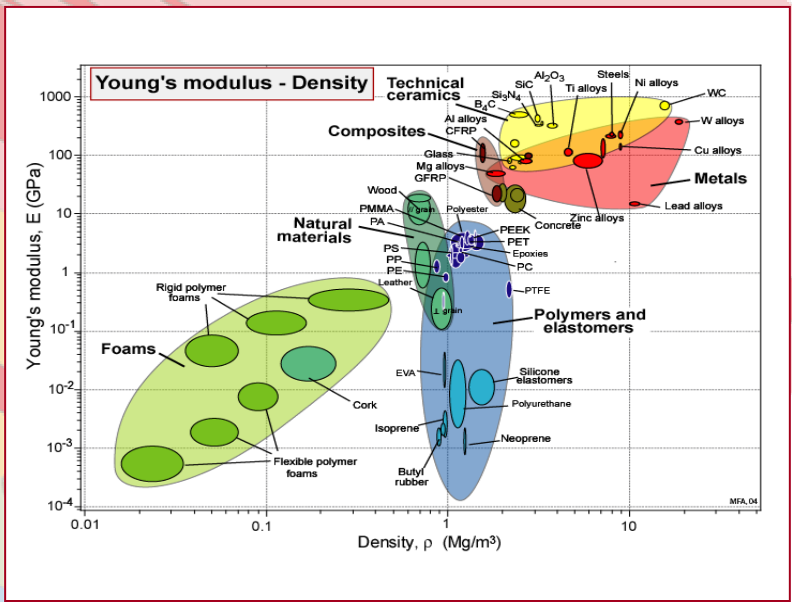
CES 2008 EDUPACK



Unit 2. Materials charts :

mapping the materials universe

New approaches to Materials Education - a course authored by Mike Ashby and David Cebon, Cambridge, UK, 2008

Outline

- **Exploring relationships: bar charts and bubble charts**
- **Elementary selection**
- **Making charts**
- **Report writing**
- ***Hands-on session 2, with exercises***

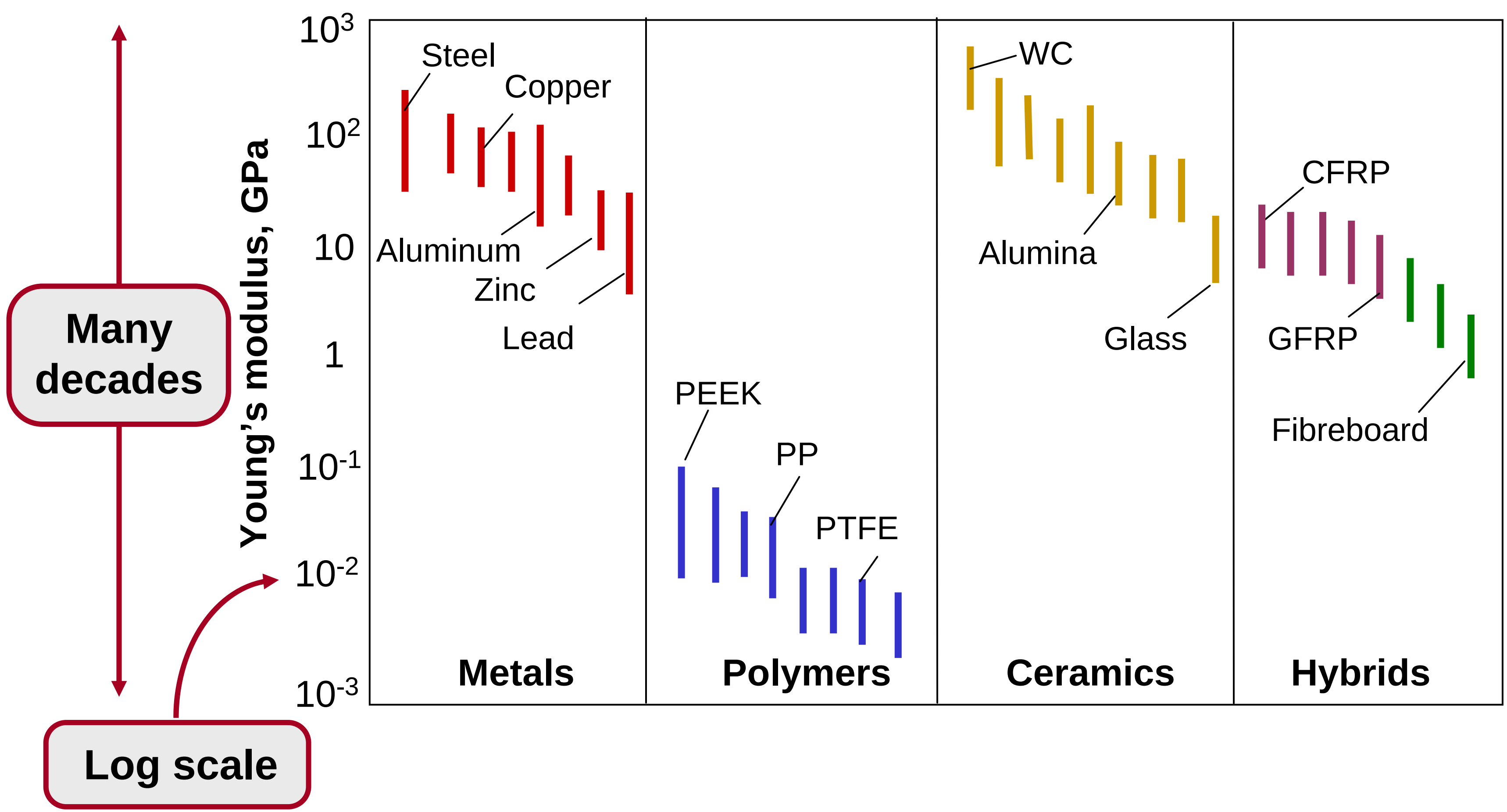
Resources:

- "Materials: engineering, science, processing and design" by M.F. Ashby, H.R. Shercliff and D. Cebon, Butterworth Heinemann, Oxford 2007, **Chapters 2.**
- "Materials Selection in Mechanical Design", 3rd edition by M.F. Ashby, Butterworth Heinemann, Oxford, 2006, **Chapter 3**.
- **CES** EduPack 2007 software (grantadesign.com)

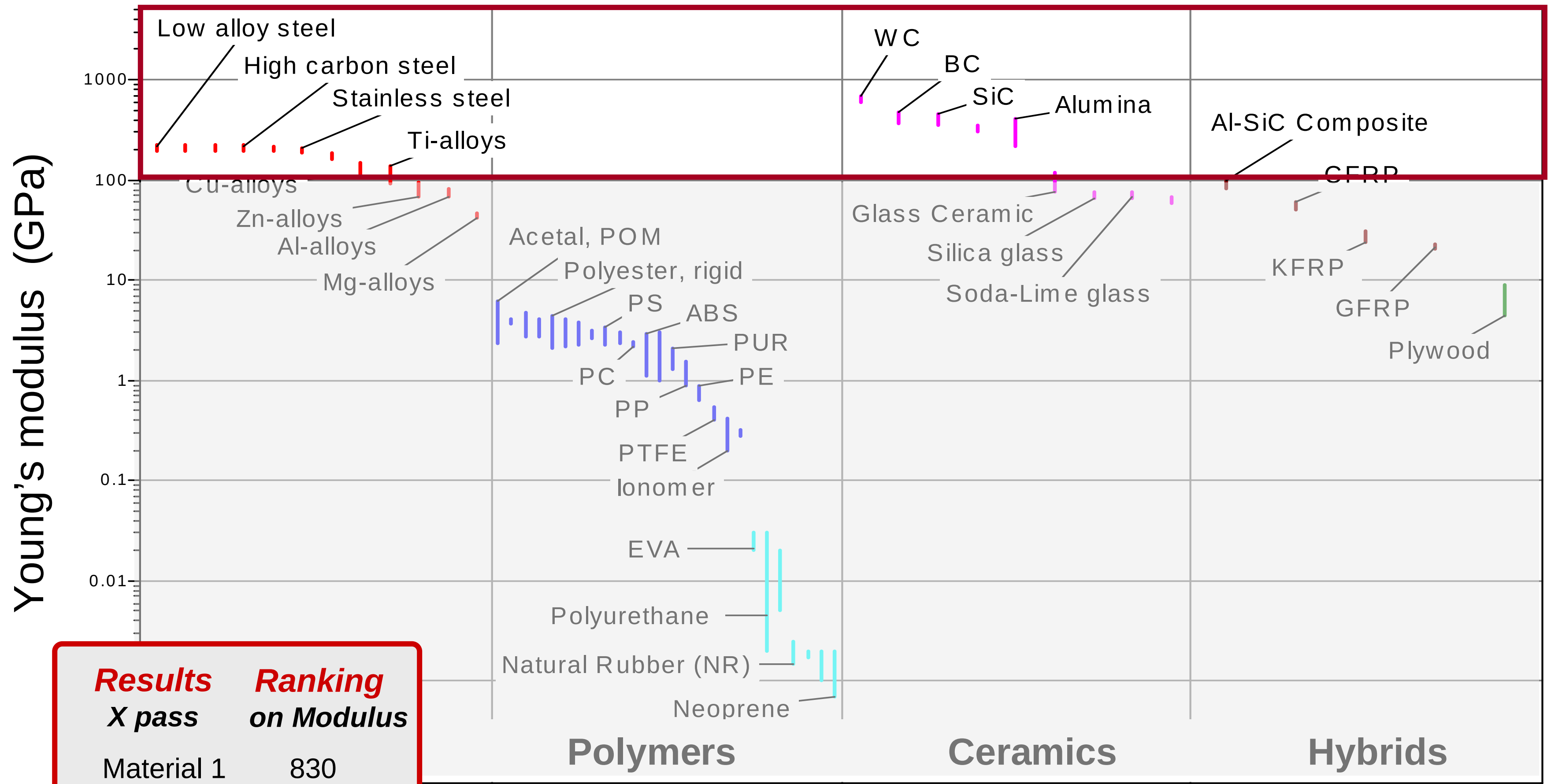
Relationships, perspective and comparisons

Data sheets do not allow comparison, perspective. For these we need →

- **Material bar-charts**
- **Material property charts**

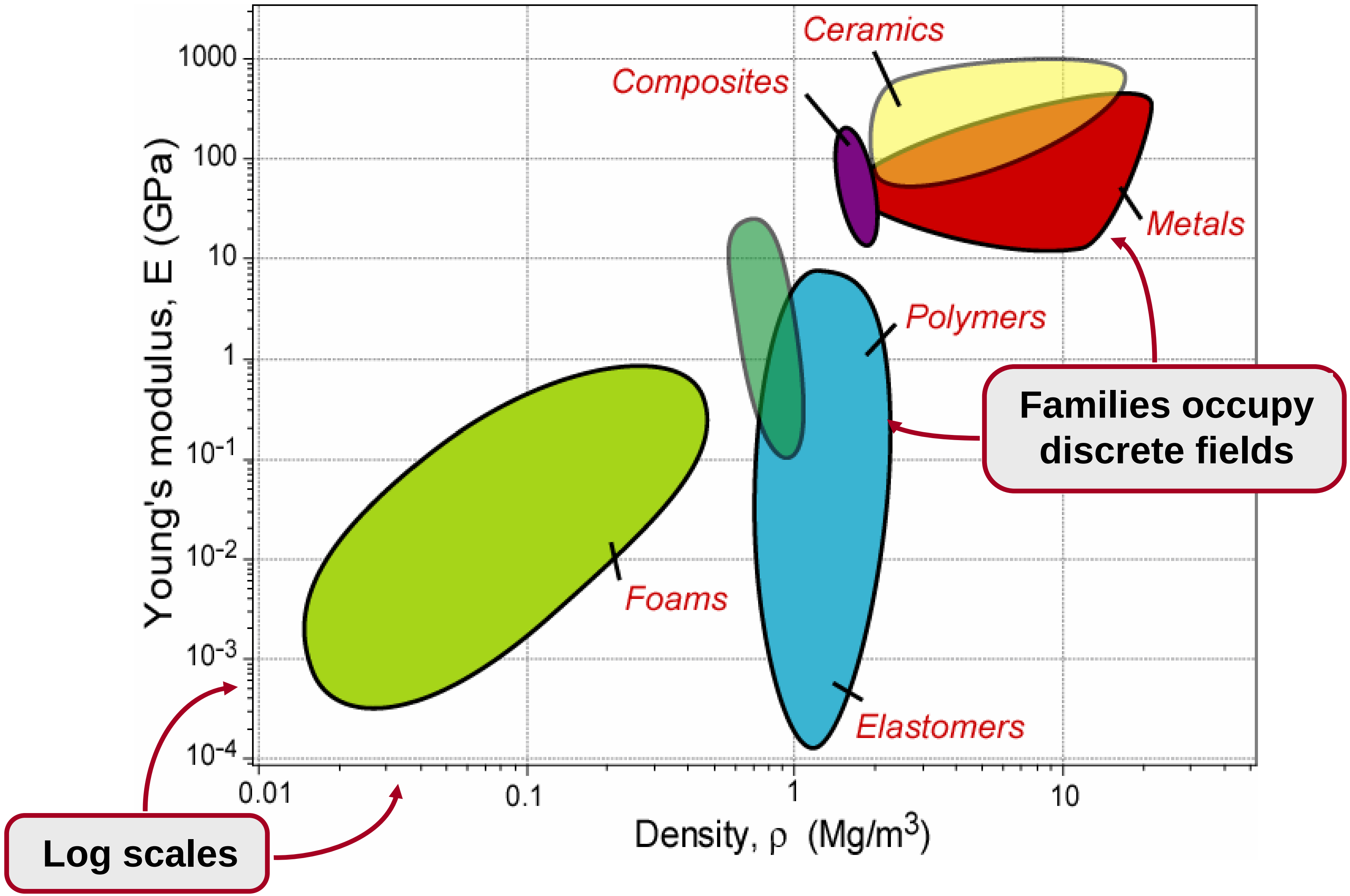


Bar- chart created with *CES* (Level1)

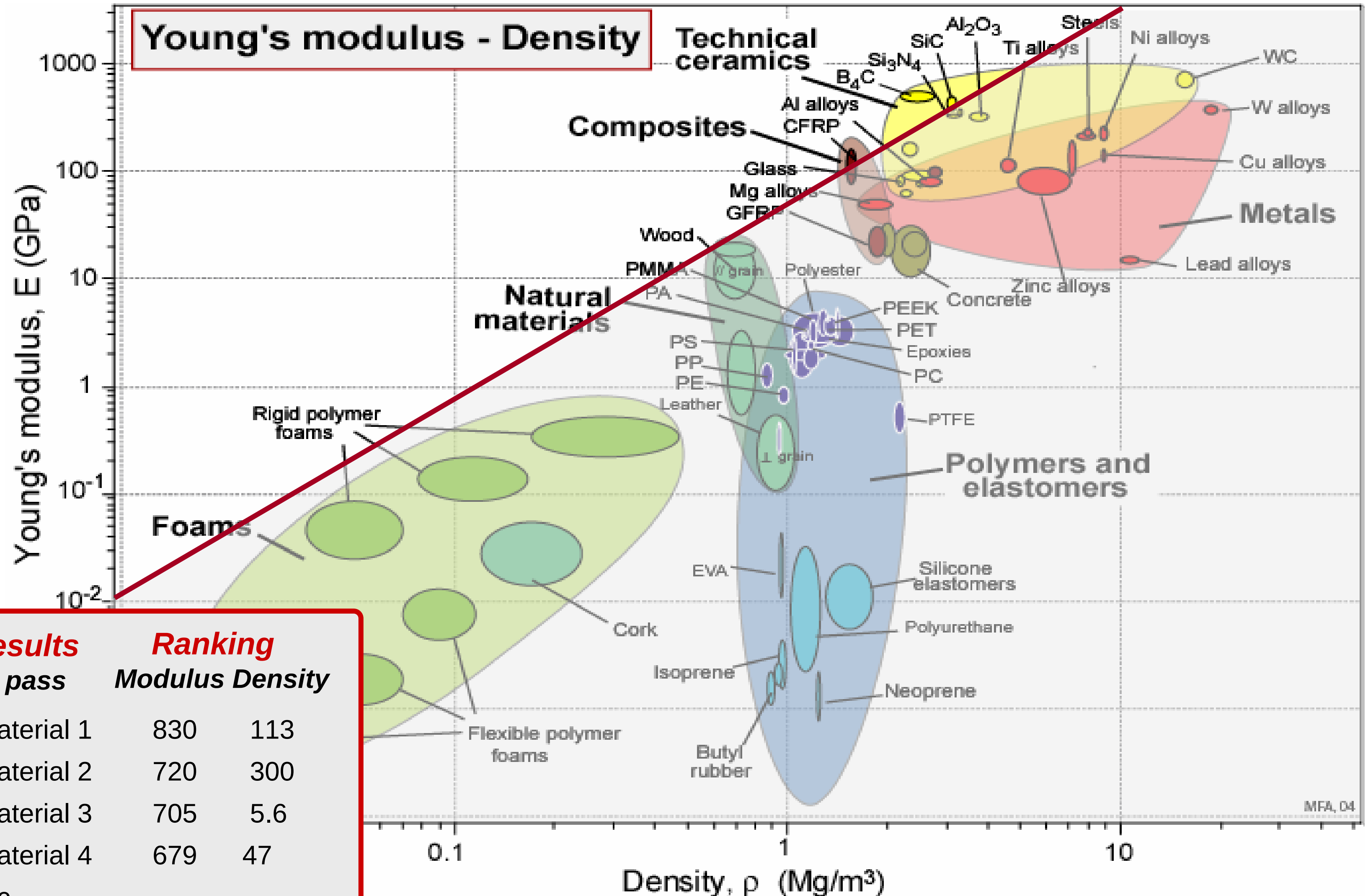


Results	***Ranking***
X pass	***on Modulus***
Material 1	830
Material 2	720
Material 3	705
Material 4	679
etc...	

Material property- charts: modulus - density



Bubble chart created with CES



Results ***X pass***	***Ranking*** ***Modulus***	***Density***
Material 1	830	113
Material 2	720	300
Material 3	705	5.6
Material 4	679	47
etc...		

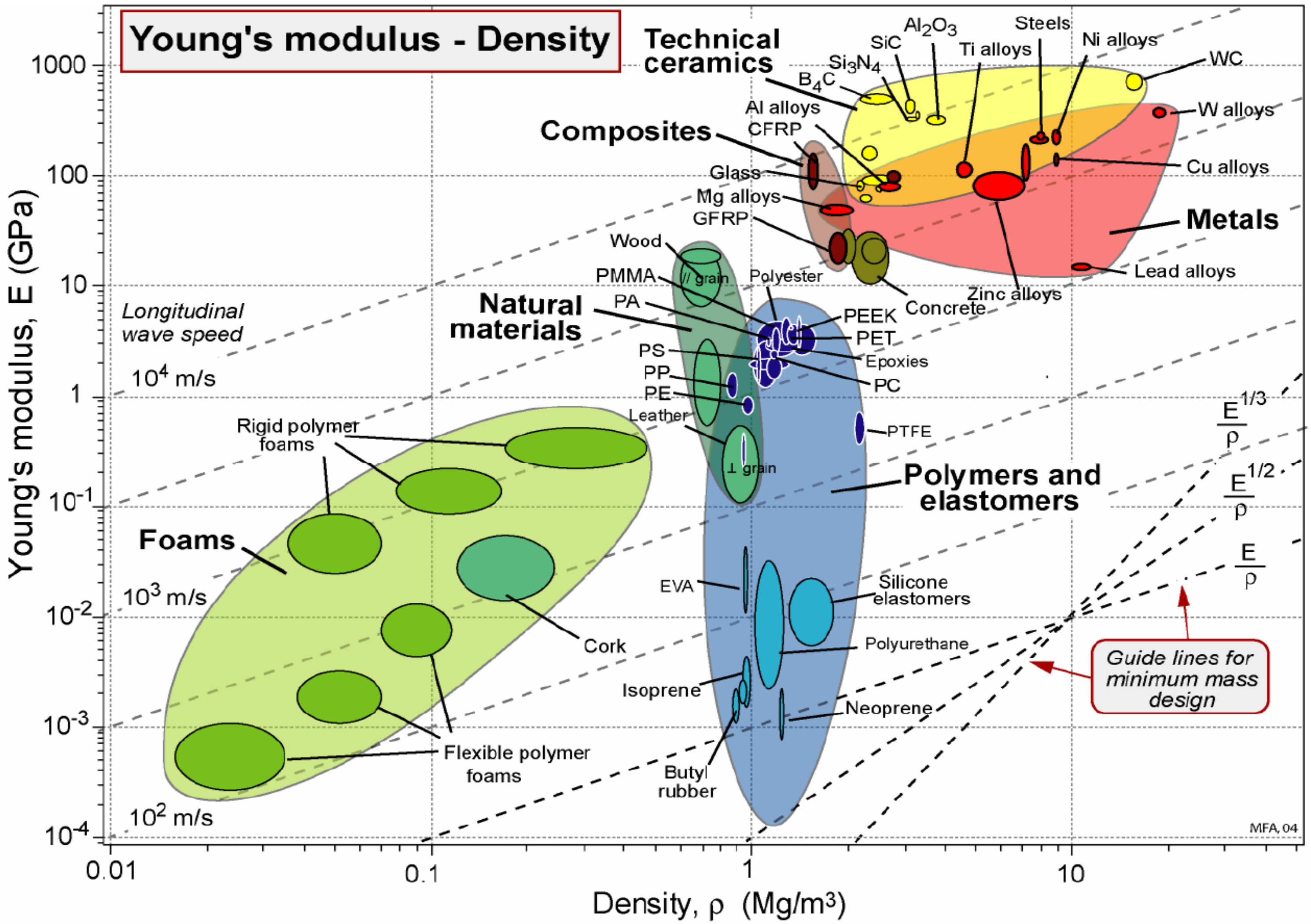
Exploring the science: mechanical properties

Why the differences?

- *Atom size and weight*
- *Bonds as (linear) springs*
- *Spring constant for various bond types.*

Manipulating properties

- *Making composites*
- *Making foams*



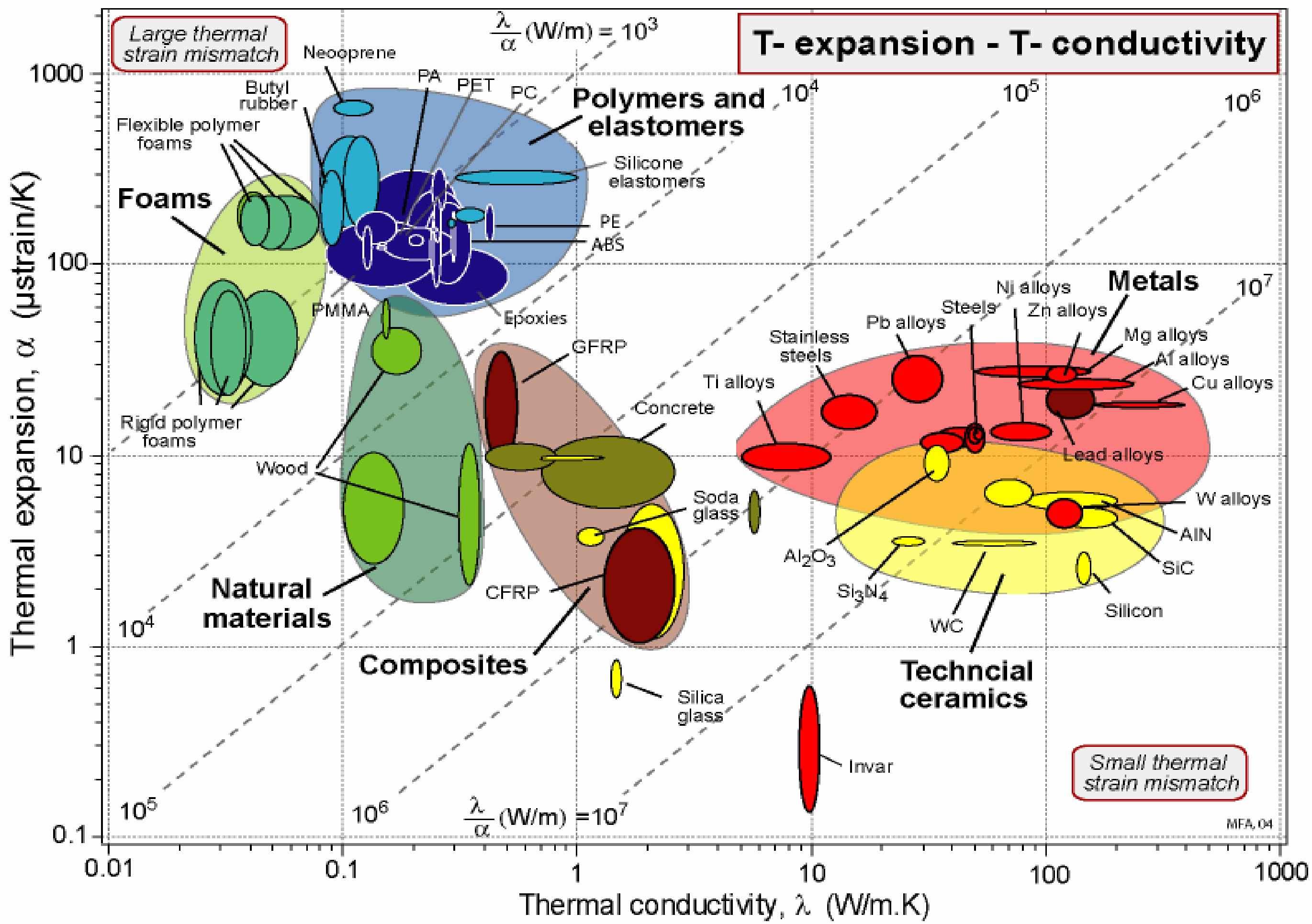
Exploring the science: thermal properties

Why the differences?

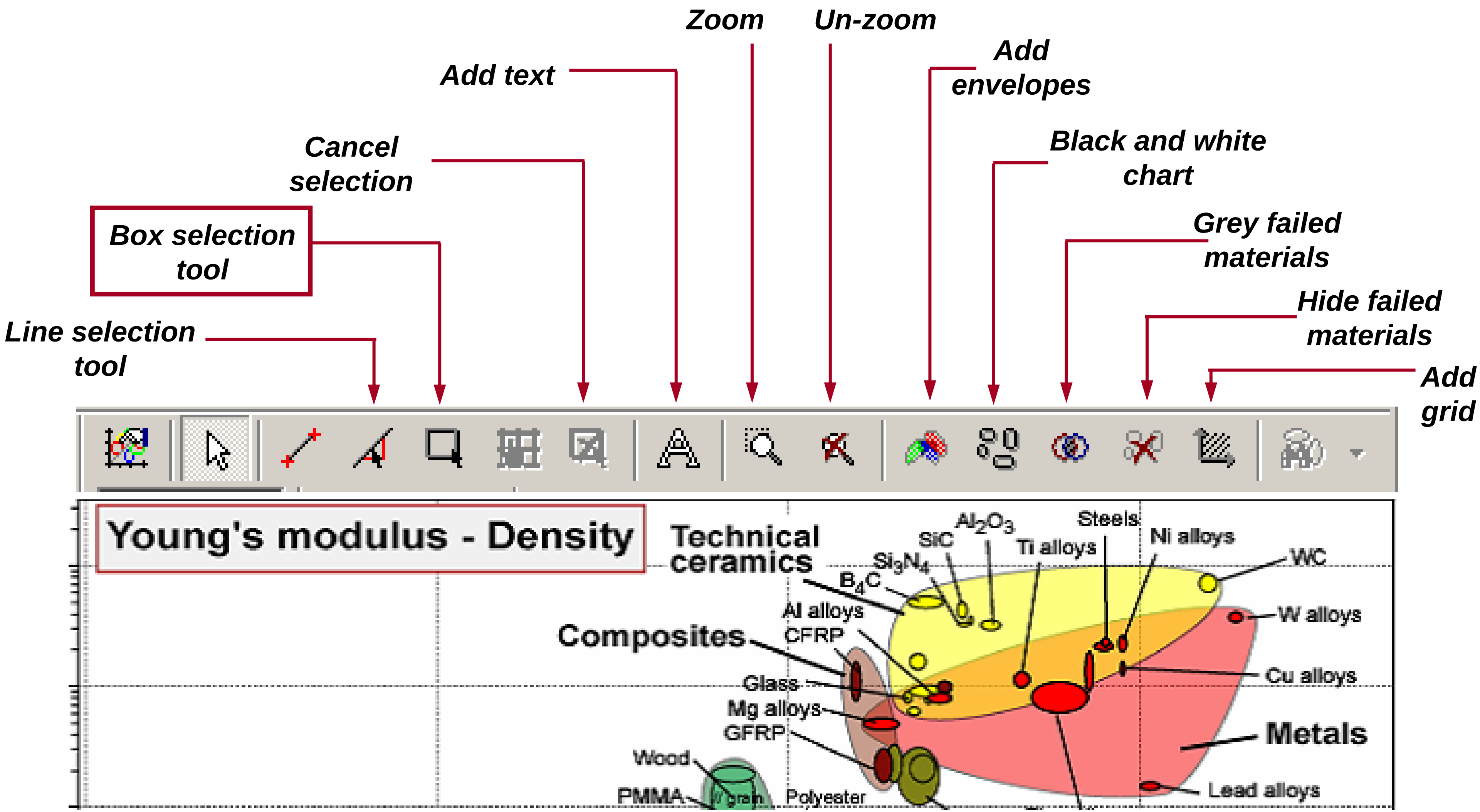
- *Bonds as non-linear springs*
- *10% expansion at melting point, so expansion goes inversely as Tm*
- *Thermal energy as atom vibration, propagates as waves, scattered by obstacles*

Manipulating properties

- *High conductivity: purity*
- *Low conductivity, obstacles and foams*



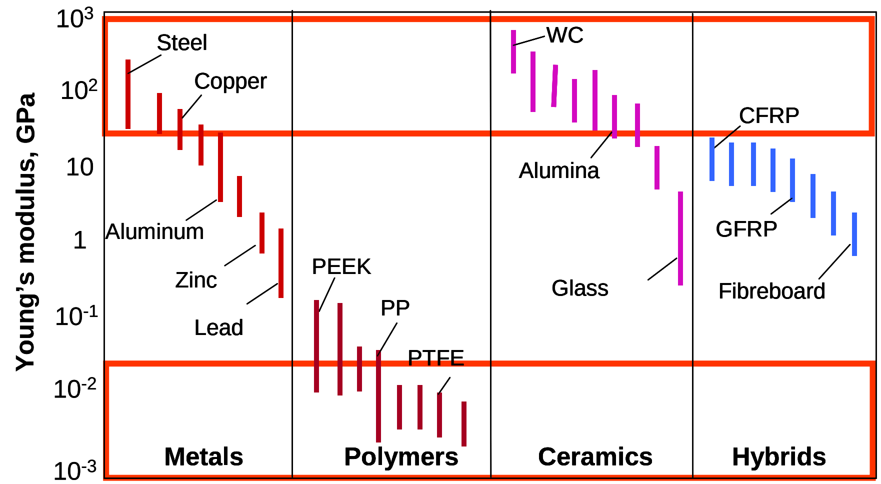
The chart-management tool bar



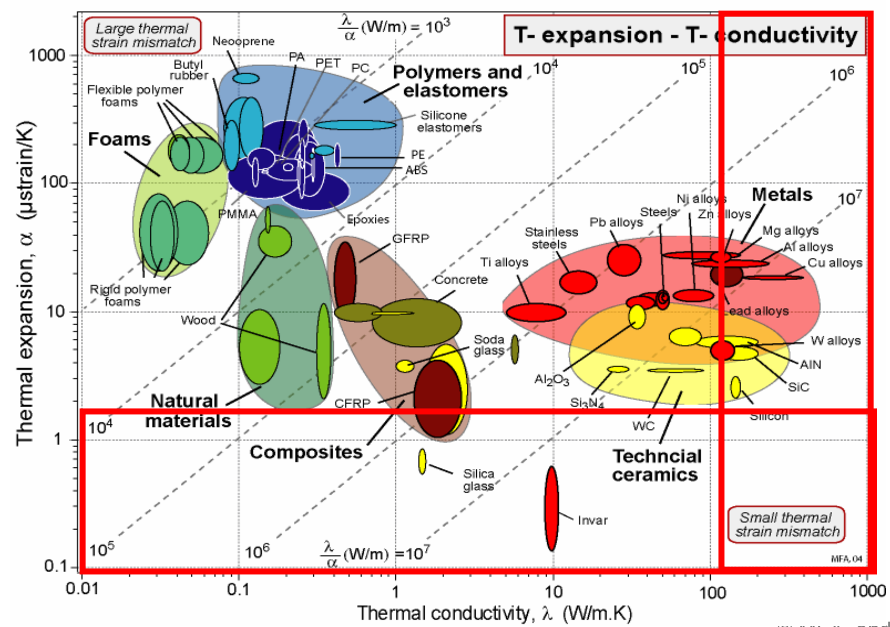
Elementary selection

At this stage students have a **tool.**

- Materials with high stiffness?
- Materials with low stiffness?



- Materials with high conductivity?
- Materials with low expansion?



Creating charts

GRANTA

File **Edit** **View** **Select** **Tools**

Toolbar → Browse | **Select** | Search | Print | Search web

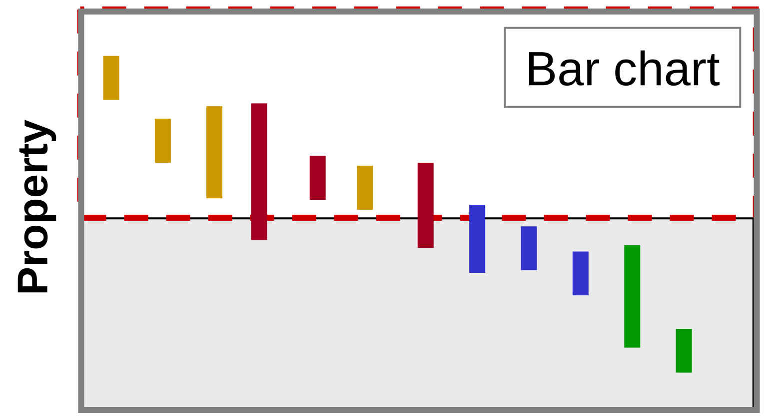
1. Selection data

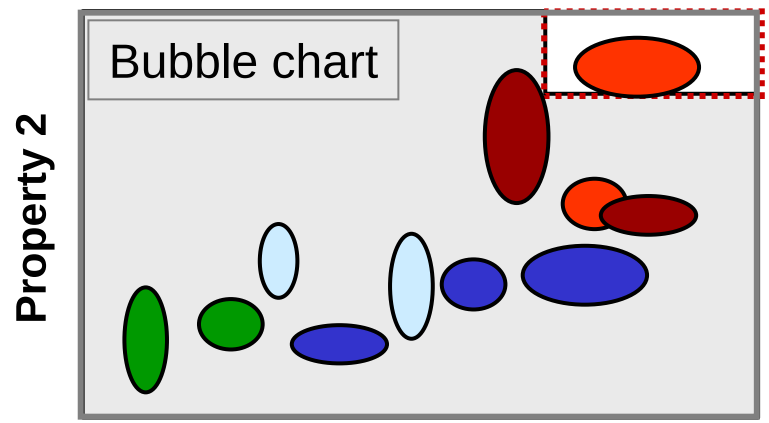
Pick a selection template ▼

2. Selection Stages

Graph **Limit** **Tree**

Results X pass	*Ranking* Prop 1	Prop 2
Material 1	830	113
Material 2	720	300
Material 3	705	5.6
Material 4	679	47
etc...		





Property 1

Charts with functions of properties

GRANTA

File Edit View Select Tools

Browse | **Select** | Search | Print | Search web

1. Selection data

Edu Level 2: Materials ▼

2. Selection Stages

Graph **Limit** **Tree**

X-axis **Y-axis**

Advanced

List of properties

- **Density**
- **Modulus**
- **Yield strength**
- **etc**

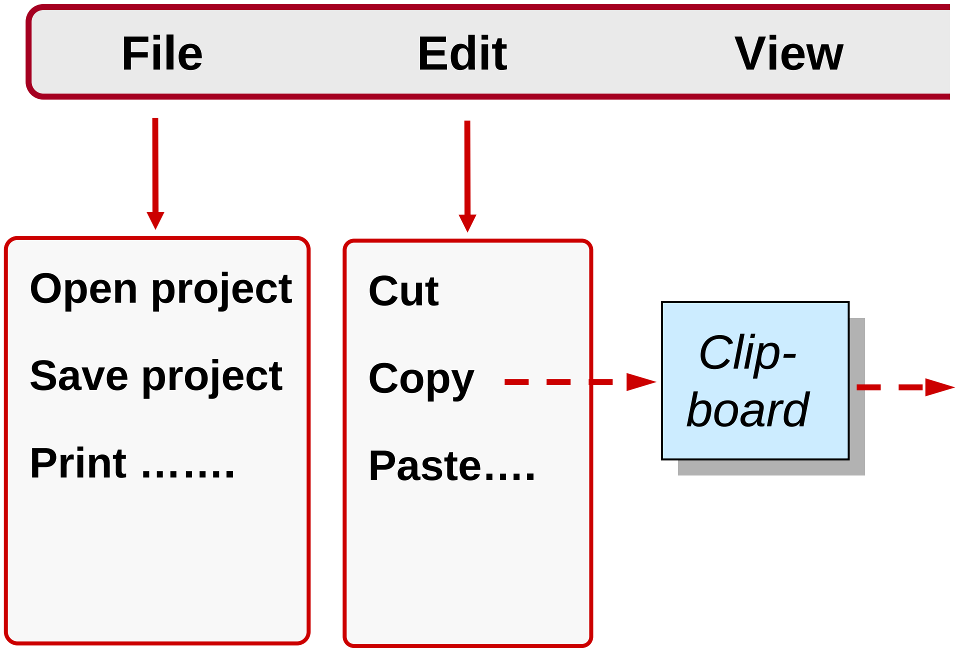
Modulus / Density

+ - / * ^ ( )

List of properties

- Density
- Modulus
- Yield strength
- etc

Report writing



Acrylonitrile-butadiene-styrene (ABS) - $(CH2\text{-}CH\text{-}C6H4)_n$

General Properties

Density	1.05	-	1.07	Mg/m^3
Price	2.1	-	2.3	US $/kg

Mechanical Properties

Young's Modulus	1.1	-	2.9	GPa
Elastic Limit	18	-	50	MPa
Tensile Strength	27	-	55	MPa
Elongation	6	-	8	%
Hardness - Vickers	6	-	15	HV
Endurance Limit	11	-	22	MPa
Fracture Toughness	1.2	-	4.2	$MPa.m^{1/2}$

Thermal Properties

Max Service Temp	350	-	370	K
Thermal Expansion	70	-	75	$10^{-6}/K$
Specific Heat	1500	-	1510	J/kg.K
Thermal Conductivity	0.17	-	0.24	W/m.K

Electrical Properties

Conductor or insulator?	Good insulator

Optical Properties

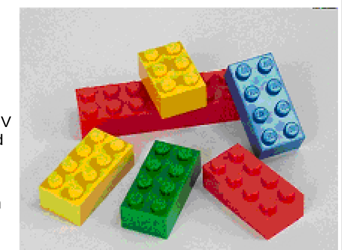
Transparent or opaque?	Opaque

Eco Properties

Energy content	91 - 110	MJ/kg
CO_2 per kg	3.2 - 3.6	kg/kg

Corrosion and Wear Resistance

Flammability	Average
Fresh Water	Good
Organic Solvents	Average
Sea Water	Good
UV	Good
Wear	Poor
etc	



What is it? ABS (Acrylonitrile-butadiene-styrene) is tough, resilient, and easily molded. It is usually opaque, although some grades can now be transparent, and it can be given vivid colors. ABS-PVC alloys are tougher than standard ABS and, in self-extinguishing grades, are used for the casings of power tools.

Design guidelines. ABS has the highest impact resistance of all polymers. It takes color well. Integral metallics are possible (as in GE Plastics' Magix.) ABS is UV resistant for outdoor application if stabilizers are added. It is hygroscopic (may need to be oven dried before thermoforming) and can be damaged by petroleum-based machining oils.

ABS can be extruded, compression moulded or formed to sheet that is then vacuum thermo-formed. It can be joined by ultrasonic or hot-plate welding, or bonded with polyester, epoxy, isocyanate or nitrile-phenolic adhesives.

Technical notes. ABS is a terpolymer - one made by copolymerising 3 monomers: acrylonitrile, butadiene and syrene. The acrylonitrile gives thermal and chemical resistance, rubber-like butadiene gives ductility and strength, the styrene gives a glossy surface, ease of machining and a lower cost. In ASA, the butadiene component (which gives poor UV resistance) is replaced by an acrylic ester. Without the addition of butyl, ABS becomes, SAN - a similar material with lower impact resistance or toughness. It is the stiffest of the thermoplastics and has excellent resistance to acids, alkalis, salts and many solvents.

Typical Uses. Safety helmets; camper tops; automotive instrument panels and other interior components; pipe fittings; home-security devices and housings for small appliances; communications equipment; business machines; plumbing hardware; automobile grilles; wheel covers; mirror housings; refrigerator liners; luggage shells; tote trays; mower shrouds; boat hulls; large components for recreational vehicles; weather seals; glass beading; refrigerator breaker strips; conduit; pipe for drain-waste-vent (DWV) systems.

The environment. The acrylonitrile monomer is nasty stuff, almost as poisonous as cyanide. Once polymerized with styrene it becomes harmless. ABS is FDA compliant, can be recycled, and can be incinerated to recover the energy it contains.

The main points

- **Visual presentation** of data as bar-charts and property (bubble) charts reveals relationships and allows comparisons
- **CES** allows a wide range of charts to be constructed
- **Box selection tool** allows elementary selection
- There are comprehensive **report-writing** facilities

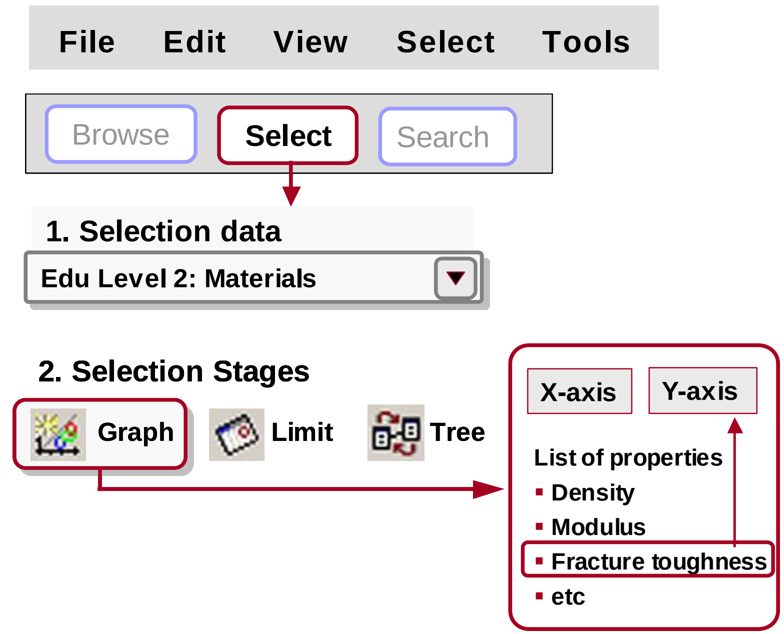
Pause for demo

Exercises: Making bar charts

GRANTA

2.1 Make a bar chart with ***Fracture toughness*** on the Y-axis using Level 1, Materials

- Click on **Select** and proceed as shown opposite
- Label two (or more) materials by clicking on the bars.
- Find the bar for **Magnesium alloys** (right click on name in Browse and select “Highlight”).
- Change the name to **Mg-alloys** and make the font larger (right click on name on the bar chart and select “Rename” to change the name and “Format” to change font size, color etc).
- Use the BOX selection tool to find the four materials with the highest values of fracture toughness. (Answer: Low alloy steels, Nickel alloys, Stainless steels, Titanium alloys).
- Change the UNITS from Metric to Imperial or *vice versa* (Tools – Options – Units – US Imperial / Metric)

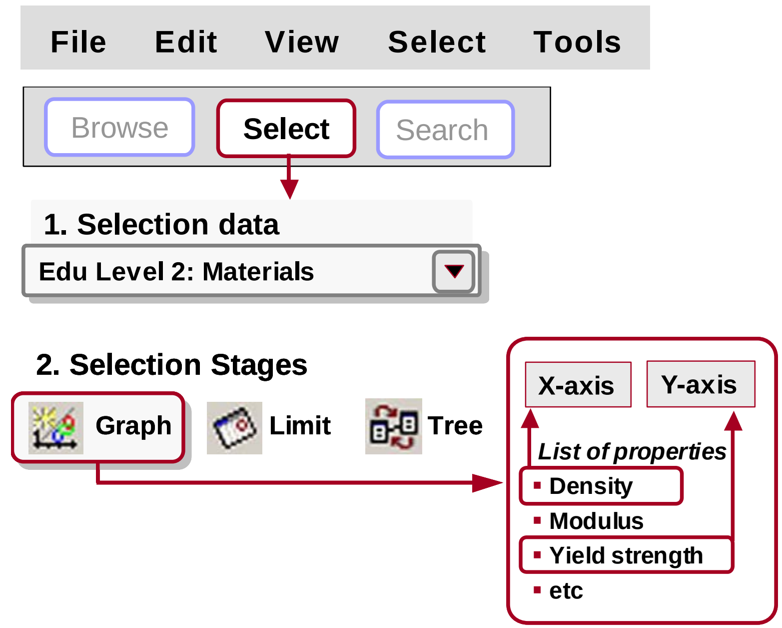


Exercises: Making bubble charts

2.2 Make a bubble chart with ***Density*** on the X-axis and ***Yield strength*** on the Y-axis using Level 1, Materials settings

- Click on **Select** and proceed as shown opposite
- Label two (or more) material by clicking on the bars.
- Switch on the envelopes
- Do any metals have yield strength less than 10 MPa (2 ksi)? (Answer: yes, Lead alloys)
- Use the BOX selection tool to find materials with a yield strength greater than 600 MPa (90 ksi) and a density less than 2000 kg/m^3 (120 lbs/cubic ft).

  (Answer: there is only one: CFRP).



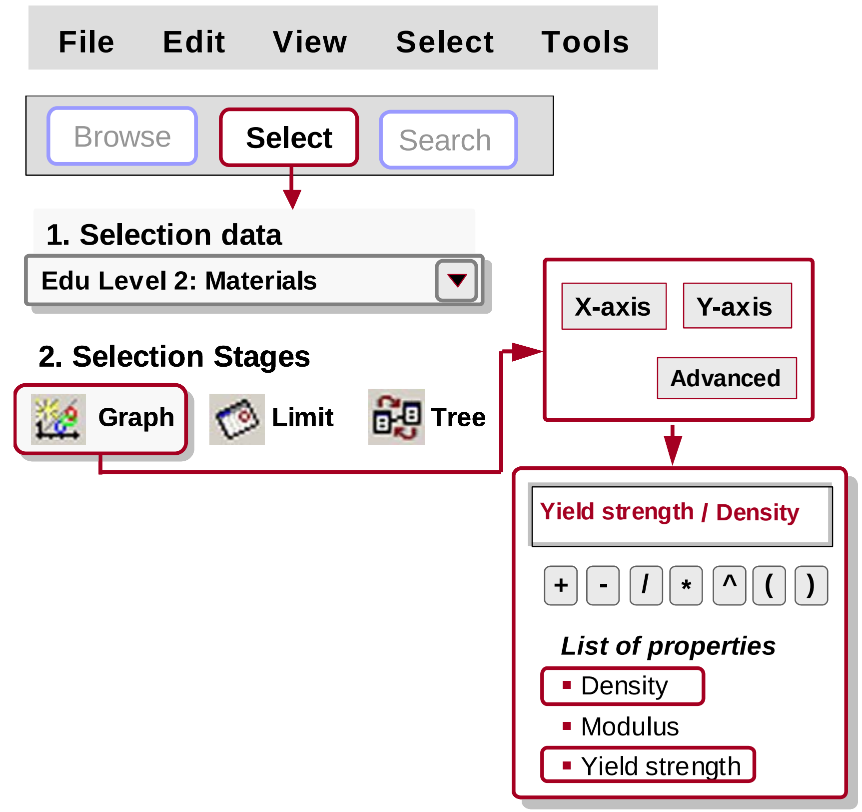
Exercises: Making functions of properties

2.3 Make a bar chart with ***Yield strength / Density*** on the Y-axis using Level 1, Materials

- Label the axis “Yield strength/Density”
- Which two materials have the highest values? (Answer: CFRP and Titanium alloys).

2.4. Now add ***Young’s modulus / Density*** to the X-axis to make a bubble chart, using Level 1, Materials

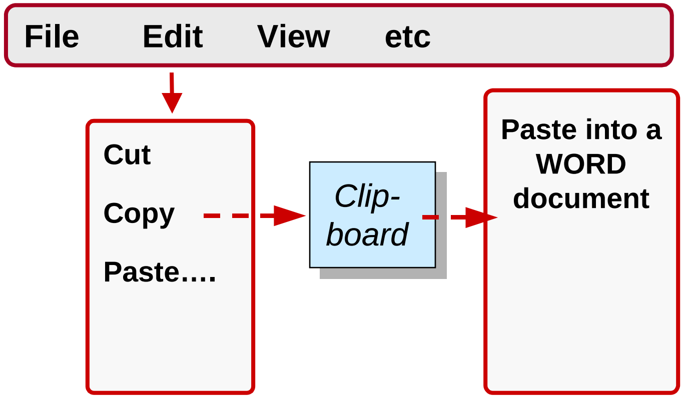
- Click on the stage name “Stage 1: Yield strength / Density” – Edit – X-axis –Advanced, then make the function Young’s modulus / Density.
- Find CFRP and GFRP

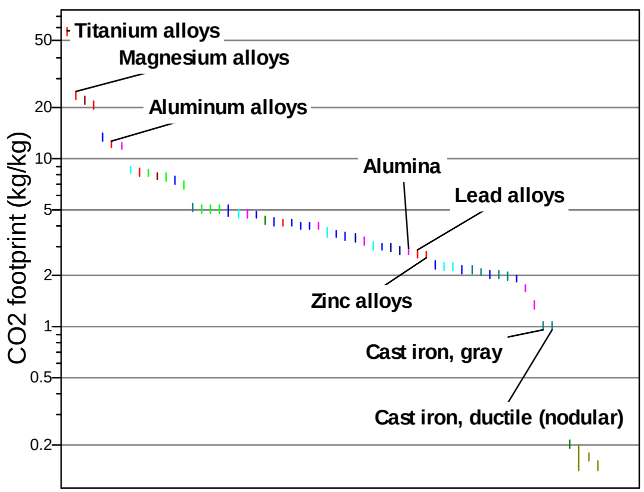


Exercises: Report writing

2.5 A manufacturer is concerned that the materials he uses have a high ***CO_2 footprint.*** He wishes to know which metals have the lowest footprint, per unit weight and per unit volume. Write a brief report advising him on this, with a record for one metal with a particularly low CO_2 footprint.

- Make a bar-chart of CO_2 footprint per unit weight. Label some of the materials Copy and paste it into WORD (use Edit – Paste special – Device independent bitmap).
- Copy a record for one of the materials with a low value of CO_2/kg and paste that into the same document.
- Reformat the document until it has the form you want.





Cast iron, ductile (nodular)

Eco properties

Embodied energy 16.4 -18.2 MJ/kg

CO2 footprint 0.97-1.07 kg/kg

Recycle True

End of unit 2