the [week 3 Tuesday] seminar we considered this question using real materials

6. Imagine a pint glass that's filled with soft, fluffy, fresh snow. If you took the snow and made it into a snowball (a) estimate what diameter the snowball would be. If the snowball then melts, (b) what volume of water do you estimate it will be.
State any assumptions you make in answering this question.

7. Concrete comprises aggregate plus cement. Explain how the measurement of density is affected by the size of the concrete sample, and estimate approximately how large a sample you need, to get a reliable measurement. Explain your reasoning.

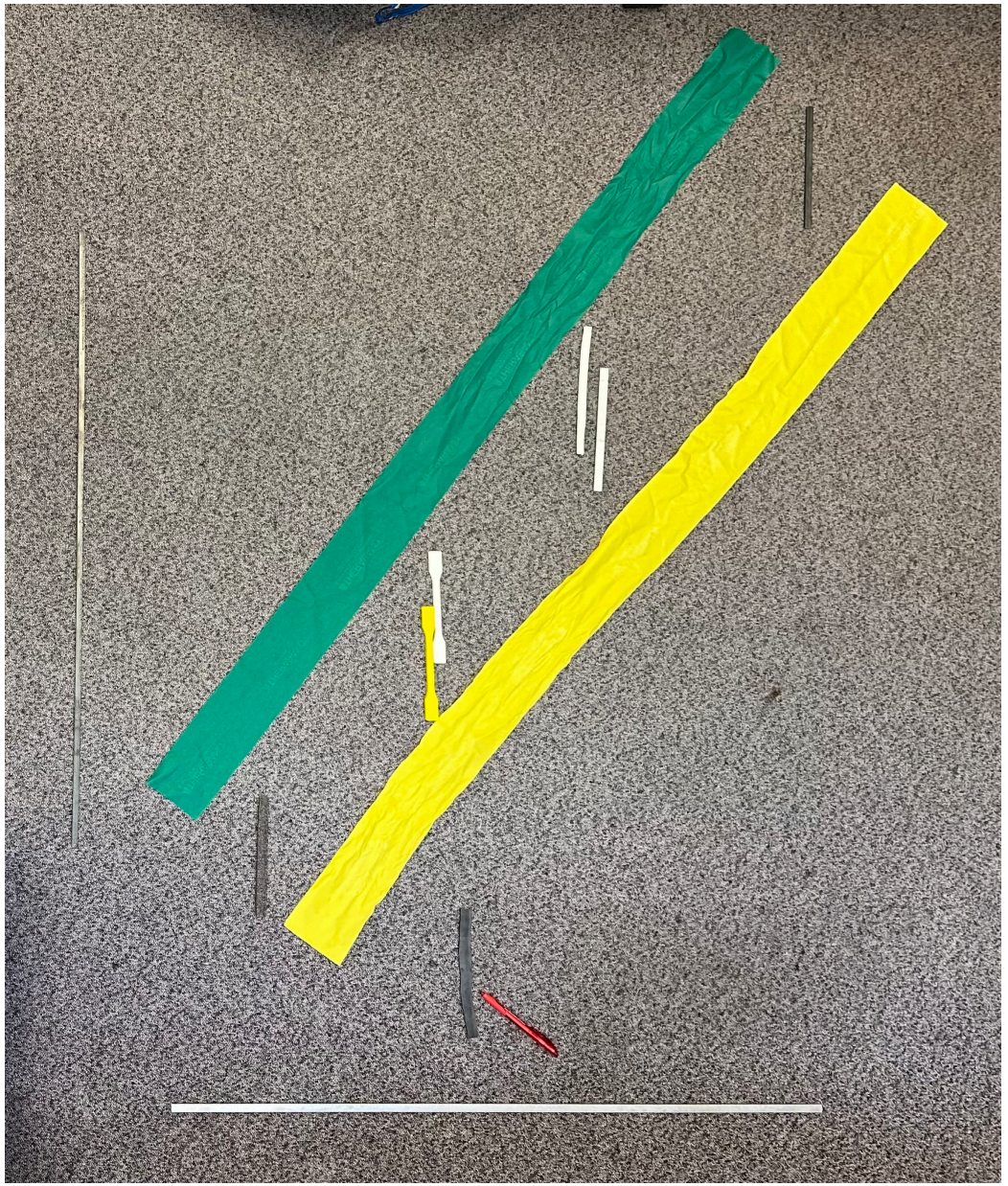
8. What can Ashby maps (sometimes called Ashby's materials selection charts) be used for?

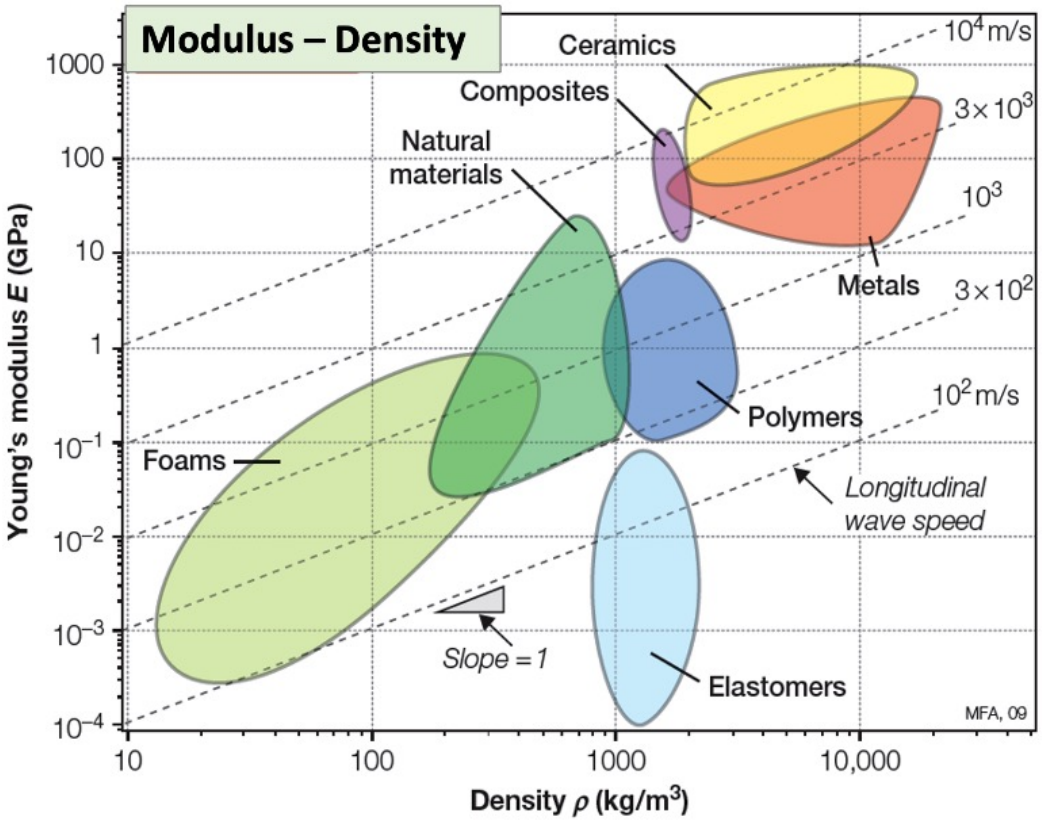
9. What relationships, or patterns, can you find between density and other engineering material properties in Ashby's materials selection charts?
For this question use Ashby's materials selection charts you can find these in the video slides, in the Library Resources (including M.F. Ashby, On the engineering properties of materials (Overview No. 80), Acta Metall, 37, 1273-1293, *1989).*

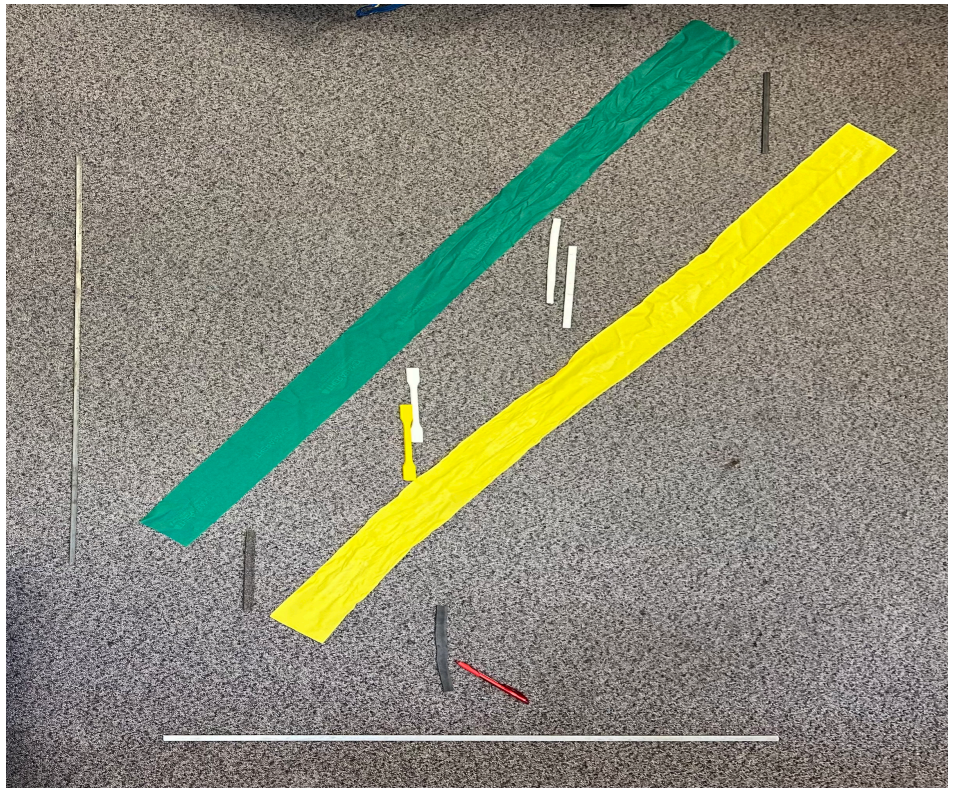
Core concepts for learning

#real stuff
#awareness
#questions
#thinking&linking
#getting-stuck
#making-mistakes
#feedback
#connection
#safe environment

[Course Guide p6]



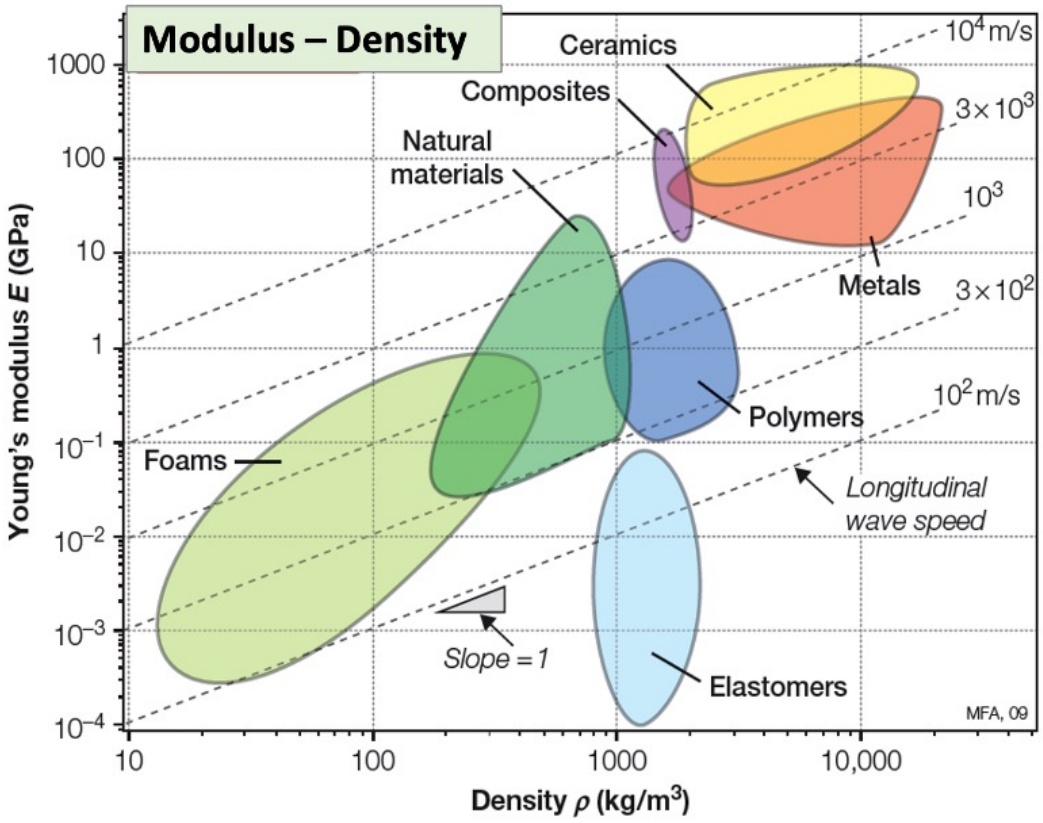

Modulus – Density
Ceramics
Composites
Natural materials
Metals
Polymers
Foams
Elastomers
Slope = 1
Longitudinal wave speed
10^4 m/s
3×10^3
10^3
3×10^2
10^2 m/s
MFA, 09
Young's modulus E (GPa)
Density ρ (kg/m^3)
1000
100
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10
100
1000
10,000



Materials selection charts show properties

knowing the small scale structure gives us a basis for understanding them

core

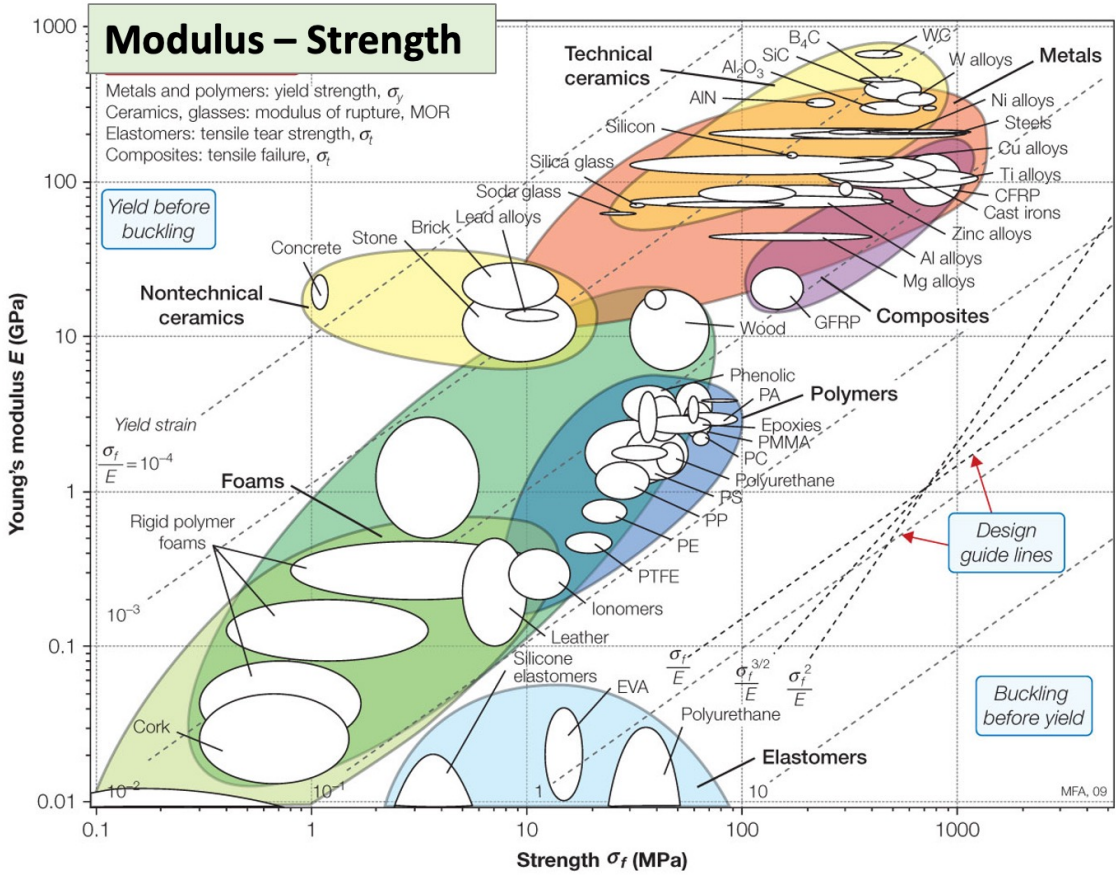


For example we will see material classes cluster because of their bonding

core

Materials selection charts show properties

knowing the small scale structure gives us a basis for understanding them



For example we will see material classes cluster because of their bonding

And that there is a variation in some properties, e.g. strength, because of other small scale structures – 'microstructure'

what’s going on in the material?

what's going on in the material?

• Question (and begin to answer) what goes on in a material when it is deformed mechanically? [from Learning outcomes: Properties]

• Continue to make links between: everyday observations, properties, material classes, and small scale structures [from Learning outcomes: small scale structure]

Core concepts for learning **#questions** #curiosity #thinking&linking [Course Guide p6]

Use of words

Being clear and precise with terminology

Use of words

- **Small scale structure** (we will often use the term **microstructure**) characterises the internal architecture of substances. A description of the composition and internal architecture of materials gives us a basis for understanding engineering properties.

- **Properties** describe in precise ways how materials behave.

[Course Guide p3]

The **WHAT** Framework

Materials

- **Classifications**
- **Properties**
- **Small scale structure** (microstructure)
- Processing / manufacturing
- **Applications**

Core concepts for learning #rigour #clear communication #thinking&linking [Course Guide p6]

From: Materials 2 Questions set 1, Comments and answers

This is important when …
collaborating across disciplines where the same terminology can mean different things

PRINCIPLE: Being clear on terminology core

When we deal with and communicate about materials & engineering **being clear** on what we mean is important.

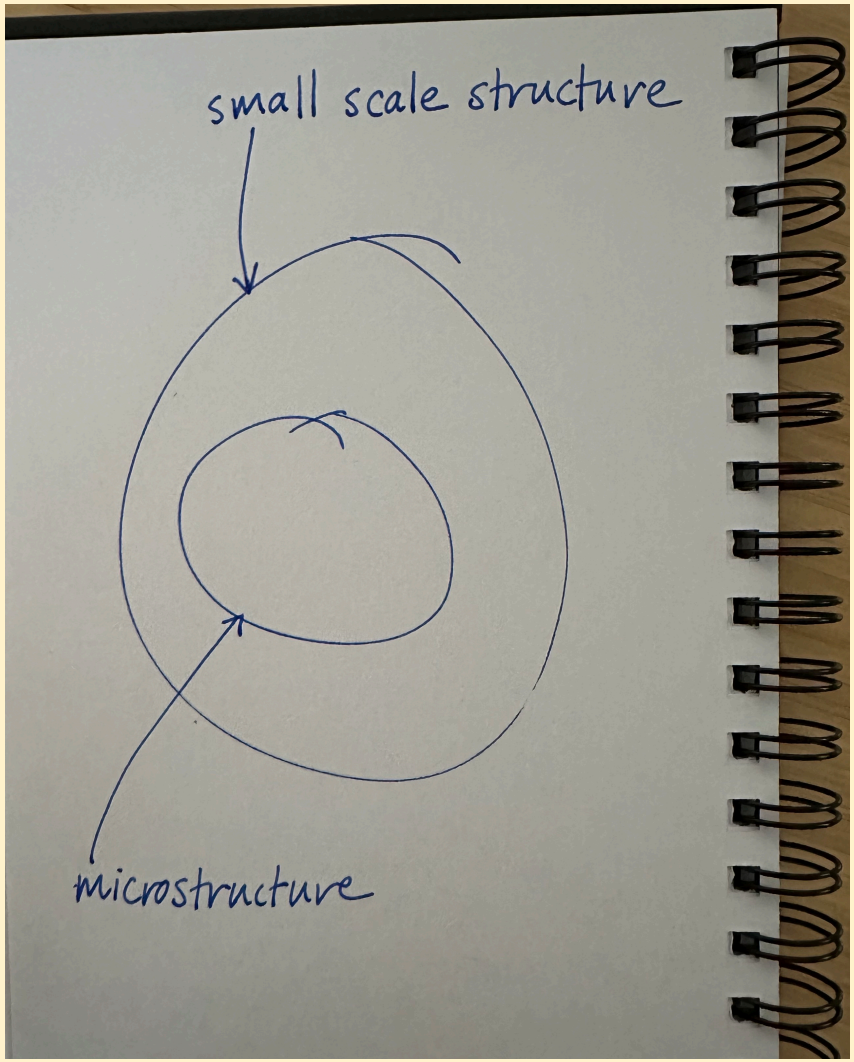
In terms of learning and using specific **terminology**, and more generally ensuring we have a shared understanding of what we mean when we use particular words in particular situations.

This is important when learning a new subject e.g. materials science and engineering in Materials 2, and when collaborating across disciplines where the same terminology can mean different things – in engineering and research. And in collaboration when the other person does not understand the specific words because they have limited knowledge of the subject.

check for understanding / ask questions

Core concepts for learning #rigour #clear communication [Course Guide p6]

Here's how I use the terms



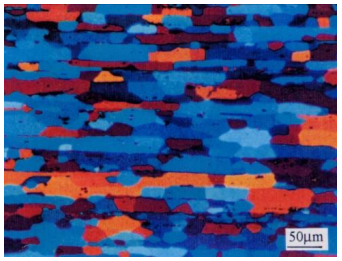
Core concepts for learning #clear communication [Course Guide p6]

Small scale structure experiment

Demonstration, using real materials

Which of these small scale structures could you 'just' see?

Microstructure

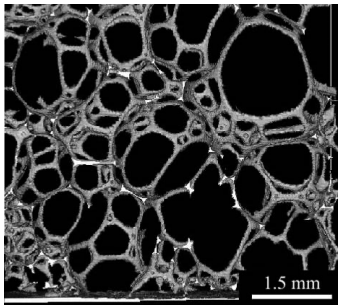


Al alloy bike frame

— 50 μm

core

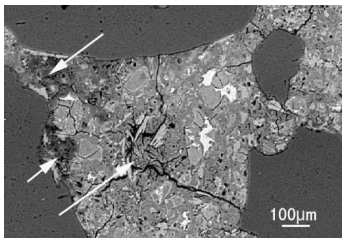
metal



open cell polymer foam (saddle)

—— 1.5 mm (1500 μm)

polymer



concrete (that's degrading)

—100 μm

ceramic

Note image scale bars – they indicate how big the features are

Based on Slide in Part-1-learning by awareness-the WHAT framework-interactive activity

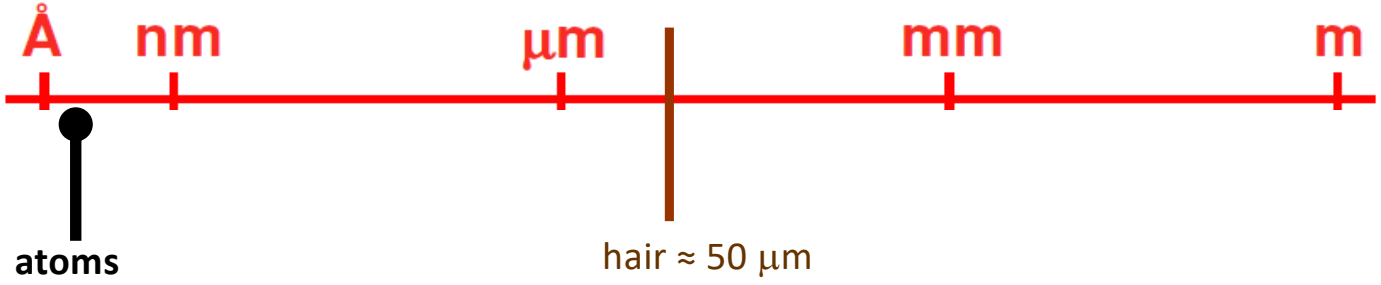
But with materials often we can’t see ‘small scale structure’

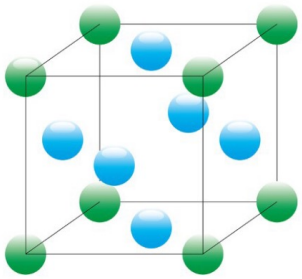
Structure on different scales

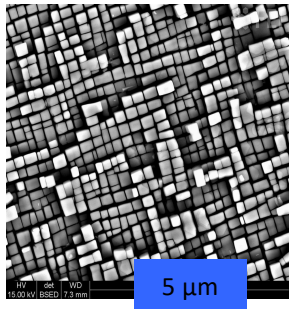
WHAT Framework

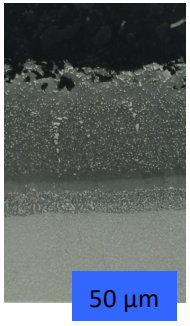
Materials

- Classifications
- Properties
- **Small scale structure (microstructure)**
- Processing / manufacturing
- Applications









www.asminternational.org

www.rolls-royce.com

New slide extra

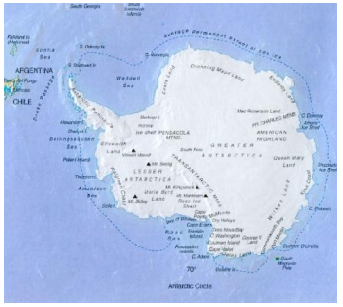
Experimental techniques & length scales

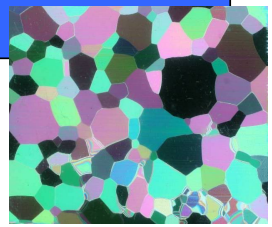
Remote sensing

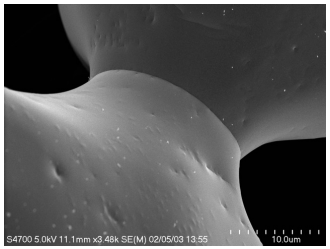
Visual observation & optical microscopy

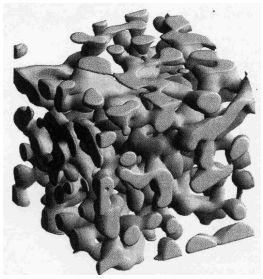
X-ray MT

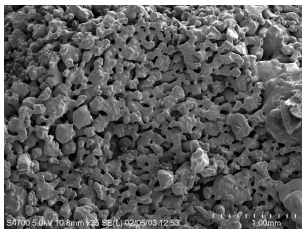
SEM











10^{-9} m 10^{-6} m 10^{-3} m 1 m 10^{3} m 10^{6} m

Small scale structure

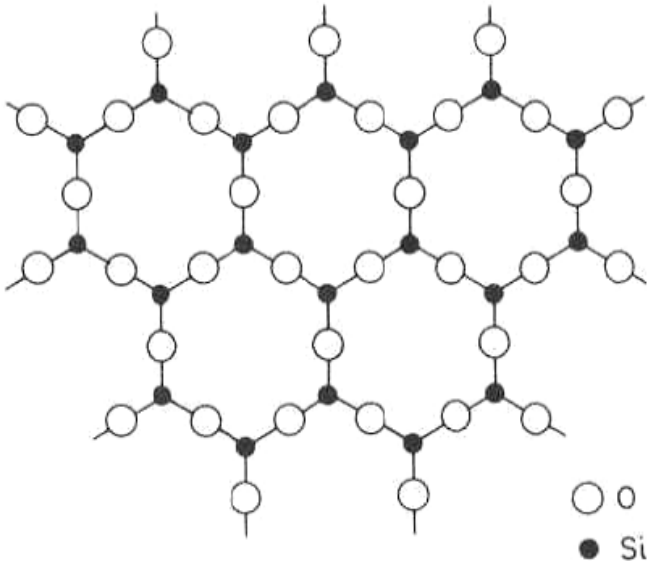
Getting into the science

material: silica, SiO_2

core

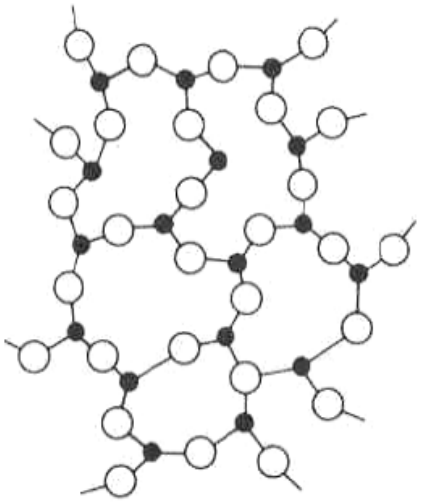
core+

Crystalline



Found in: sand, soil, granite, and many rocks and minerals

Amorphous



(silica) glass

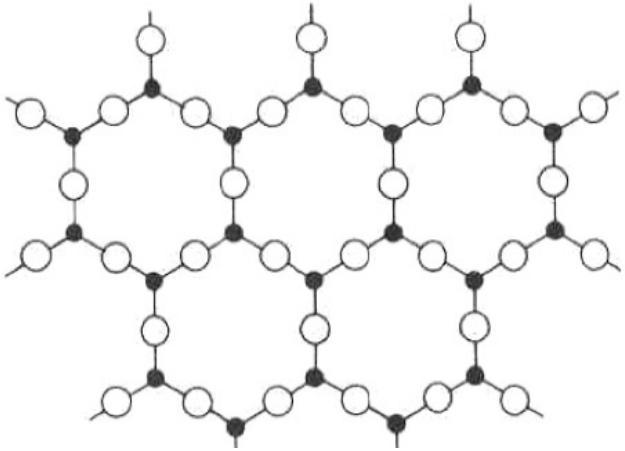
Let’s make things simpler

to look only at the ‘internal architecture’

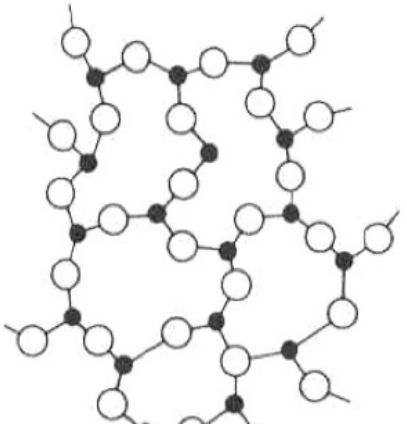
(and, for now, forget about what elements are present)

“As to methods, there may be a million and then some, but principles are few. The man who grasps **principles** can successfully select his own methods. The man who tries methods, ignoring principles, is sure to have trouble.” Emmerson c. 1911

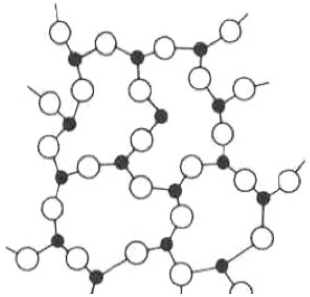
Crystalline



Amorphous

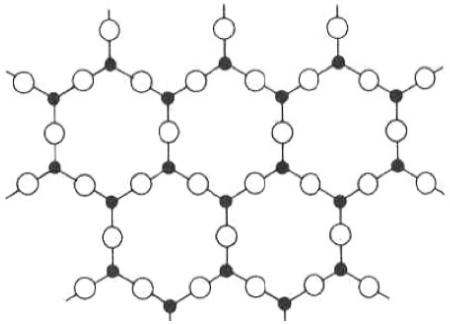


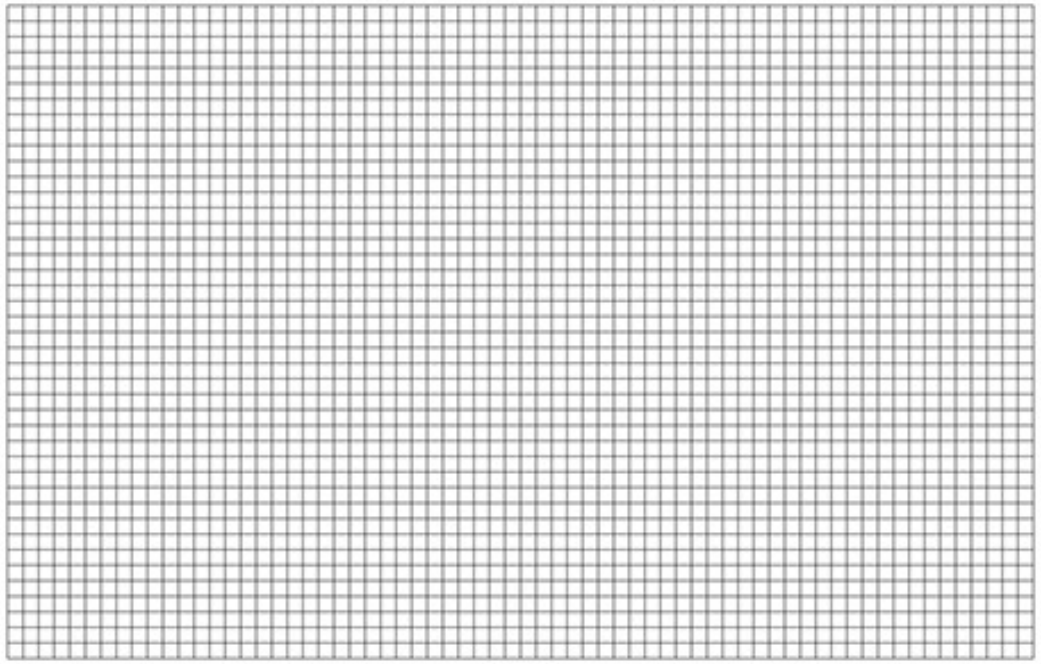
Amorphous



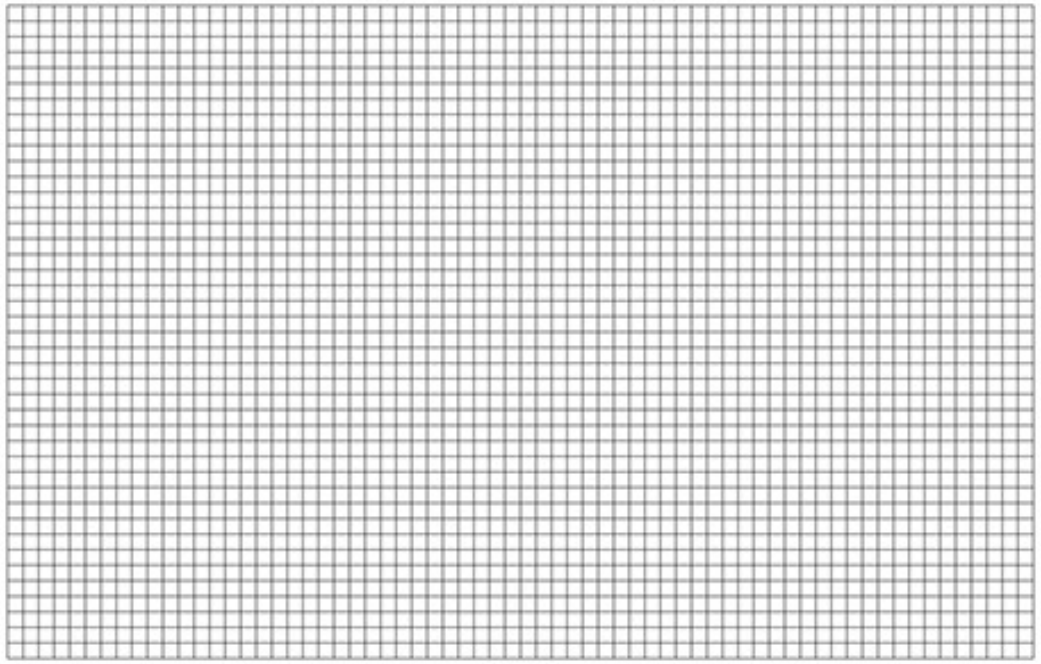
Amorphous

Crystalline





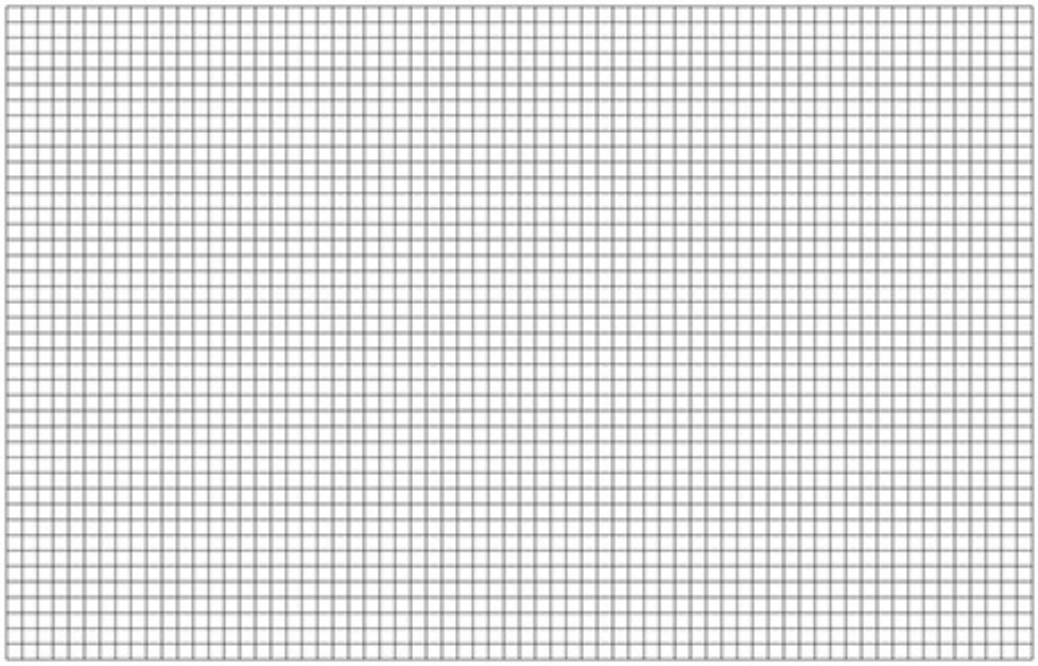
Crystalline



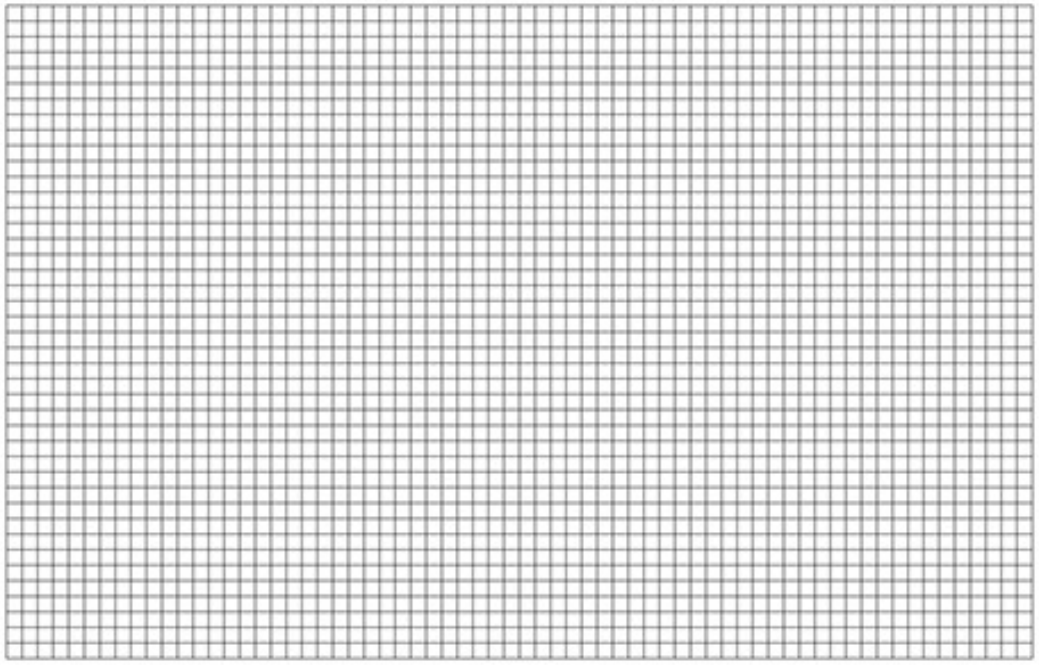
amorphous materials (no lattice)

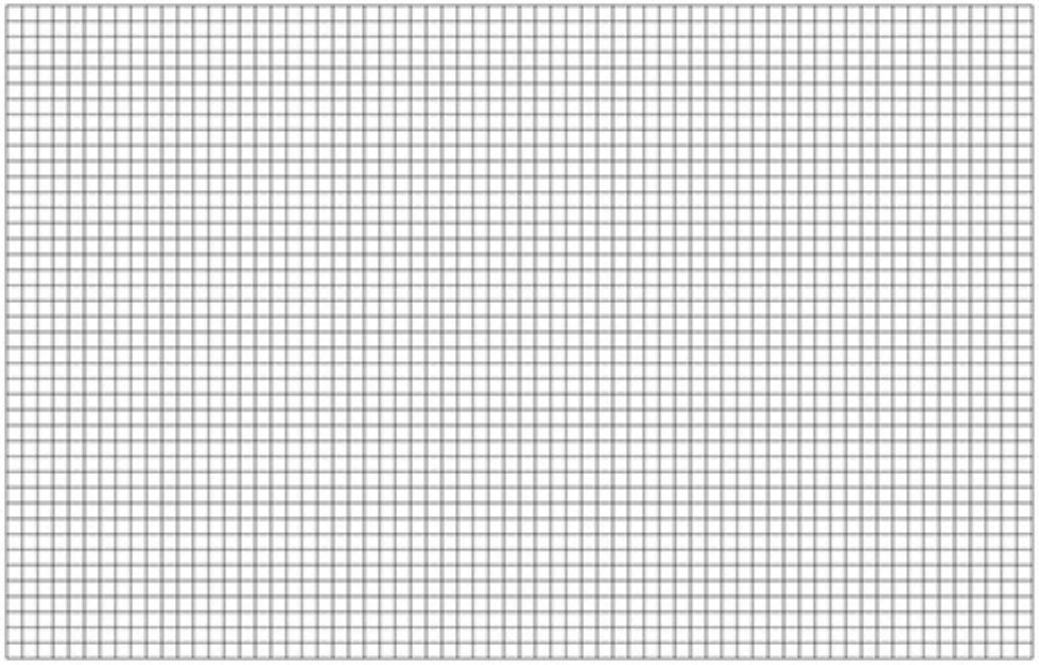
polymers
& glass

crystalline materials (with a lattice)



metals &
ceramics



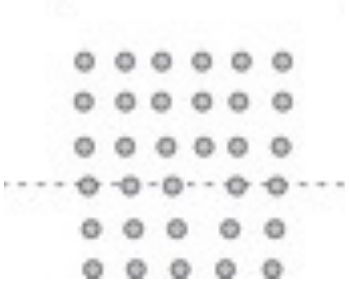


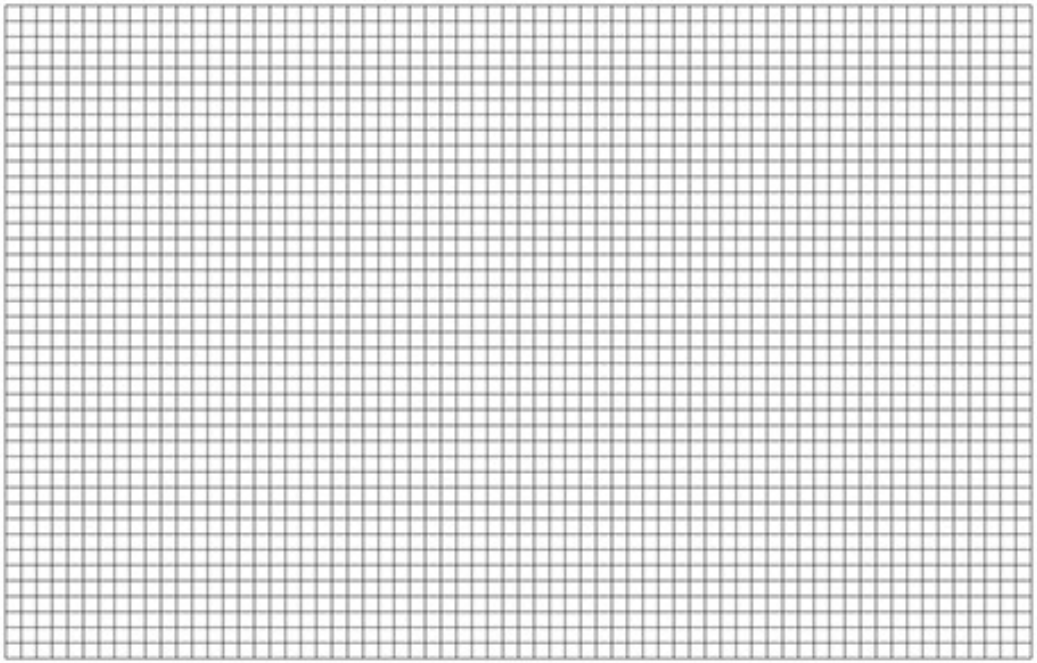
At a simple – but deep – level spaghetti and graph paper give us insight into the small scale structure of solid materials

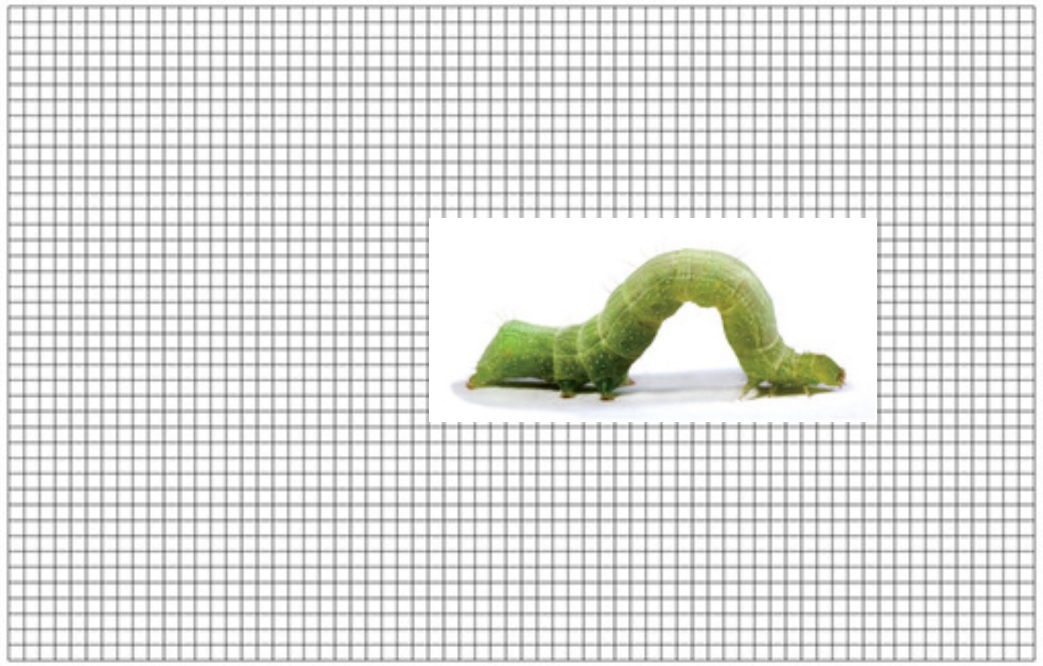
adding some complexity

metals – the lattice is not perfect

atoms missing







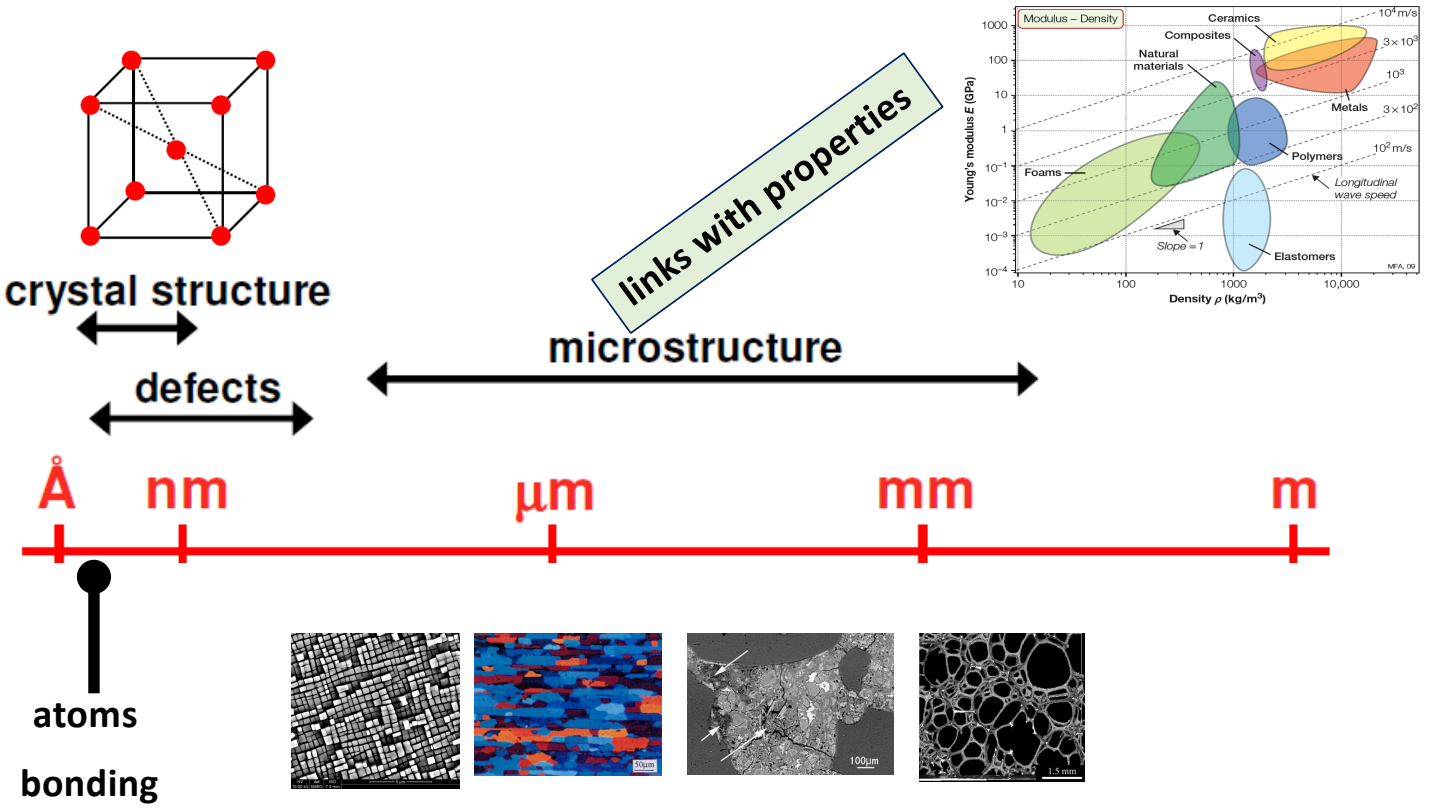
imagine the movement that's possible in the lattice

metals

more sophisticated and more realistic

Covered more comprehensively in the course content on small scale structure

Small scale structures in materials: what to take from this section



we can change microstructure

Core concepts for learning … #thinking&linking [Course Guide p6]

microstructure movie

extra

– some stunning microstructure images

available on Learn after the lecture

Questions & not knowing

cultivating and developing a good environment for learning

… we can ask questions that inspire curiosity

Materials classification: metals, polymers & ceramics

these are the three main classes of materials

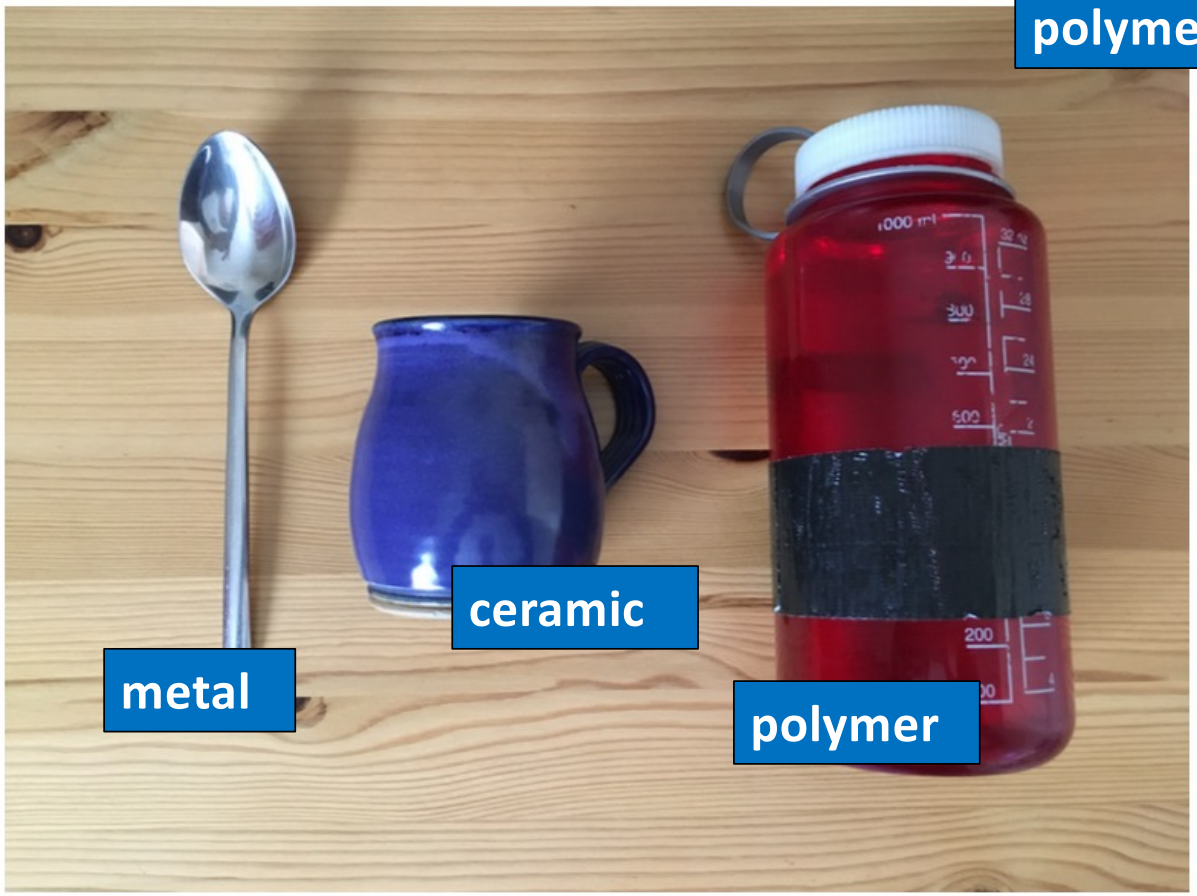
Frame: aluminium alloy — **metal**

Saddle: polymer foam — **polymer**

Tyres: rubber — **polymer**

Block: concrete — **ceramic**

from Part-1-learning by awareness-the WHAT framework-interactive activity



Wood = natural polymer
And we can see the small scale structure

WHAT Framework

Materials

- **Classifications**
- **Properties**
- **Small scale structure** (microstructure)
- Processing / manufacturing
- **Applications**

Examples of microstructures