



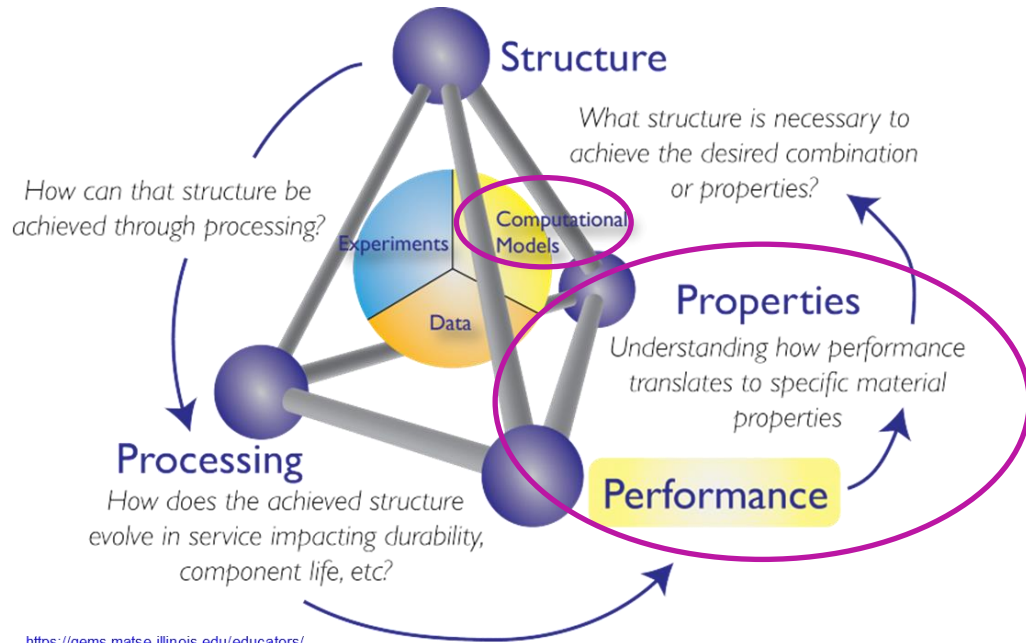
Aalto University  
School of Engineering

# COE-C2004 - Materials Science and Engineering

## Exercise 5

*Prof. Junhe Lian*  
*Zinan Li*

# GRANTA overview



**Overview:** Materials and process selection tool

## Basic Features:

- Look up information
- Create Charts
- Select materials or processes
- Assess design by Eco Audit

## Features unique to Granta EduPack:

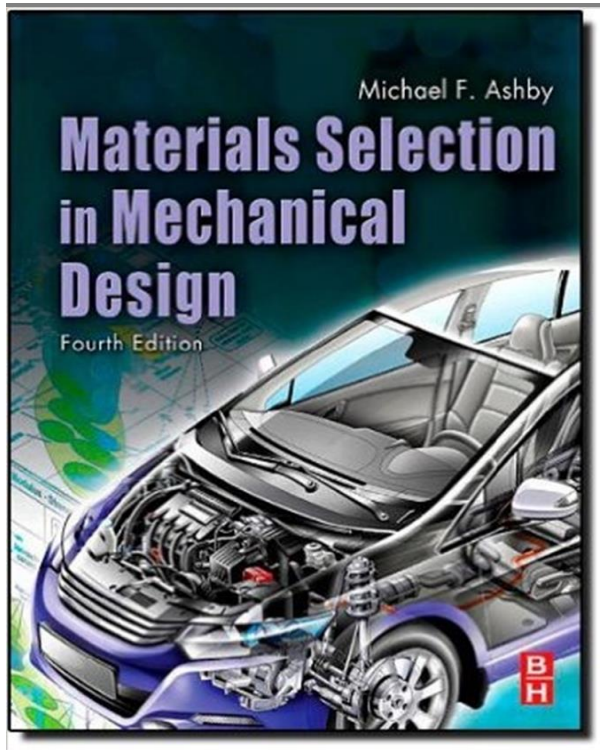
- Level Structure
- Science Notes
- Video Tutorials
- Online teaching resources

<https://www.ansys.com/products/materials/granta-edupack/>

# Textbook and software

## Textbook

**Ashby, Michael F.**  
**Materials Selection in Mechanical Design**  
(Chapter 3, 5 and 7).



## Software

**GRANTA EduPack**  
(was Cambridge Engineering Selector,  
from Granta Design Software, now part of ANSYS)



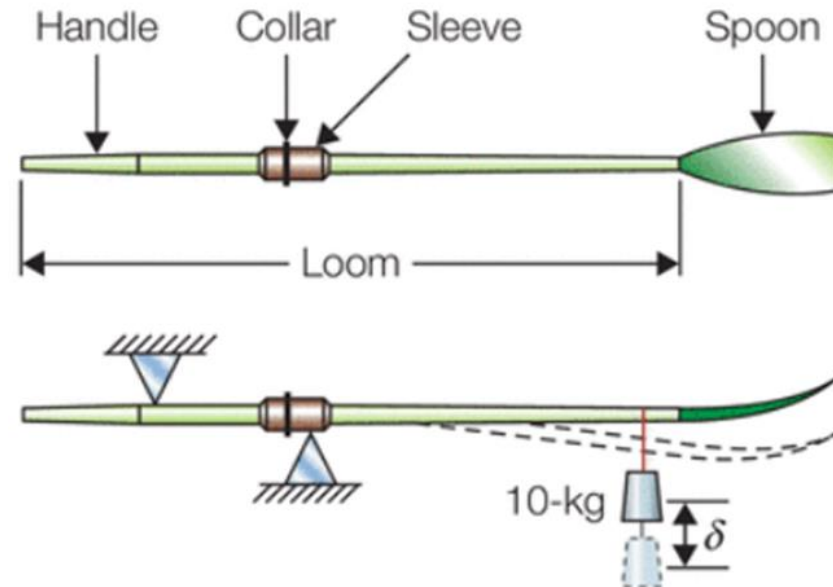
# Tasks

# Example task

## *Material selection for Oars*

A beam as light as possible and strong enough to carry, without breaking the bending moment exerted by the person, i.e., the stiffness must be met

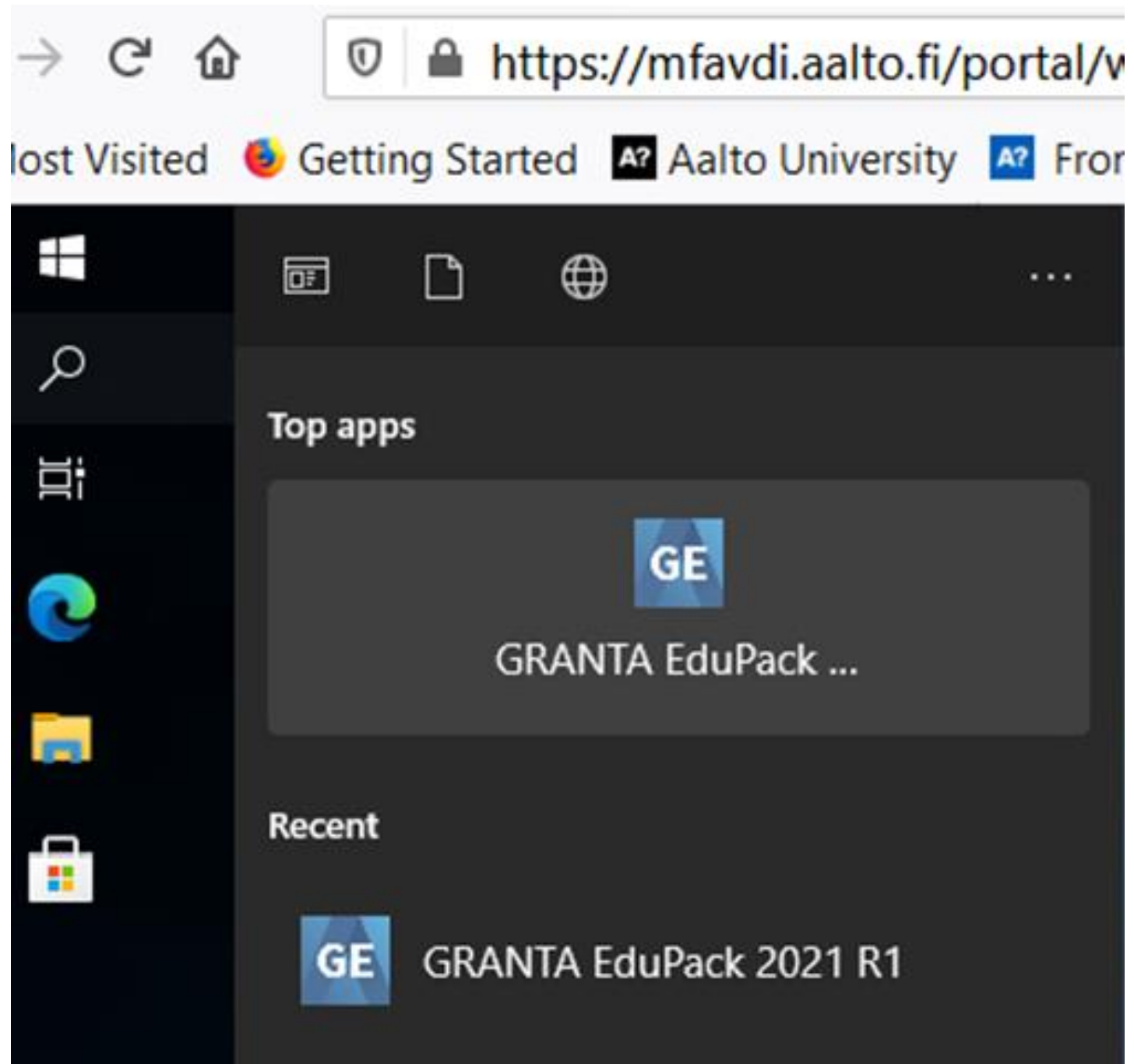
- Derive the formula for the material performance index from the performance objective
- Draw the material selection maps with density and Young's modulus as axes



# GRANTA operations

# Access to the software

*Local installation and VDI connection*



## Access to GRANTA EduPack

### Method 1 – Local Software Installation

#### Step 1. Check system requirements.

GRANTA EduPack is designed for computers running Windows. To install GRANTA EduPack, you will need the following:

- A compatible Microsoft® Windows® operating system;
  - Windows 8 32-bit or 64-bit,
  - Windows 10 32-bit or 64-bit.
- 4 GB of RAM, 4 GB of available hard disk space.
- Microsoft .NET Framework version 4.6.2, Microsoft Report Viewer 2010 SP1, and Microsoft VC 141 redistributable.
  - If any of these are not installed, they will be installed during the GRANTA EduPack installation. You may need to restart your computer and the installer. You may need to restart your computer. If you restart your computer, you will have to restart the installer, too.
  - For the French, German, and Spanish language installations, you will also require the appropriate language packs for these, which are usually installed with your OS.
- Administrator rights and Internet access.

For macOS or Linux users, the following two options should be considered (both require you to have a licensed version of Windows):

- Boot Camp—Boot Camp is software that comes installed with macOS (compatible with macOS 10.6 or later) that allows you to run compatible versions of Microsoft Windows on an Intel-based Mac. As Boot Camp runs the Windows operating system directly, the performance of Windows applications is not affected. The downsides of using Boot Camp are the risks involved with re-partitioning the hard drive and the need to boot into Windows each time you wish to use GRANTA EduPack.
- Install Windows on a virtual machine on your Mac. This allows you to run Windows software, including GRANTA EduPack, from inside macOS as if it were installed on your Mac.

#### Step 2. Download software copy from Aalto download service.

- visit [Download.aalto.fi](https://download.aalto.fi);

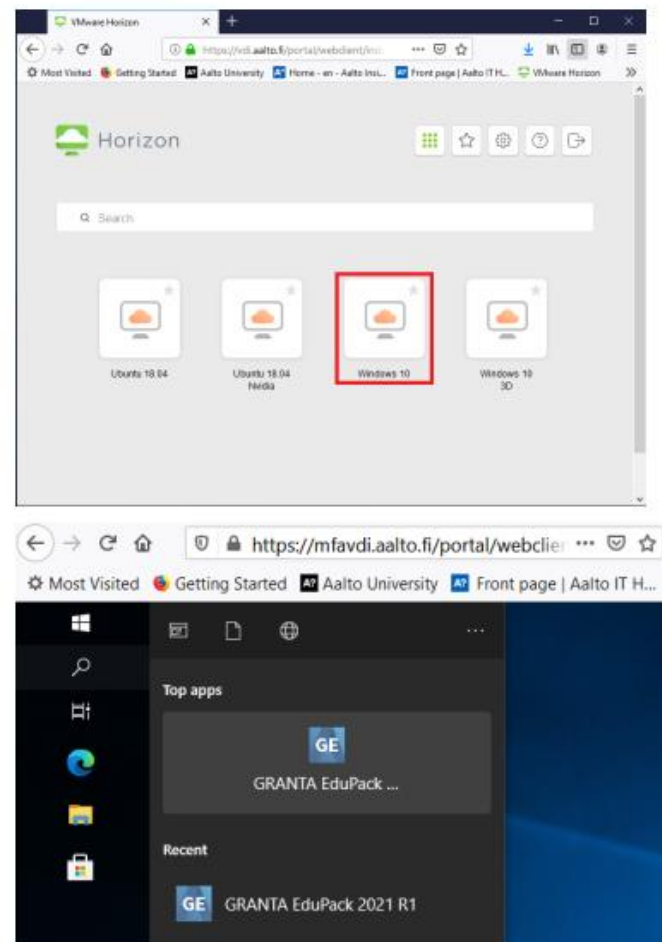
NOTE: Aalto user credentials log in is needed – **YOU NEED TO LOGIN TO AALTO VPN FIRST**

## Access to GRANTA EduPack

### Method 2 – Launch Application via Remote Access

Alternatively, you can get access remotely to the Windows classroom computers from your own device, using the VDI system via VMware Horizon Client [vdi.aalto.fi](https://vdi.aalto.fi) or [mfavdi.aalto.fi](https://mfavdi.aalto.fi) (Aalto user credentials log in is required). Check [Remote access to Windows classroom computers](#) for more information.

- GRANTA EduPack 2021 R1 application is available on virtual computer "Windows 10" on [vdi.aalto.fi](https://vdi.aalto.fi);





# GRANTA EduPack 2021R1

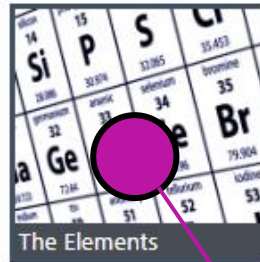
[quick start](#) [★ what's new](#) [+ add database](#) [extra databases](#)

## Databases

Introductory

### Level 1, general

- Schools, **1<sup>st</sup> year** college
- **69** materials, **74** processes



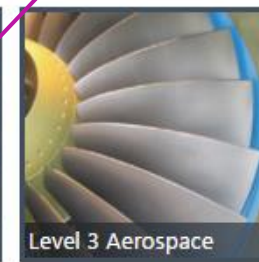
### Level 2, general

- **1<sup>st</sup>-3<sup>rd</sup> year** students of Engineering, Materials Science and Design
- **100** materials, **116** processes

Advanced

### Level 3, general

- **3<sup>rd</sup>-4<sup>th</sup> year, masters and research**
- **4169** materials, **247** processes





### The Elements Database

- Schools-University students
- **149** records, periodic table

# Changing database - different levels

## Level 2

 change database  first steps

1. Select a table

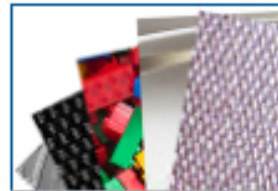
**MaterialUniverse** >

ProcessUniverse

Reference

Producers

2. Filter by subset





**All Materials**



**Foams**

## Level 3

 change database  first steps

1. Select a table

**MaterialUniverse** >

ProcessUniverse

Reference

Producers

Shape

Structural Sections

2. Filter by subset



**All Materials**



**Composites**

# Intuitive navigation

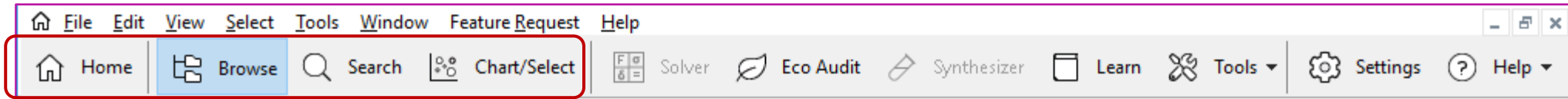
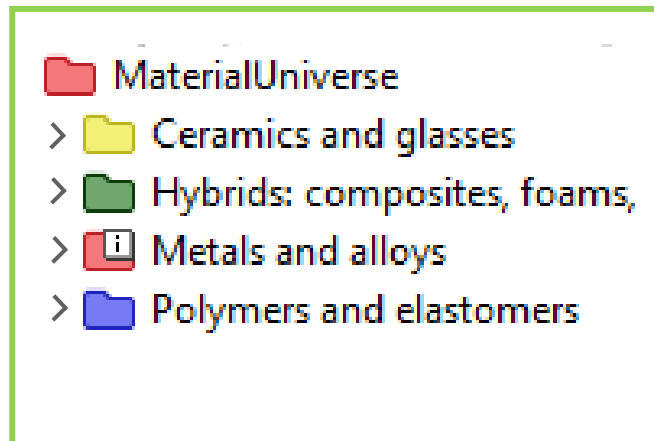


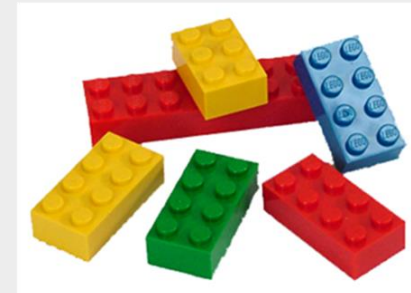
Table: **MaterialUniverse** ▼

Subset: **All materials** ▼



## Acrylonitrile-butadiene-styrene (ABS)

**The material.** 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.



### General properties

Density	i	1.01e3	-	1.21e3	kg/m <sup>3</sup>
Price	i	* 2.5	-	3	USD/kg
Date first used	i				1937

### Mechanical properties

Young's modulus	i	1.1	-	2.9	GPa
Yield strength	i	18.5	-	51	MPa
Tensile strength (elastic limit)	i	27.6	-	55.2	MPa
Elongation	i	1.5	-	100	% strain
Hardness - Vickers	i	5.6	-	15.3	HV
Fatigue strength at 10 <sup>7</sup> cycles	i	11	-	22.1	MPa
Fracture toughness	i	1.19	-	4.29	MPa.m <sup>1/2</sup>

and...

[Thermal properties](#)

[Electrical properties](#)

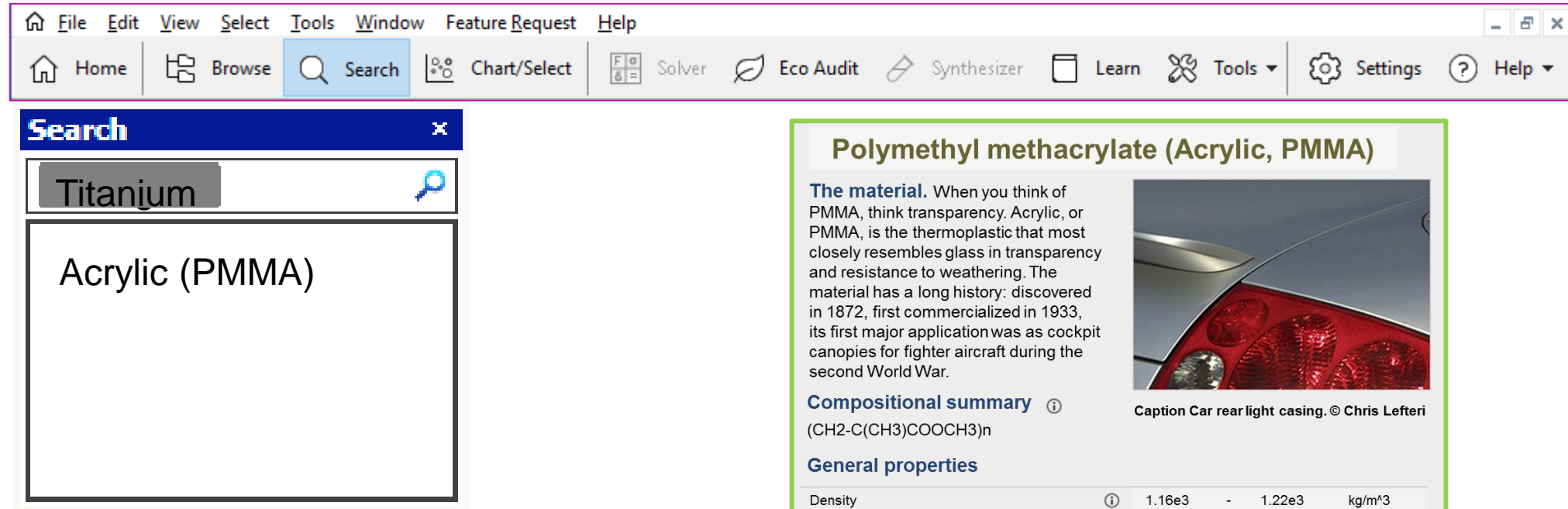
[Optical properties](#)

[Processability](#)

[Eco properties etc.](#)

[Links to Processes](#)

# The Search function



**Search**

Titanium

Acrylic (PMMA)

**Polymethyl methacrylate (Acrylic, PMMA)**

**The material.** When you think of PMMA, think transparency. Acrylic, or PMMA, is the thermoplastic that most closely resembles glass in transparency and resistance to weathering. The material has a long history: discovered in 1872, first commercialized in 1933, its first major application was as cockpit canopies for fighter aircraft during the second World War.

**Compositional summary** ⓘ  
 $(\text{CH}_2-\text{C}(\text{CH}_3)\text{COOCH}_3)_n$

**General properties**

Density	ⓘ	1.16e3	-	1.22e3	kg/m³
Price	ⓘ	* 3.14	-	3.74	USD/kg
Date first used	ⓘ				1933

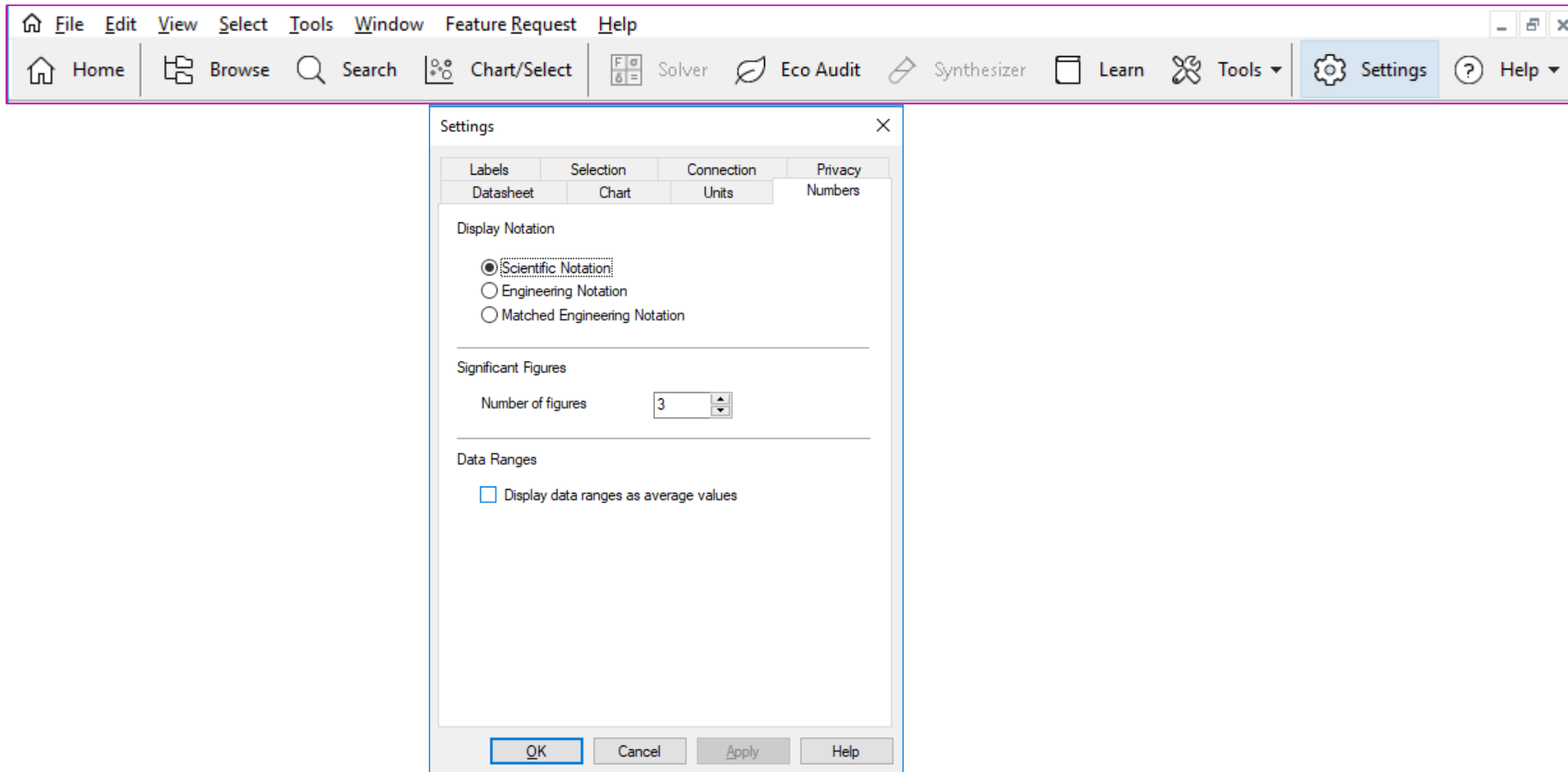
**Mechanical properties**

Young's modulus	ⓘ	2.24	-	3.8	GPa
Yield strength (elastic limit)	ⓘ	53.8	-	72.4	MPa
Tensile strength	ⓘ	48.3	-	79.6	MPa
Elongation	ⓘ	2	-	10	% strain
Hardness - Vickers	ⓘ	16.1	-	21.9	HV
Fatigue strength at 10 <sup>7</sup> cycles	ⓘ	* 15.2	-	32.7	MPa

**Caption** Car rear light casing. © Chris Lefteri

- Not sensitive to CASE but to spelling
- Searches all data-tables
- Operators AND, OR, NOT, \* ...
- Categorizes all results
- Highlights search term in datasheet

# Changing the data settings (units etc.)







# Accessing the science behind the properties








## Acrylonitrile-butadiene

**The material.** ABS (Acrylonitrile-butadiene) is a tough, resilient, and easily molded. It is although some grades can now be transparent. ABS can be given vivid colors. ABS-PVC alloys are used in standard ABS and, in self-extinguishing grades, for the casings of power tools.

### General properties

Density		1.01e3	-
Price		* 2.5	-
Date first used			-

### Mechanical properties

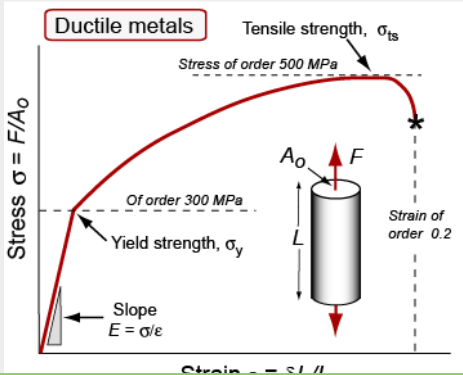
Young's modulus		1.1	-
Yield strength		18.5	-
Tensile strength (elastic limit)		27.6	-
Elongation		1.5	-
Hardness - Vickers		5.6	-
Fatigue strength at 10 <sup>7</sup> cycles		11	-
Fracture toughness		1.19	-

## Young's modulus

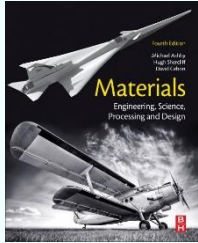
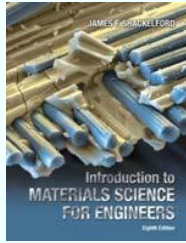
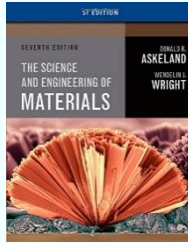
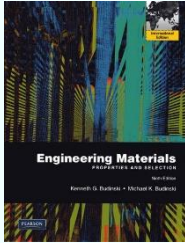
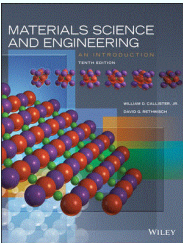
### Definitions and measurement.

Figure 1 shows a typical tensile stress-strain curve. The initial part is linear (Hooke's law), and it is elastic, meaning that the strain is recoverable – the material returns to its original shape when the stress is removed. Stresses above the elastic limit cause permanent deformation or fracture

**The origins of moduli.** Atoms are packed together, some weakly, some strongly. The stronger the bond, the higher is the modulus of the solid. Think of the bonds as springs (Figure 3). The atoms have an equilibrium spacing; a force pulls them a little, to a new spacing, but when it is released they return back to their original spacing.



Author	Title	Chapter
Callister	"Materials Science and Engineering: an Introduction"	6
Budinski	"Engineering Materials: Properties and Selection"	2
Askeland	"The Science and Engineering of Materials"	6
Shackelford	"Introduction to Materials Science for Engineers"	6
Ashby et al	"Materials: Engineering, Science, Processing, Design"	4, 5



# HELP, Video tutorials, ...

The screenshot shows the GRANTA EduPack Help interface. At the top, a software menu bar includes File, Edit, View, Select, Tools, Window, Feature Request, and Help. Below this is a secondary toolbar with icons for Home, Browse, Search, Chart/Select, Solver, Eco Audit, Synthesizer, Learn, Tools, Settings, and Help. A red arrow points from the 'Help' button in this toolbar to the 'Help' section of the main interface. The main interface has a dark header with the 'GRANTA EduPack Help' title and a search bar. A left sidebar lists navigation topics: Welcome, Bienvenue, Willkommen, Bienvenido, 欢迎, New for 2021 R1, Getting started, Browse and Search, Chart and selection stages, Tools, About data, Settings, and Acknowledgements, copyright, and licensing. The main content area features the Ansys logo, the text 'GRANTA EDUPACK', and a welcome message for the 2021 R1 version. It provides a brief overview of the software's purpose and lists key features: Browse and visualize information, Quickly search for reliable data, Select materials to optimize design, Estimate life cycle environmental impact, Use models to predict properties and costs, and Learn about material properties using science notes and an online glossary. It also mentions that video tutorials and quick start exercises are available. On the right side, a red-bordered box contains a detailed table of contents with links to various help topics, categorized by function: CES EduPack overview (in multiple languages), Browse / Search, Select, Tools, Databases, and Installation and Help. Red arrows indicate the flow from the toolbar's Help button to the Help section and then to the detailed table of contents.

GRANTA EduPack Help

Search

**Ansys**

GRANTA EDUPACK

Welcome | Bienvenue | Willkommen | Bienvenido | 欢迎

Welcome to the Help for GRANTA EduPack 2021 R1

GRANTA EduPack is designed to support the teaching of materials and processes across all levels of study.

- Browse and visualize information about materials and processes.
- Quickly search for reliable data.
- Select materials and processes to optimize your design.
- Estimate the life cycle environmental impact of a product during early-stage design.
- Use models to predict properties and costs.
- Learn about material properties using science notes and an online glossary.

Video tutorials and Quick start exercises are available to help you quickly get the most out of GRANTA EduPack.

Find out how Keyboard shortcuts and accessibility make GRANTA EduPack easier to use and more accessible to everyone.

**CES EduPack overview Languages**

- CES EduPack overview [8:13]
- CES EduPack overview in French [8:56]
- CES EduPack overview in Spanish [8:46]
- CES EduPack overview in German [8:43]
- CES EduPack overview in Chinese [8:31]

**Browse / Search**

- How to navigate with Browse (part 1 of 3) [3:17]
- How to navigate with Browse (part 2 of 3) [4:29]
- How to navigate with Browse (part 3 of 3) [3:11]
- Make the most of Advanced Search [3:28]
- How to select materials [2:57]

**Select**

- How to select materials [2:57]
- Create Charts [5:31]
- Format your Charts [5:37]
- Get the most out of Charts [4:02]
- Limit your material choices [3:34]
- Discover the Tree [2:30]
- Explore and combine stages [3:34]

**Tools**

- Add your own records [3:18]
- Create your customized Subsets [3:44]
- Personalize your Settings [1:50]
- Discover the Eco Audit tool [7:17]
- Learn more about the Eco Audit Enhanced tool [4:53]
- Explore Hybrid Synthesizer features [4:32]
- Estimate the cost of a part [5:00]

**Databases**

- Introductory Elements database [3:01]
- Introductory Architecture database [3:10]
- Introductory and advanced Bioengineering db [4:03]
- Learn more about the advanced Level 3 database [3:50]
- Advanced Aerospace database [2:48]
- Advanced Sustainability database [6:03]
- Advanced Polymer database [3:25]
- Advanced Eco Design database [2:50]

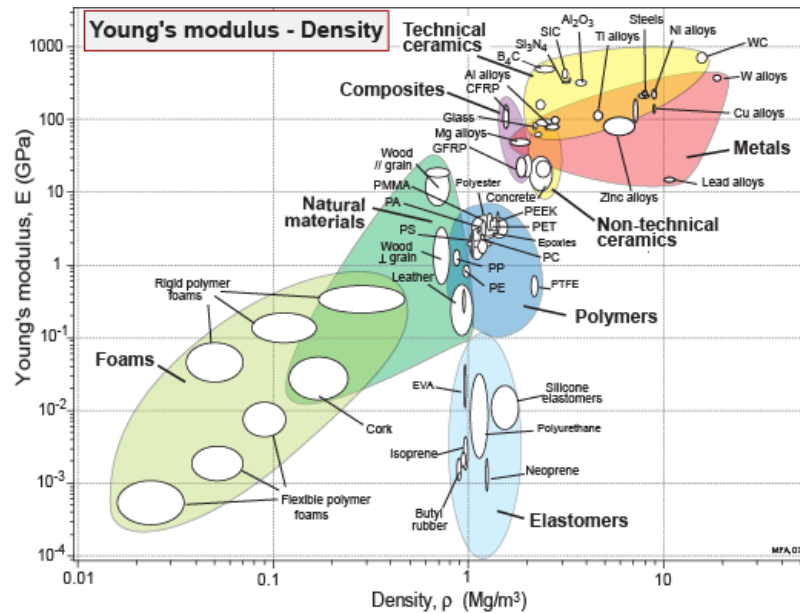
**Installation and Help**

- Installation and support(part 1 of 2) [3:10]
- Installation and support(part 2 of 2) [2:02]
- Find all answers at Help Online [2:42]
- Explore Learn Online [2:20]

# Creating charts



# Charts



- Exploring relationships: property charts
- Making charts
- Custom subsets, adding your own materials
- Report writing

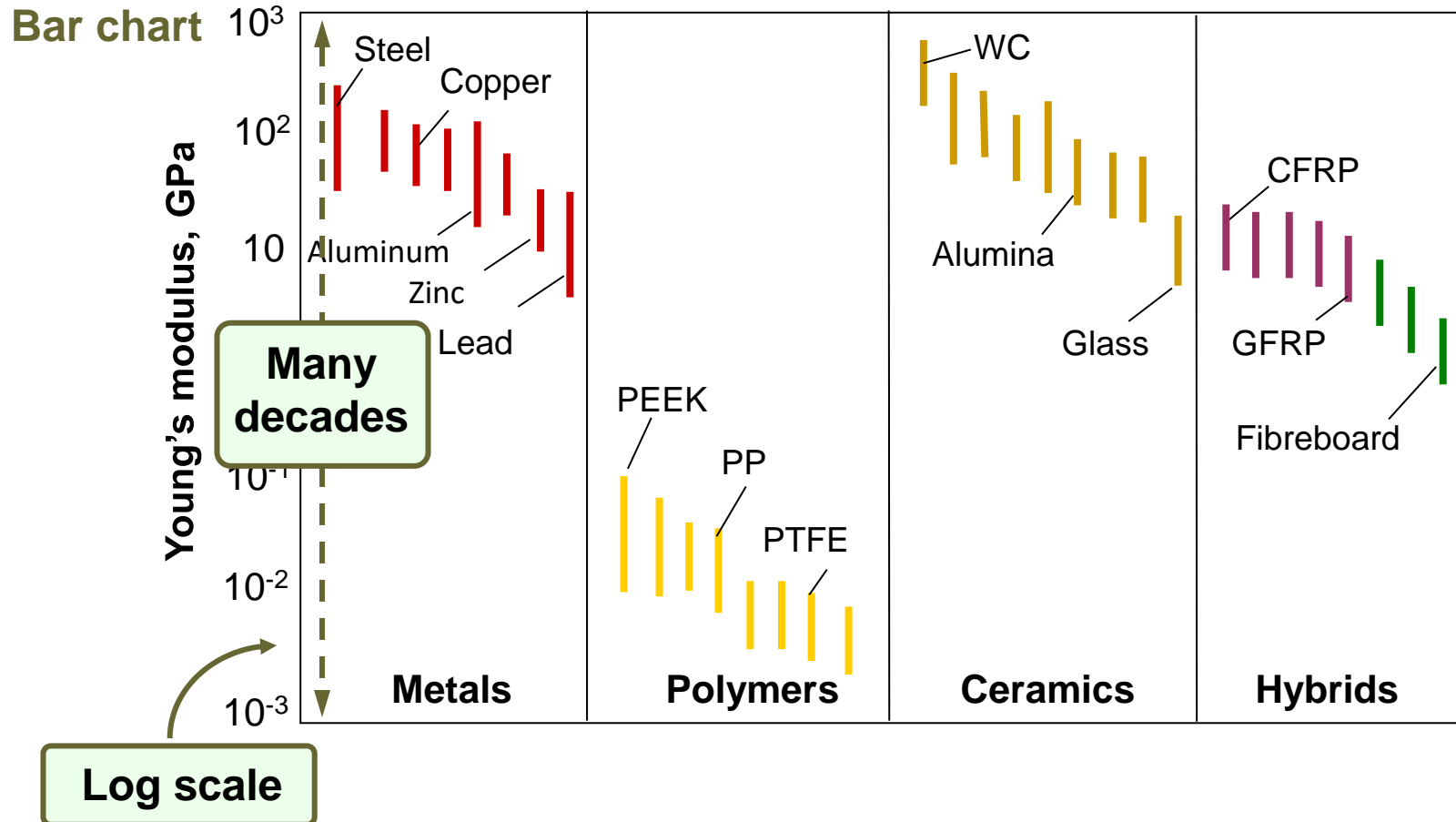
# Bar charts

Data sheets = numbers, words

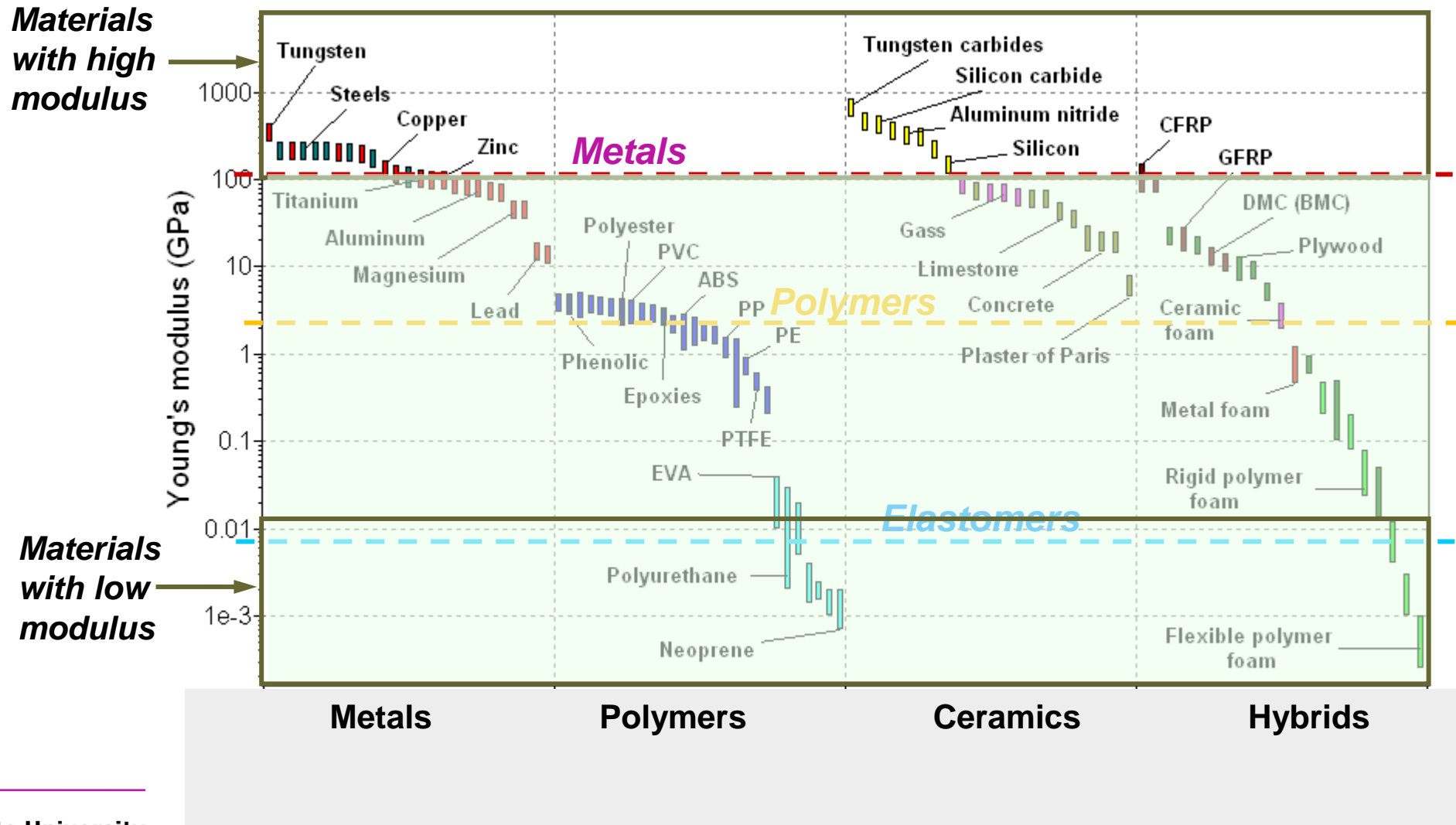
We want **meaning**



Property charts

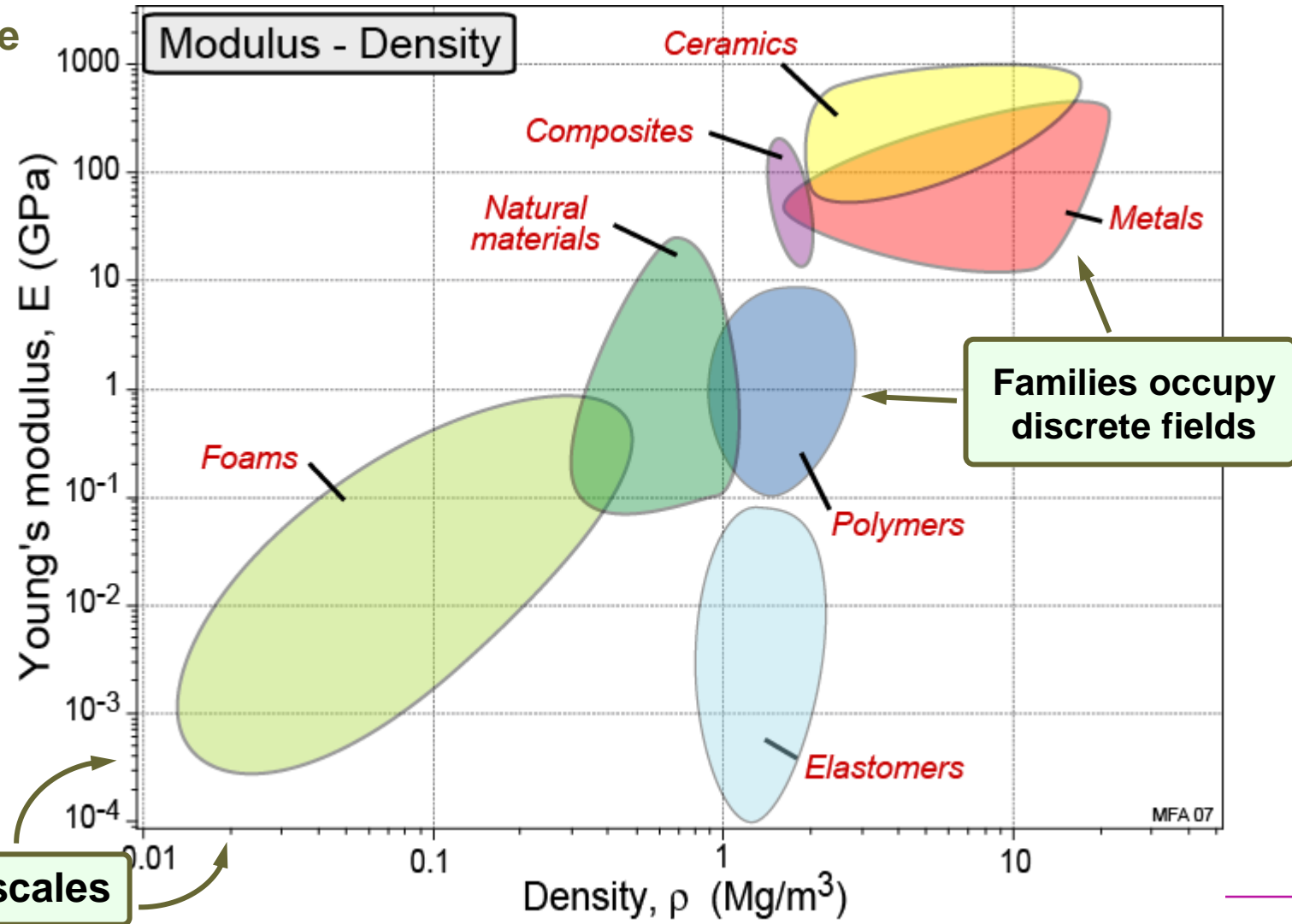


# Bar-chart created with *GRANTA EduPack*

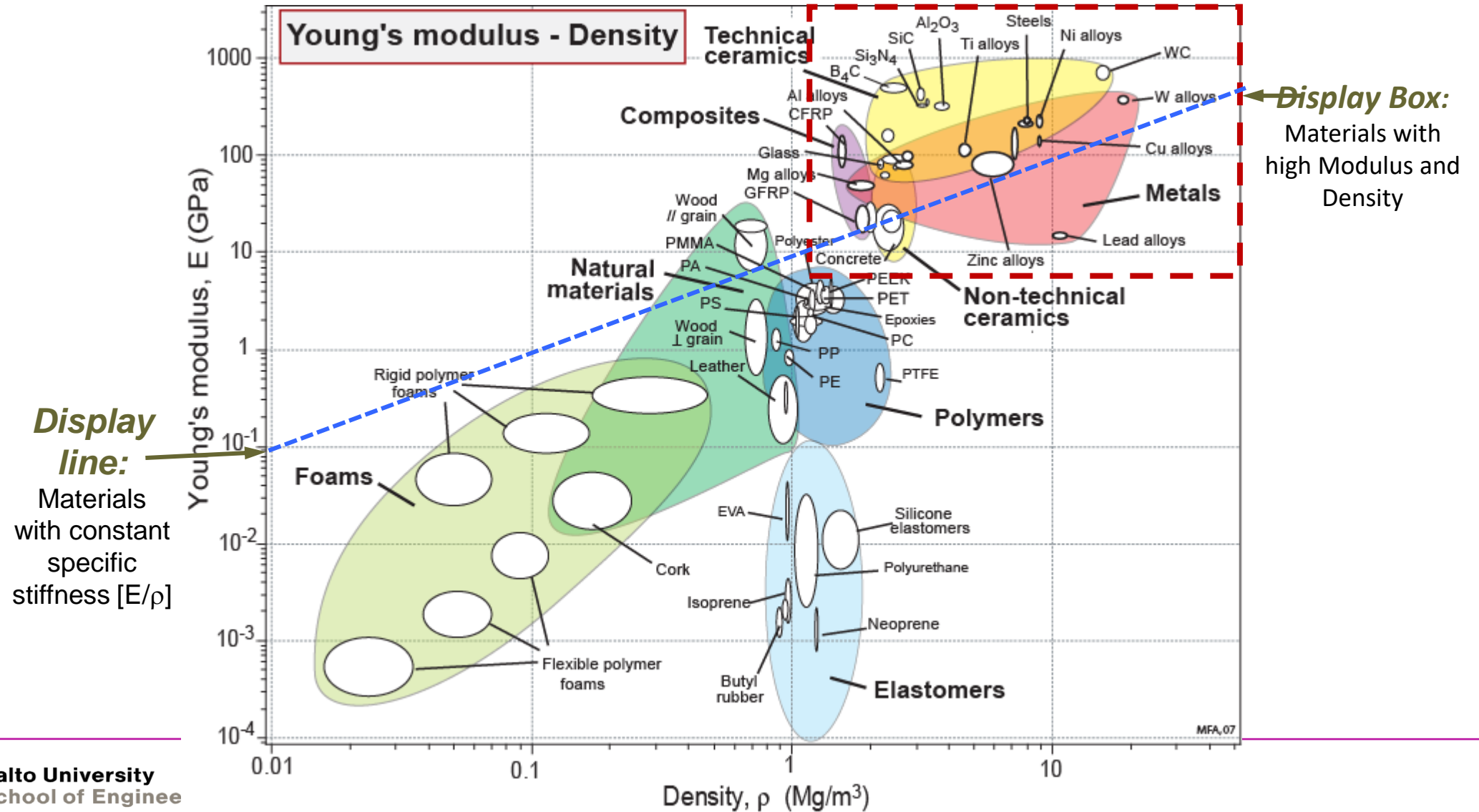


# Bubble charts

Bubble  
chart



# Bubble chart created with CES EduPack

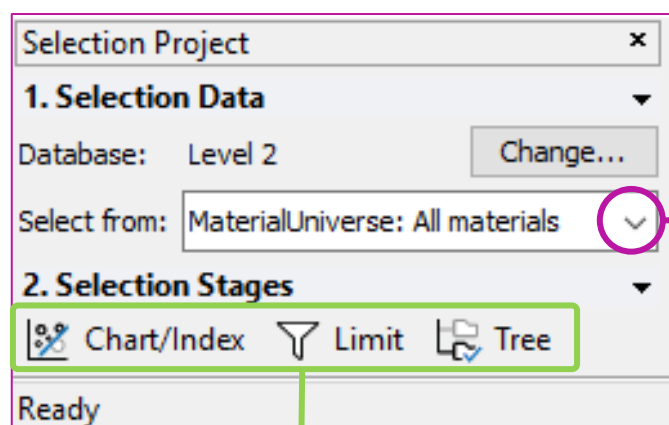
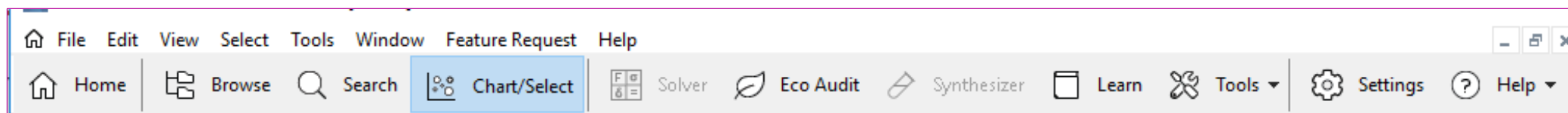


# Table chart

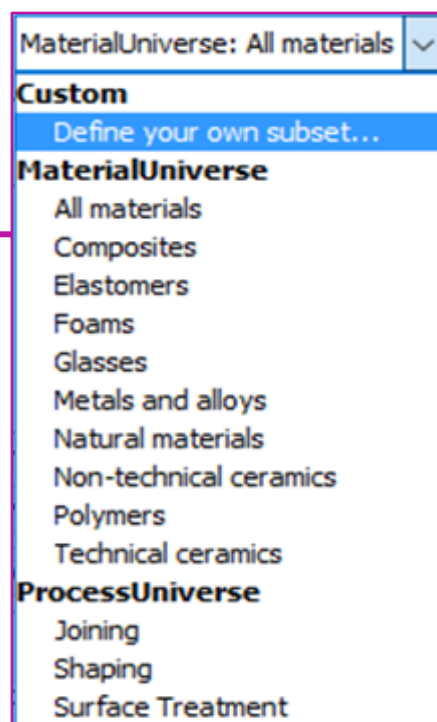
## Discrete data

Composites	Plastics
Foams	Non-technical ceramics
Metals	Technical ceramics
Elastomers	Natural materials

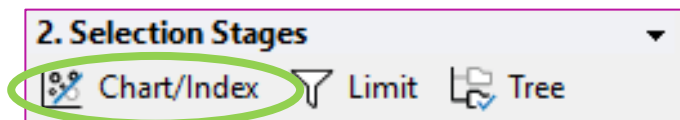
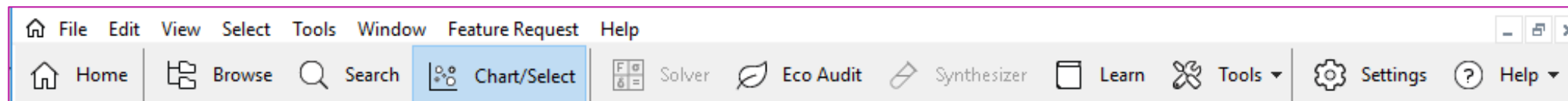
# Creating charts for selection



Plotting and selection tools



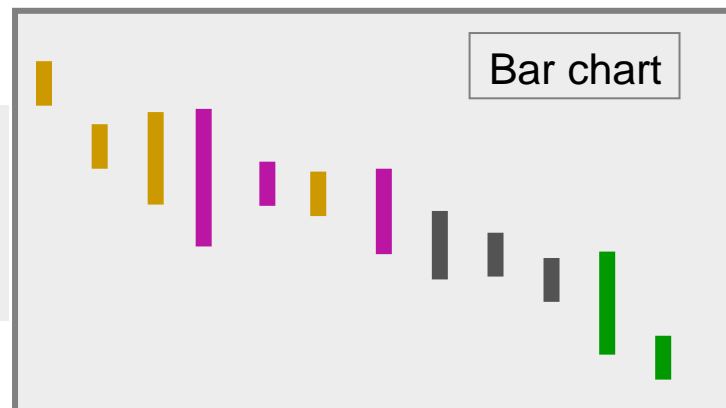
# Creating charts for selection



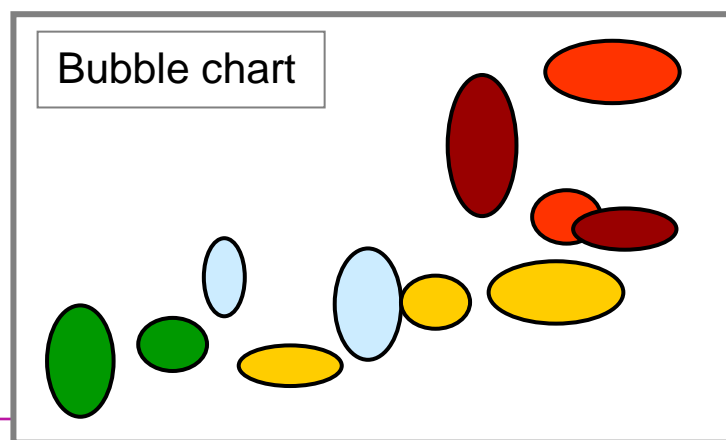
Choose:

X-Axis	Y-Axis
<b>List of properties</b>	
<ul style="list-style-type: none"><li>▪ Density</li><li>▪ Yield strength</li><li>▪ Young's modulus</li><li>▪ etc.</li></ul>	

Property



Property 1



Property 2



# Creating advanced charts for selection

The screenshot displays the software's main menu and a workflow for creating charts. The menu bar includes File, Edit, View, Select, Tools, Window, Feature Request, and Help. Below it, a secondary bar contains Home, Browse, Search, Chart/Select (highlighted), Solver, Eco Audit, Synthesizer, Learn, Tools, Settings, and Help. A dropdown menu titled '2. Selection Stages' is open, showing 'Chart/Index' (circled in green), 'Limit', and 'Tree'. A green arrow points from 'Chart/Index' to a 'Choose:' section. This section has tabs for 'X-Axis' and 'Y-Axis', with 'Y-Axis' selected. Below the tabs is a 'List of properties' box containing 'Density', 'Yield strength', 'Young's modulus', and 'etc.'. A green box labeled 'Advanced' is highlighted in the list, with a green arrow pointing to a chart area. The chart area is divided into two sections: 'Bar chart' and 'Bubble chart'. The 'Bar chart' section shows a vertical bar chart with bars of various colors (yellow, purple, orange, green, grey). The 'Bubble chart' section shows a scatter plot with bubbles of various colors (green, cyan, grey, red). A vertical label 'Modulus / Density / DensityModulus / Density' is positioned to the left of the bubble chart. Below the bubble chart, a box labeled 'Yield strength / Density' contains a list with 'etc'.

2. Selection Stages

Chart/Index Limit Tree

Choose:

X-Axis Y-Axis

List of properties

Advanced

- Density
- Yield strength
- Young's modulus
- etc.

Bar chart

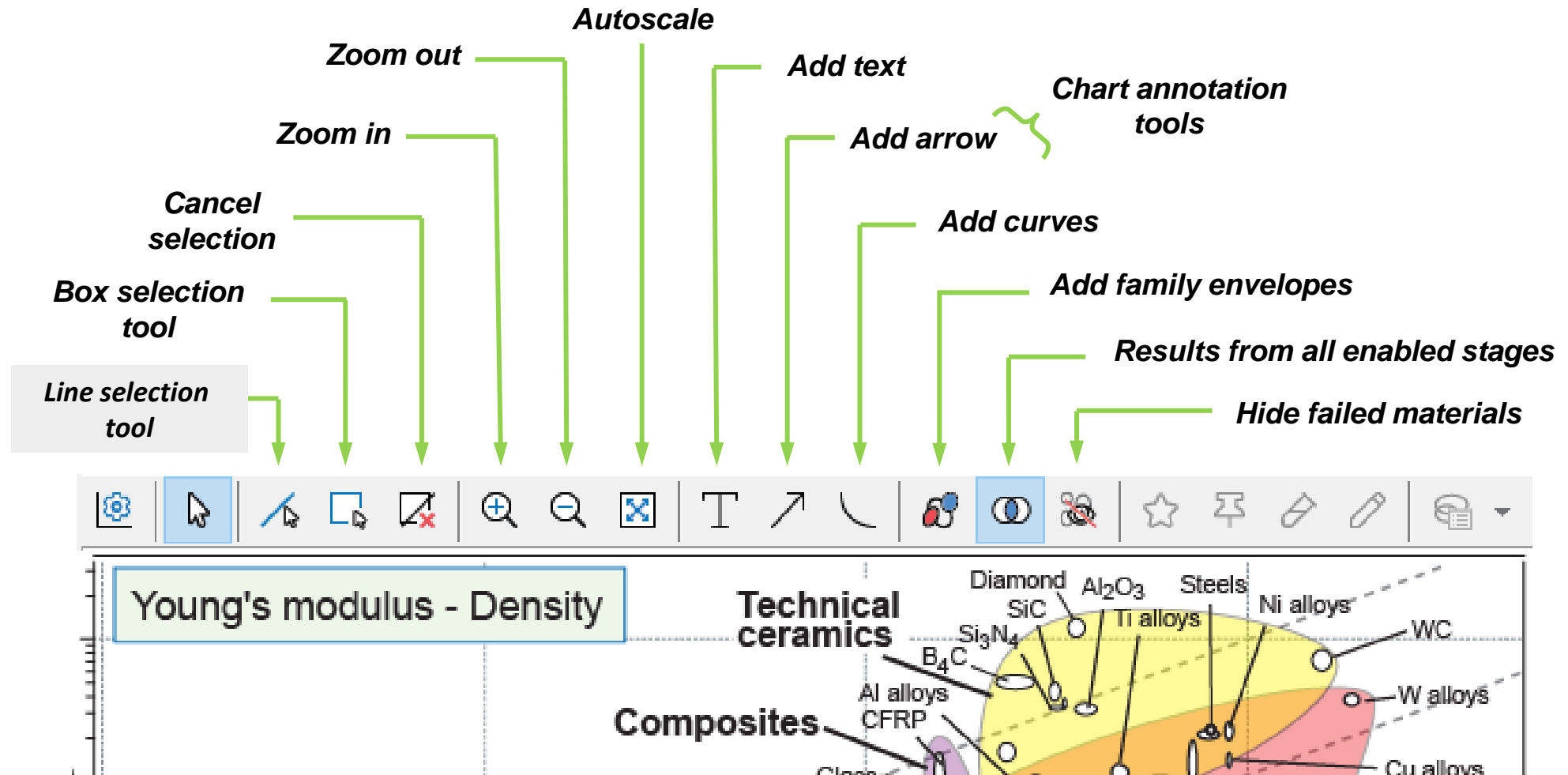
Bubble chart

Modulus / DensityModulus / Density

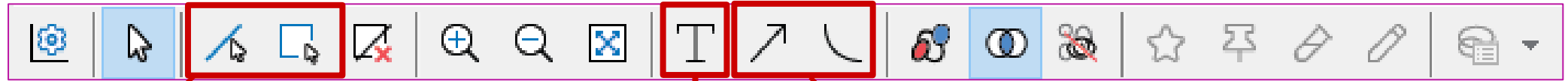
Yield strength / Density

- etc

# The chart-management tool bar



# The line, box and curve tools



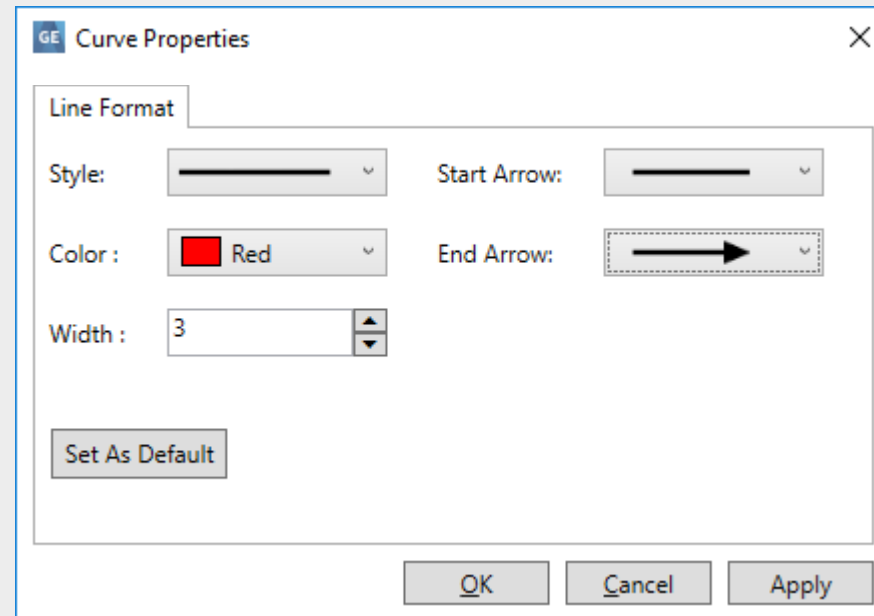
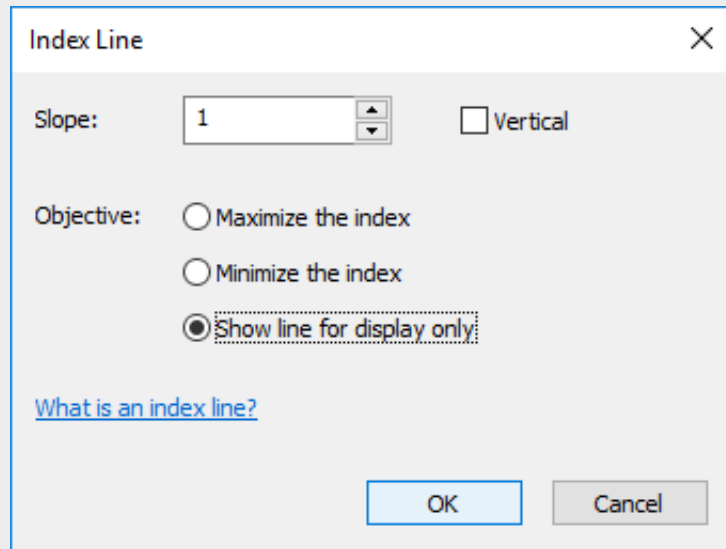
Add **boxes** and **lines**

Add **text** to chart

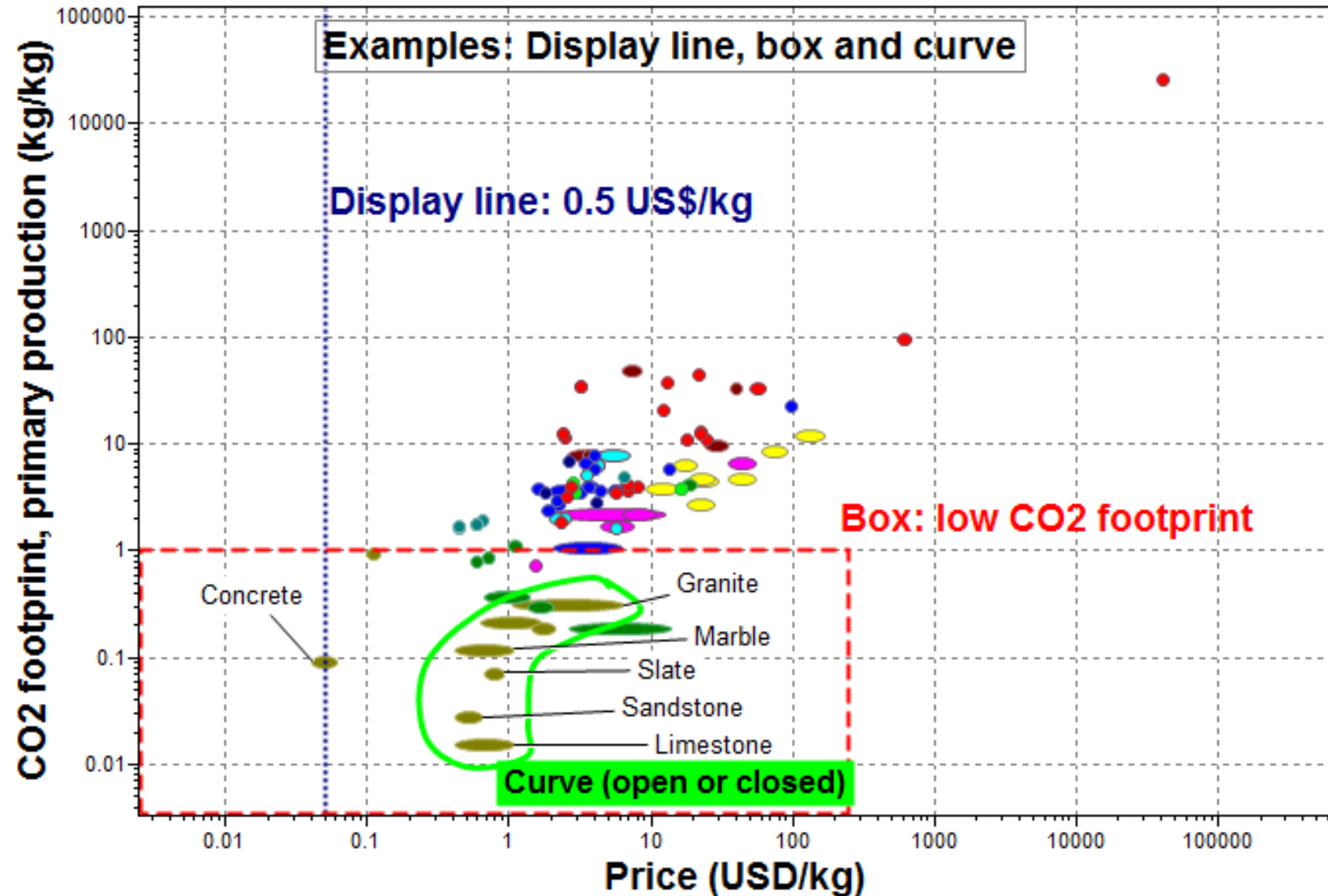
Display **curves** and **arrows**

For annotation, select display only:

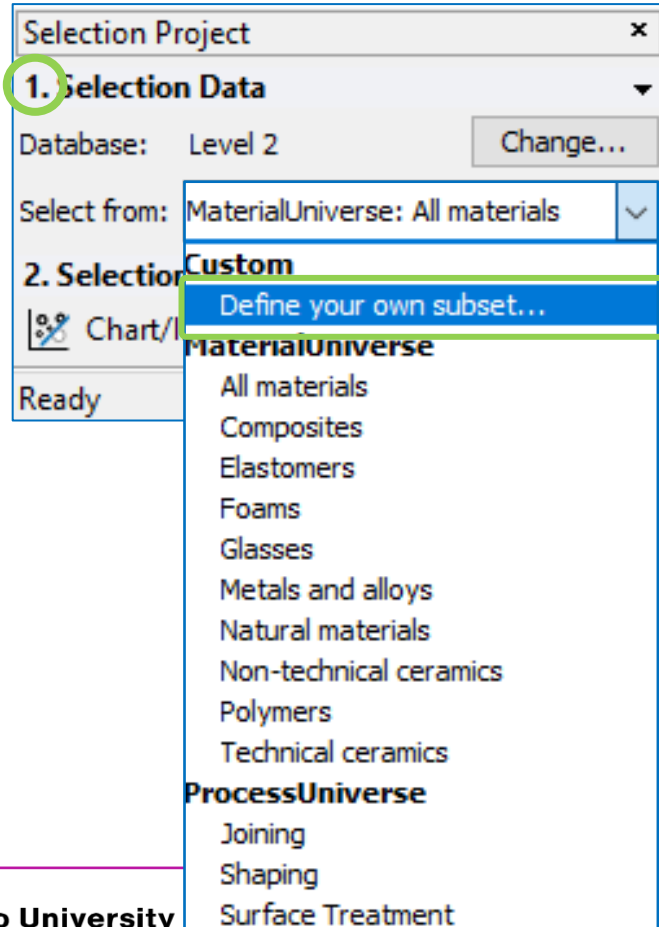
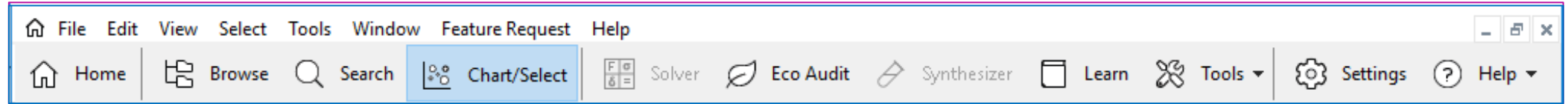
Right-click on line, box or curve to format:



# Annotation tools in charts



# Custom subsets



## Custom subset

**Selection table:**

MaterialUniverse

**Initial subset:**

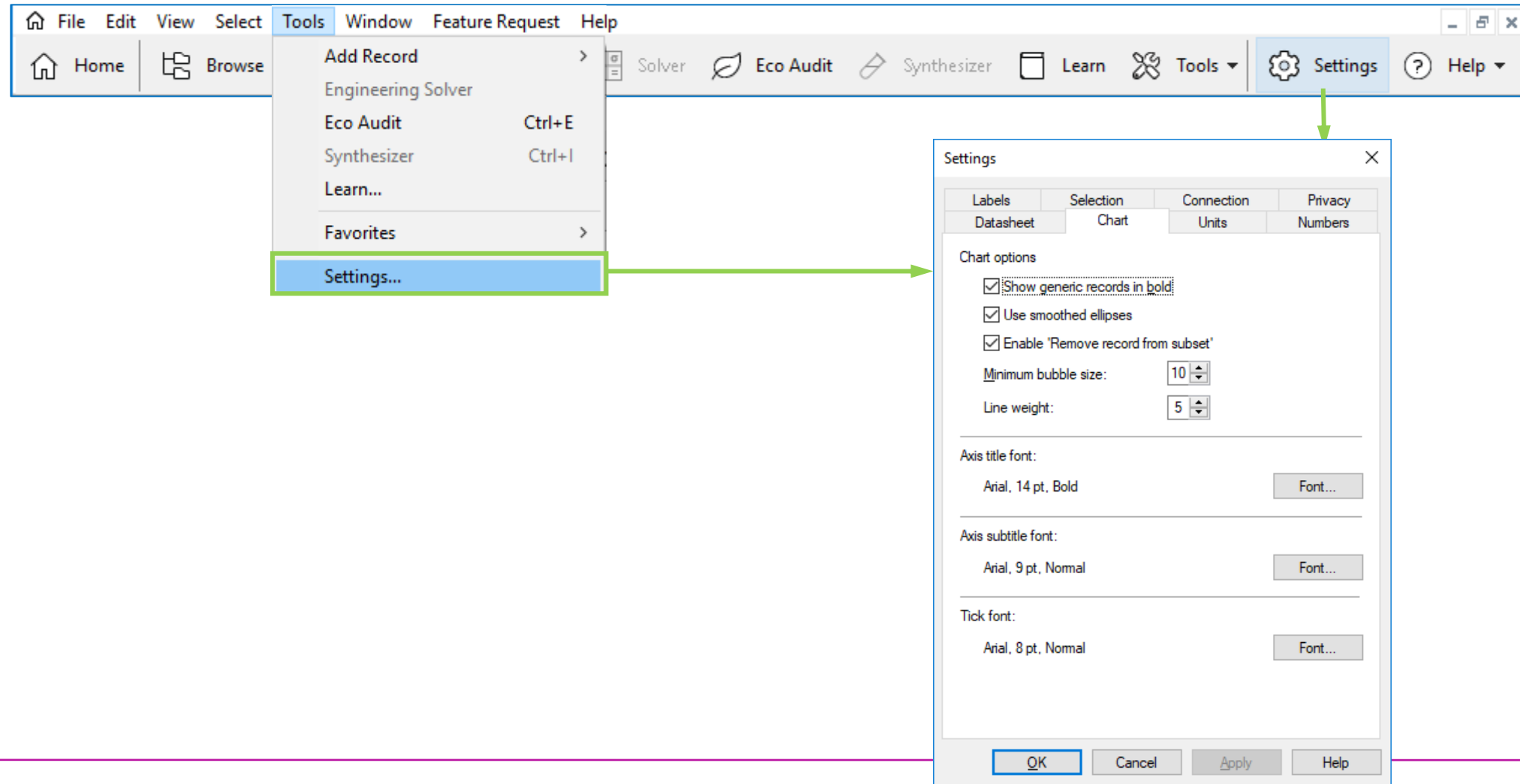
All materials

**Selection attributes:**

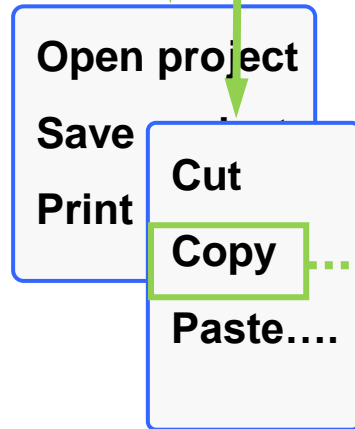
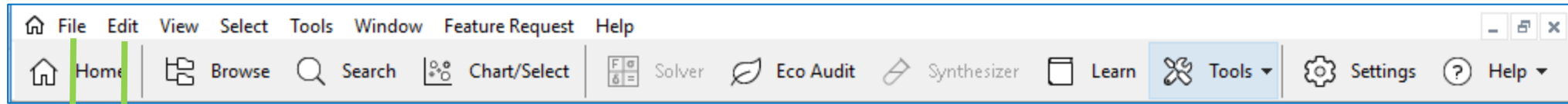
All properties

- 
- The diagram shows a tree view of the 'MaterialUniverse' folder. The 'MaterialUniverse' folder is highlighted with a red box. It contains several subfolders, each with a colored icon and a checkbox:
- ☐ Ceramics and glasses (yellow icon)
  - ☐ Electrical components (Eco Audit) (grey icon)
  - ☐ Hybrids: composites etc (green icon)
  - ☒ Metals and alloys (red icon with an 'i' in a circle)
  - ☒ Polymers and elastomers (blue icon)

# Changing the Chart settings (labels etc.)



# Saving projects, report writing



Clip-board

To WORD

For best results  
Paste Special -  
Device Independent Bitmap.

## Paste

**Acrylonitrile butadiene styrene (ABS)**

Description  
Image

Caption  
1. ABS pellets. © Shutterstock 2. ABS allows detailed moldings, accepts color well, and is tough enough to survive the worst that children can do to it. © Gettyimages

The material  
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 tougher than standard ABS and, in self-extinguishing grades, are used for the casings of power tools.

Compositional summary  
Block terpolymer of acrylonitrile (15-35%), butadiene (5-30%), and styrene (40-60%).

General properties

Density	1.01e3	-	1.21e3
Price	2.5	-	3
Date first used	1937	-	

Mechanical properties

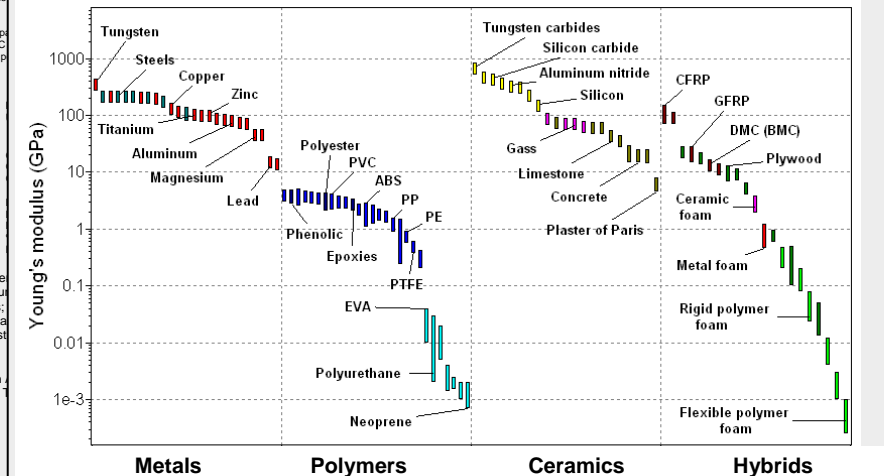
Young's modulus	1.1	-	2.9
Shear modulus	0.319	-	1.03
Bulk modulus	3.8	-	4
Poisson's ratio	0.391	-	0.422
Yield strength (elastic limit)	18.5	-	51
Tensile strength	27.6	-	55.2
Compressive strength	31	-	86.2
Elongation	1.5	-	100
Hardness - Vickers	5.6	-	15.3

Typical uses  
Safety helmets; camper tops; automotive instrument panels and other interior fittings; home-security devices and housings for small appliances; commercial business machines; plumbing hardware; automobile grilles; wheel covers; refrigerator liners; luggage shells; tote trays; mower shrouds; boat hulls; lawnmower recreational vehicles; weather seals; glass beading; refrigerator breaker switch waste-vent (DWV) systems.

Tradenames  
Clardex, Comalloy, Cycogel, Cycolac, Hanalac, Lastilac, Lupos, Lustran, Novodur, Polyfabs, Polyfac, Porene, Ronfalin, Sinkral, Terluran, Toyolac, etc.

Links  
Reference  
ProcessUniverse  
Producers

## Copy - Paste



# Making your own records

The screenshot shows the software interface with the 'Tools' menu open, highlighting the 'Add Record' option. A green arrow points from the 'Add Record' menu item to the 'Add Record' dialog box. The dialog box contains fields for 'Name' (My material) and 'Notes'. Below these are sections for 'General properties', 'Mechanical properties', and 'Thermal properties'. The 'Mechanical properties' section includes fields for Young's modulus (230, 280 GPa), Yield strength (1000, 1200 MPa), Hardness, and Fracture toughness. The 'Thermal properties' section includes fields for Max service temp (30, 33 C) and T-conductivity. A 'Table' dropdown menu is also visible, showing 'MaterialUniverse' as the selected option.

Or, right click on a chart to add limited data to it...

**User Defined Record - MaterialUniverse**

**Record Details**

Name:  Color: Orange

Name cannot be empty

Notes:

\* Records are not added to the database, but saved with the project file.

**Selection Attributes**

	Minimum	Maximum	
Density	<input type="text"/>	<input type="text"/>	kg/m <sup>3</sup>

To add properties, include the attribute in your Selection Project first.

OK Cancel

**General properties**

**Mechanical properties** Min. Max.

Young's modulus	<input type="text" value="230"/>	<input type="text" value="280"/>	GPa
Yield strength	<input type="text" value="1000"/>	<input type="text" value="1200"/>	MPa
Hardness	<input type="text"/>	<input type="text"/>	Vickers
Fracture toughness	<input type="text"/>	<input type="text"/>	MPa.m <sup>1/2</sup>

**Thermal properties** Min. Max.

Max service temp	<input type="text" value="30"/>	<input type="text" value="33"/>	C
T-conductivity	<input type="text"/>	<input type="text"/>	W/m.K
etc			

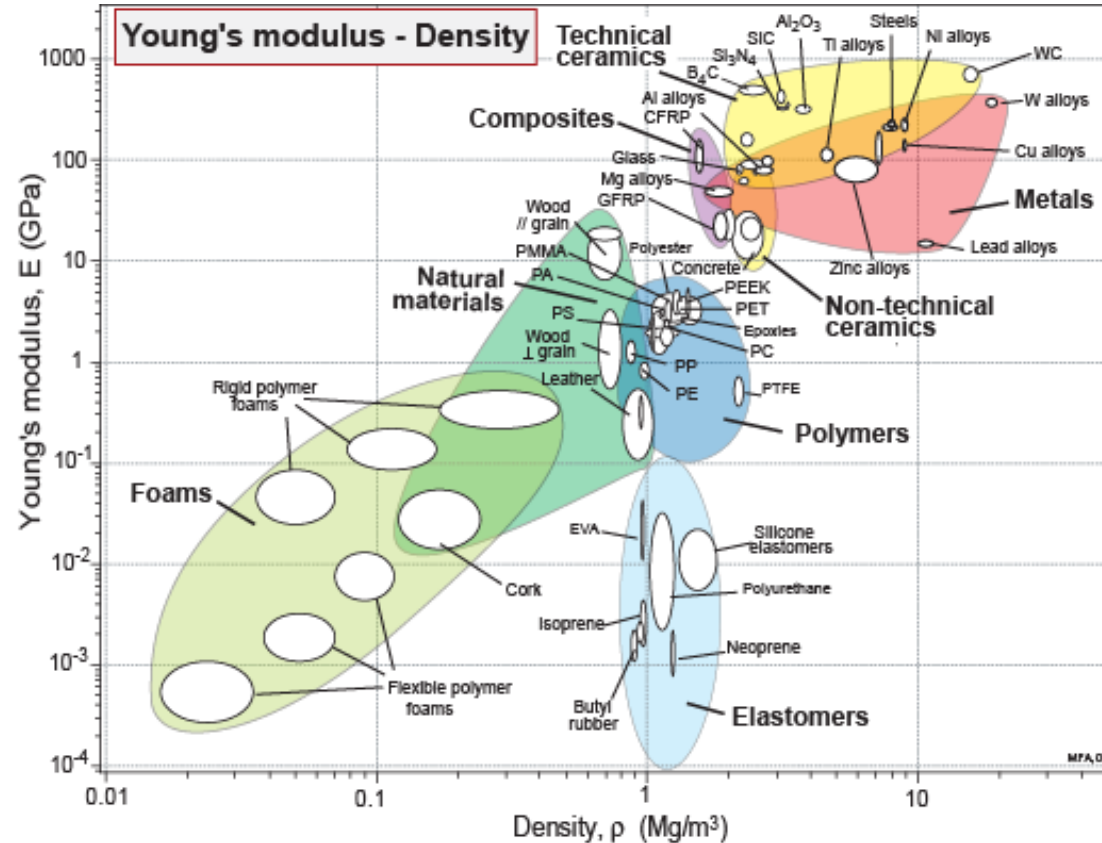
Table: MaterialUniverse

- MaterialUniverse
- ProcessUniverse
- Producers
- Reference



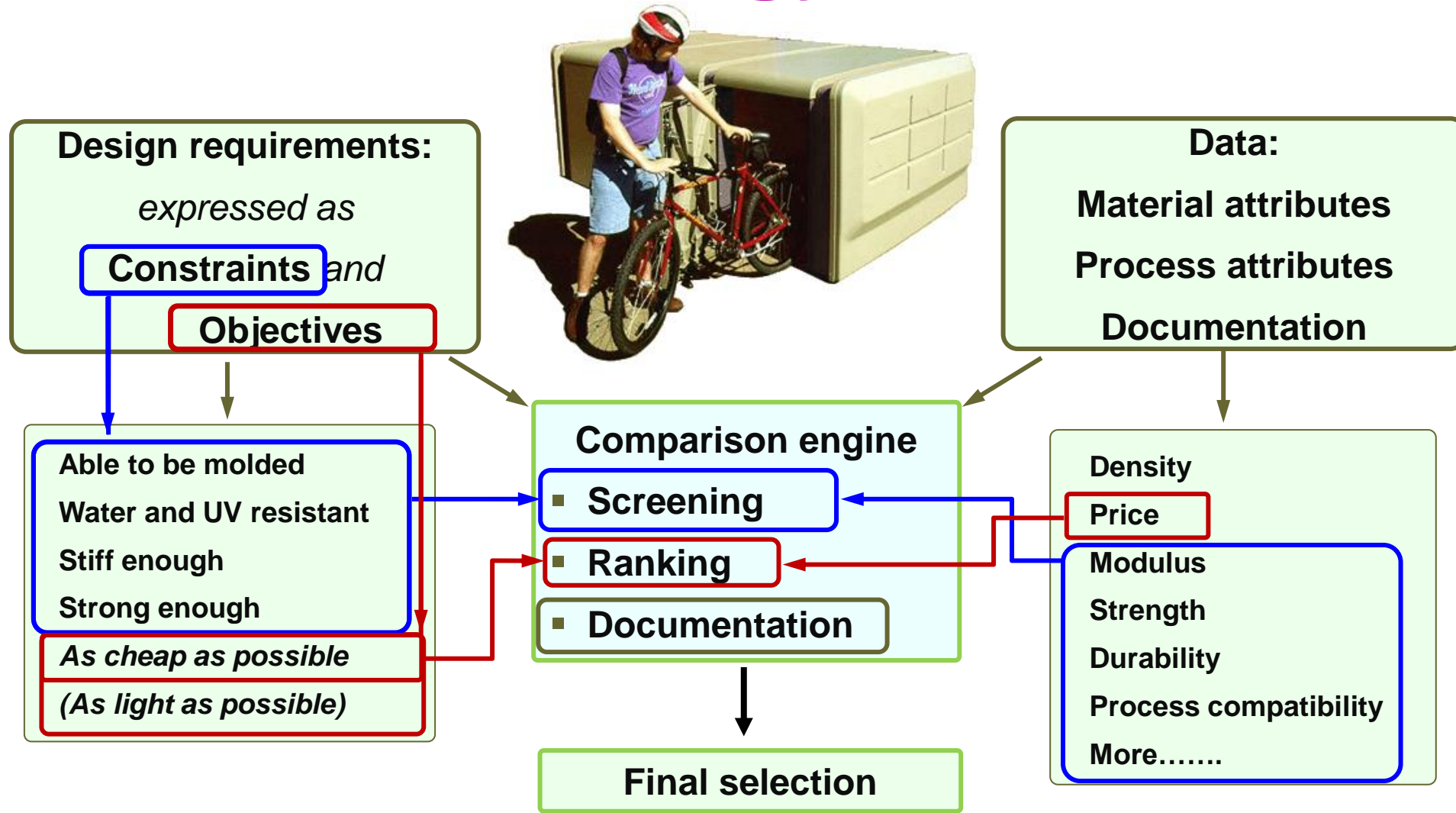
# Make selection

# Selection procedure



- Translation: deriving material index
- Screening: applying attribute limits
- Ranking: indices on chart
- Documentation

# The selection strategy: materials



# Translation is important

*Translation: “express design requirements as constraints and objectives”*

## Design requirements

### Typical Constraints

*What essential conditions must it meet ?*

- ***Be strong enough***
- ***Conduct electricity***
- ***Tolerate 250°C***
- ***Be able to be cast***

### Typical Objectives

*What measure of performance is to be maximized or minimized ?*

- ***Mass***
- ***Volume***
- ***Eco-impact***
- ***Cost***

*Screening: “use constraints to eliminate materials that can’t do the job”*

# What is a “material index”?

Component performance is limited by either:

- a single material property e.g. **tensile strength**,
- a material property group, e.g. **modulus / density**,

$$\sigma_{ts}$$

$$E / \rho$$

*The  
**material index**  
for the design*

## To maximize performance:

- First apply all **constraints**
- Then select materials with the **biggest or smallest index**

# Simple one-property indices



Protective visor  
for motorcyclists

## Design requirement

### Constraints

- Transparent - of optical quality
- Able to be molded

### Objective

- As tough as possible –  
maximize fracture toughness  $K_{1c}$

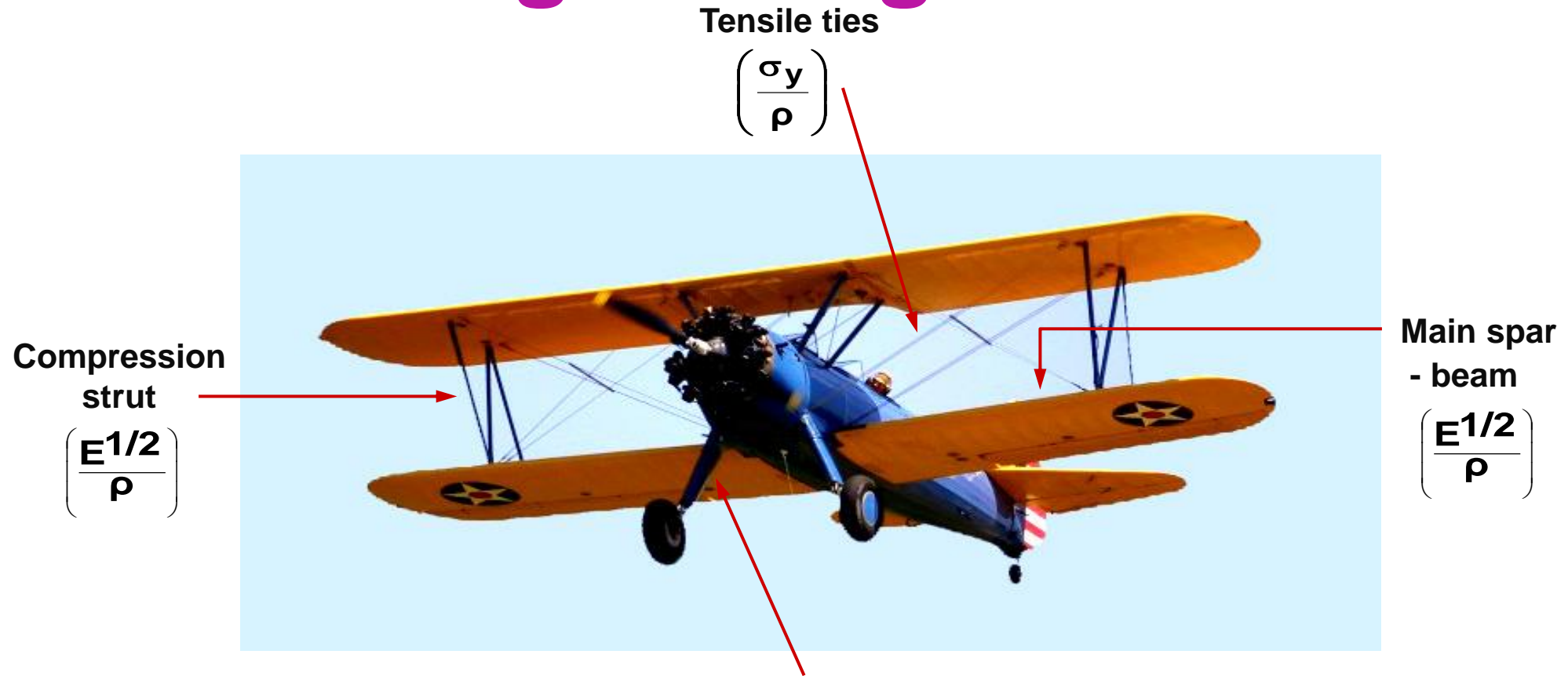
The material index: choose material with largest  $K_{1c}$

### Alternative objective

- As cheap as possible –  
minimize material cost  $C_m$

The material index: choose material with smallest  $C_m$

# Minimum weight design - indices



Undercarriage - bending  
and compression

$$\left( \frac{\sigma_y^{2/3}}{\rho} \right)$$

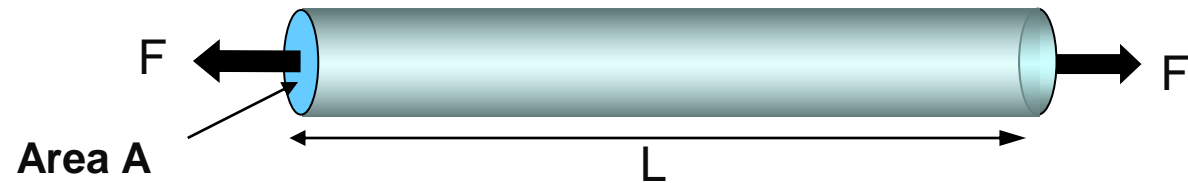
$E$  = Young's modulus  
 $\rho$  = Density  
 $\sigma_y$  = Yield strength

# Index for a strong, light tie-rod

Strong tie of length  $L$  and minimum mass

Function

*Tie-rod*



Constraints

- *Length  $L$  is specified*
- *Must not fail under load  $F$*

*Equation for constraint on A:*

$$F/A < \sigma_y$$

Objective

*Minimize mass  $m$ :*

$$m = A L \rho$$

$m$  = mass  
 $A$  = area  
 $L$  = length  
 $\rho$  = density  
 $\sigma_y$  = yield strength

Performance metric

$$m = F L \left( \frac{\rho}{\sigma_y} \right)$$

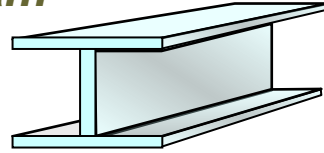
Chose materials with largest  $M = \left( \frac{\sigma_y}{\rho} \right)$



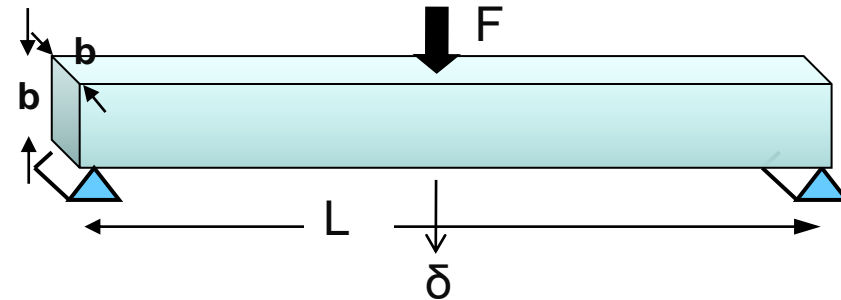
# Index for a stiff, light beam

Function

**Beam**



Stiff beam of length  $L$  and minimum mass



Square section,  
area  
 $A = b^2$

Constraints

- Length  $L$  is specified
- Must have bending stiffness  $> S^*$

Equation for constraint on  $A$ :

$$S = \frac{F}{\delta} = \frac{CEI}{L^3} = \frac{CEA^2}{12L^3}$$

Objective

Minimize mass  $m$ :

$$m = AL\rho$$

$m$  = mass  
 $A$  = area  
 $L$  = length  
 $\rho$  = density  
 $S$  = stiffness ( $F/\delta$ )  
 This beam:  $\delta = FL^3/CEI$   
 $C$  = constant (here, 48)  
 $E$  = Young's modulus  
 $I$  = second moment of area  
 ( $I = b^4/12 = A^2/12$ )

Performance  
metric

$$m = \left( \frac{12L^5 S^*}{C} \right)^{1/2} \left( \frac{\rho}{E^{1/2}} \right)$$

Chose materials  
with largest

$$M = \left( \frac{E^{1/2}}{\rho} \right)$$

# Material index

Component performance is limited by either:

- one single material property e.g. tensile strength,  $\sigma_{ts}$
  - a group of material properties. modulus / density,  $E / \rho$
- material index for the design*

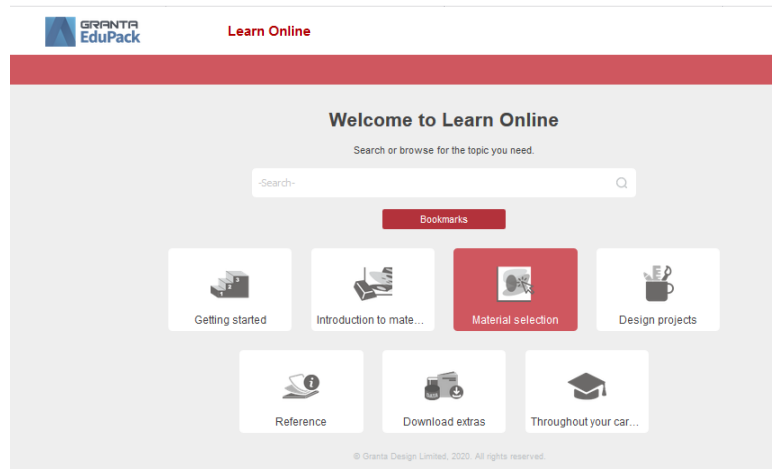
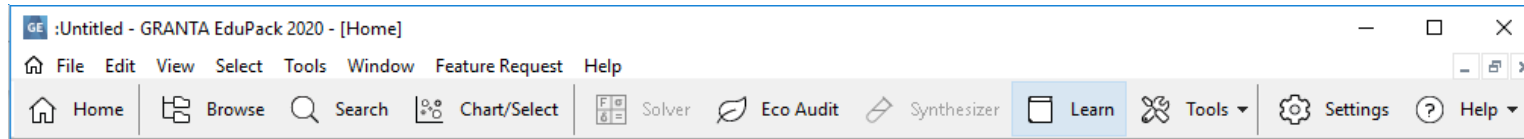


Table of performance indices

Click the buttons to view a table of relevant performance indices.

	Mass	Cost	Embodied Energy	CO <sub>2</sub> Footprint
Stiffness-limited design	kg	\$	H <sub>m</sub>	CO <sub>2</sub>
Strength-limited design	kg	\$	H <sub>m</sub>	CO <sub>2</sub>

Vibration-limited design    Damage-tolerant design    Abrasion-resistant design    Thermo-mechanical design

Electro-mechanical design    Vapour barrier design    Strength-limited design to optimize performance

To maximize performance:

- First apply all **constraints**
- Then select materials with the **extreme index**

# Screening with a CHART STAGE

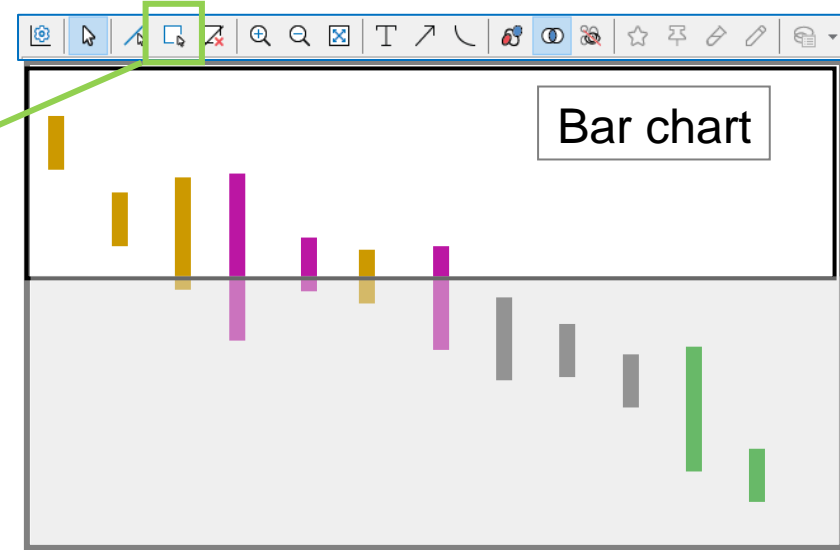
## 2. Selection Stages

Chart/Index Limit Tree



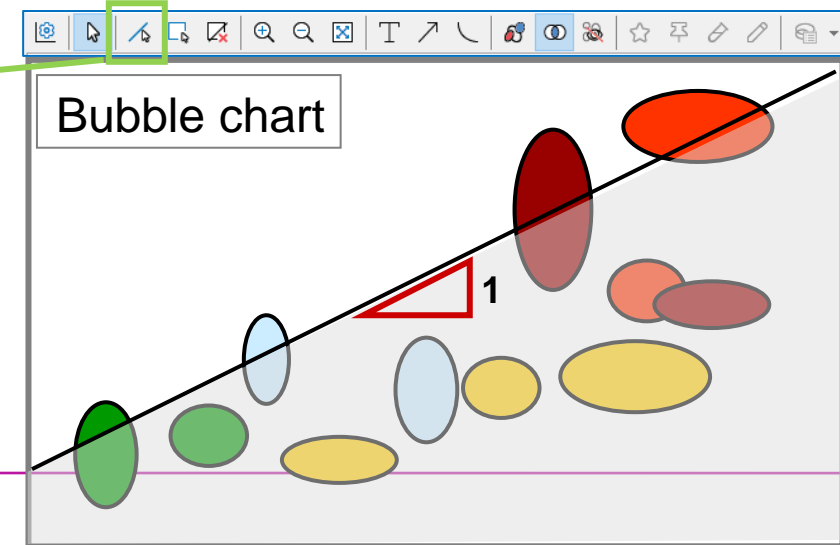
Box selection tool

Property



Line/gradient selection tool

Property 2



### Results

X out of 100 pass

### Ranking

Prop 1 Prop 2

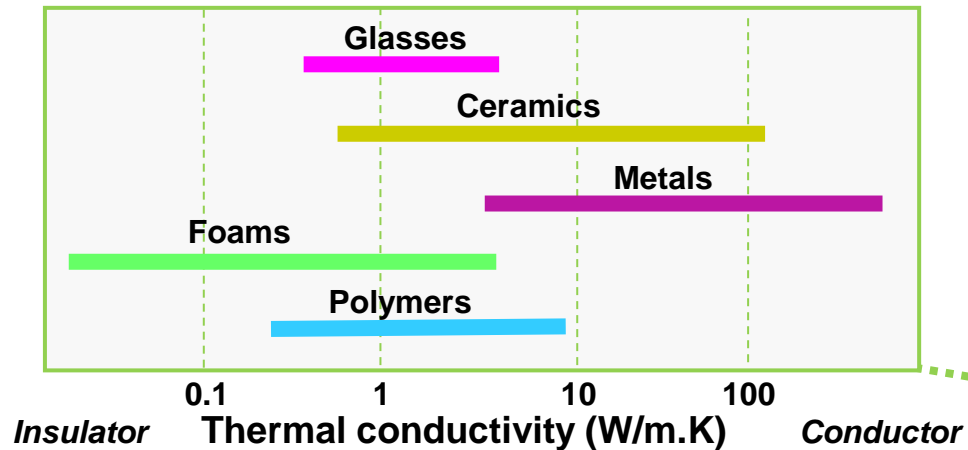
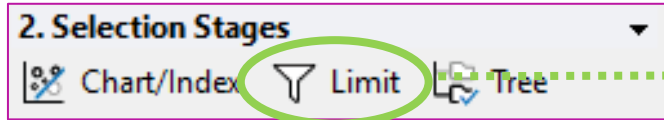
Material 1	2230	113
Material 2	2100	300
Material 3	1950	5.6
etc...		



Aalto University  
School of Engineering

Property 1

# Screening with a LIMIT STAGE



<b>Results</b>	<b>Ranking</b>	
<i>X out of 100 pass</i>	<i>Prop 1</i>	<i>Prop 2</i>
Material 1	2230	113
Material 2	2100	300
Material 3	1950	5.6
etc...		

**General properties**

**Mechanical properties**    *Min.*    *Max.*

Young's modulus		100		GPa
Yield strength		50		MPa
Hardness		70		Vickers
Fracture toughness		16		MPa.m <sup>1/2</sup>

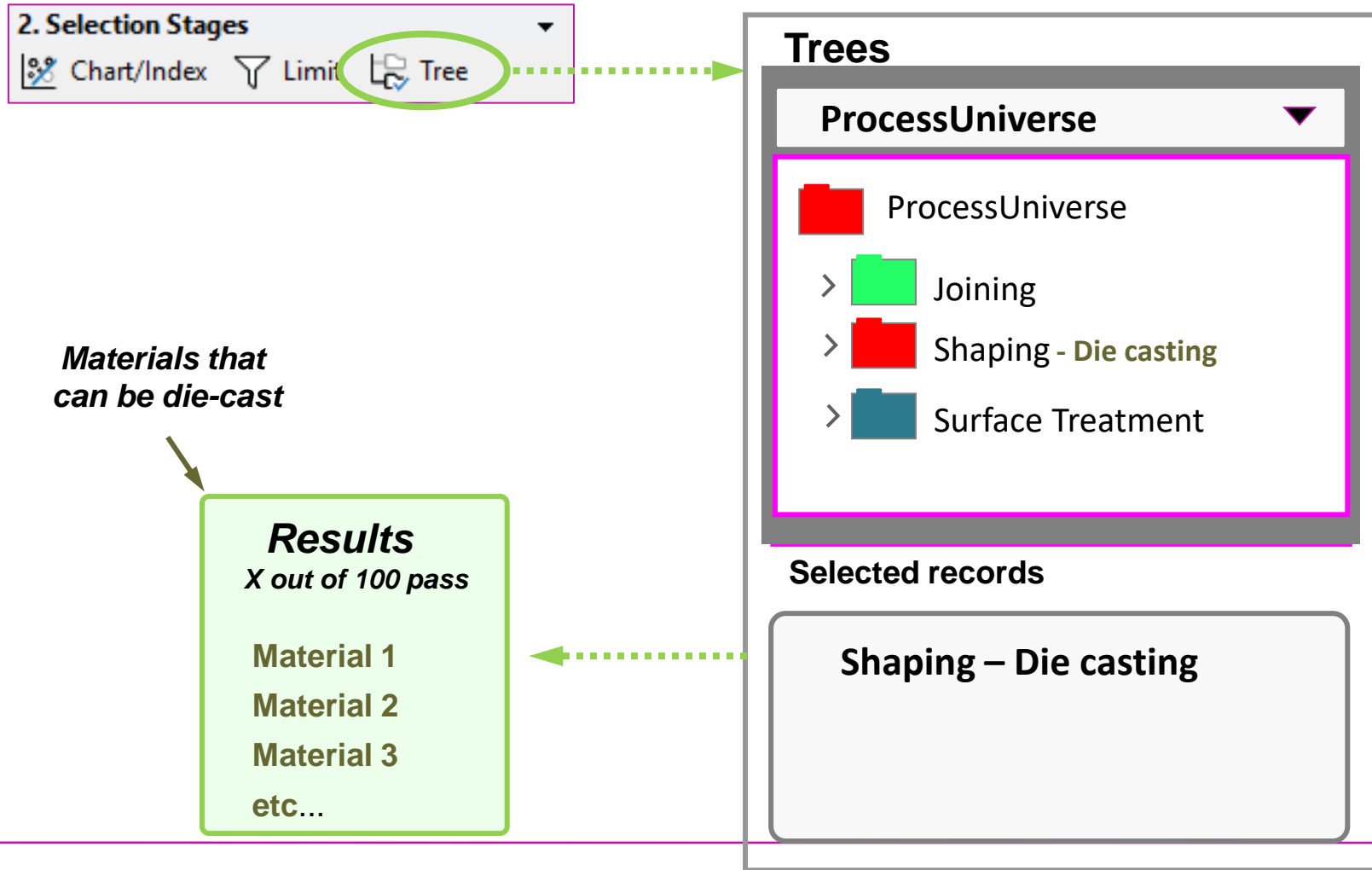
**Thermal properties**    *Min.*    *Max.*

Max service temp		200		C
T-conductivity			1	W/m.K
T-expansion			10	10 <sup>-6</sup> /C
Specific heat		1600		J/kg.K

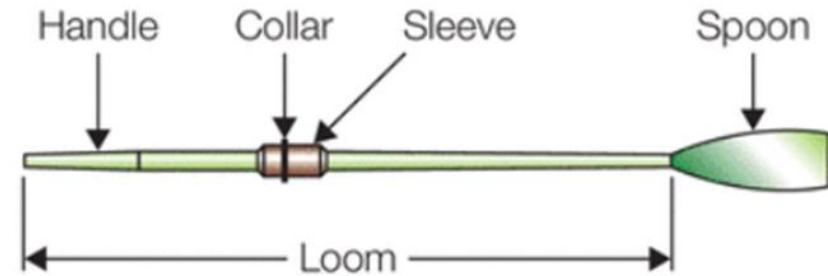
**Electrical properties**

**Eco properties**

# Screening with a TREE STAGE



# Example task: Materials for Oars



**Step 1 – Determine Design Requirements**

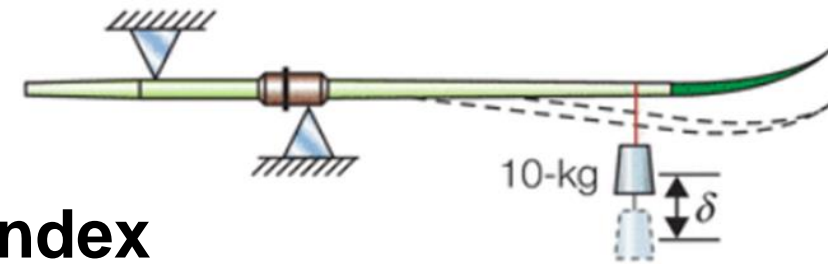
...

**Step 2 – Determine Material performance index**

... (*explanations with formula, eq.s ...*)

**Step 3 – Plot the chart in order to determine the best possible choice**

...

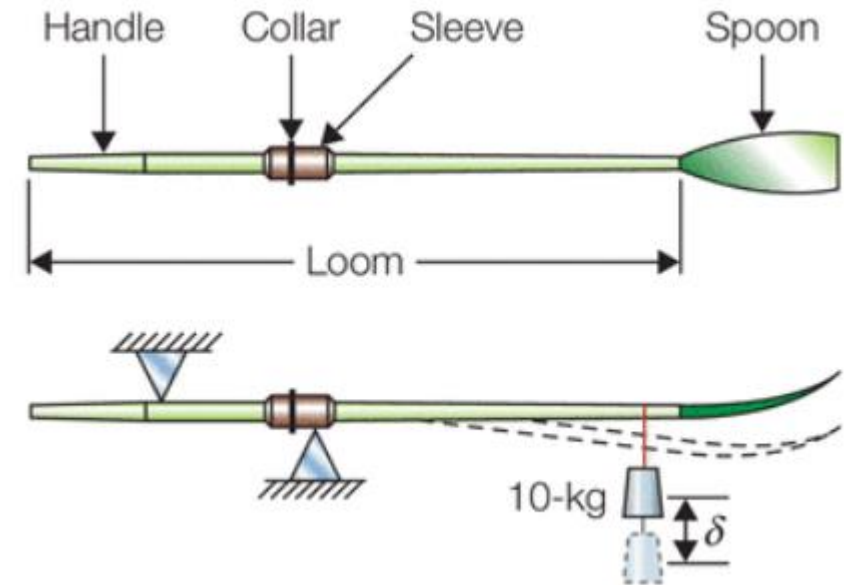


# Example task: Materials for Oars

**Minimize mass** for **given bending stiffness** (and length)

$$m = AL\rho \qquad S \propto \frac{EI}{L^3} \propto E \frac{A^2}{L^3}$$

$$m \propto \sqrt{\frac{SL^3}{E}} L\rho = \sqrt{S} \cdot L^{5/2} \cdot \frac{\rho}{\sqrt{E}}$$



# Ranking, using charts

Light stiff beam:

Index  $M = \frac{E^{1/2}}{\rho}$

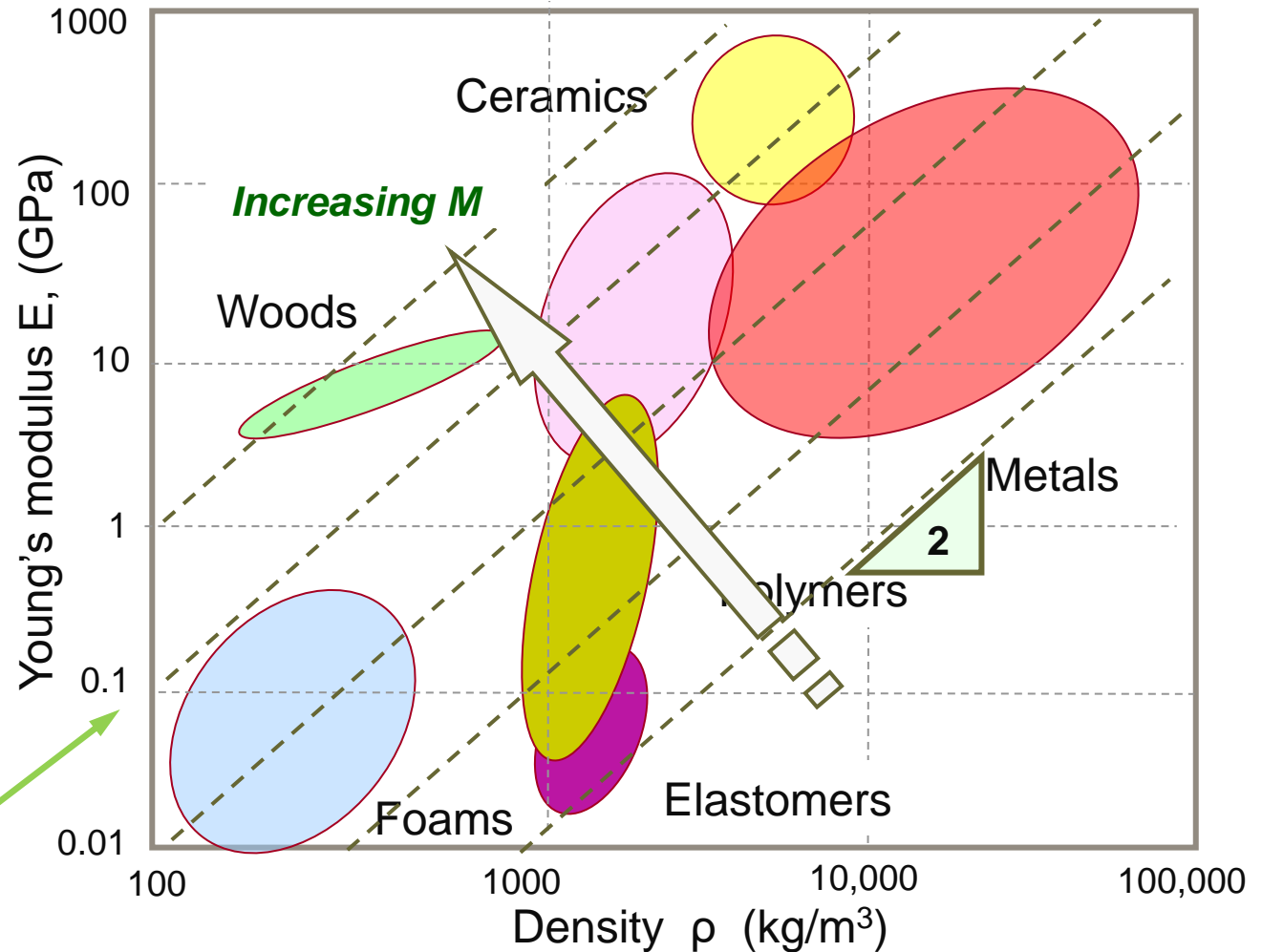
Rearrange:

$$E = \rho^2 M^2$$

Take logs:

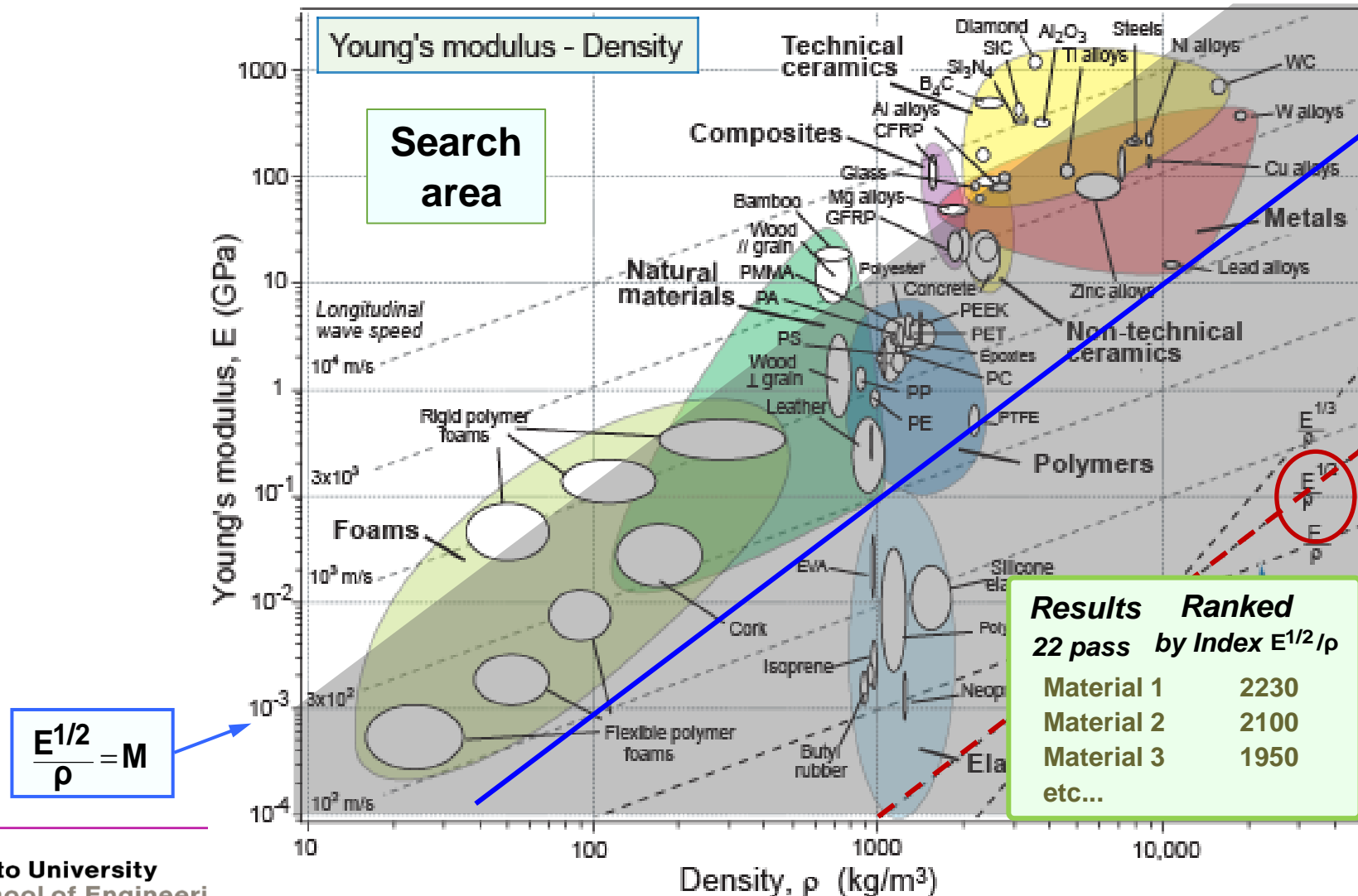
$$\text{Log } E = 2 \log \rho + 2 \log M$$

Function	Index	Slope
Tie	$E/\rho$	1
Beam	$E^{1/2}/\rho$	2
Panel	$E^{1/3}/\rho$	3

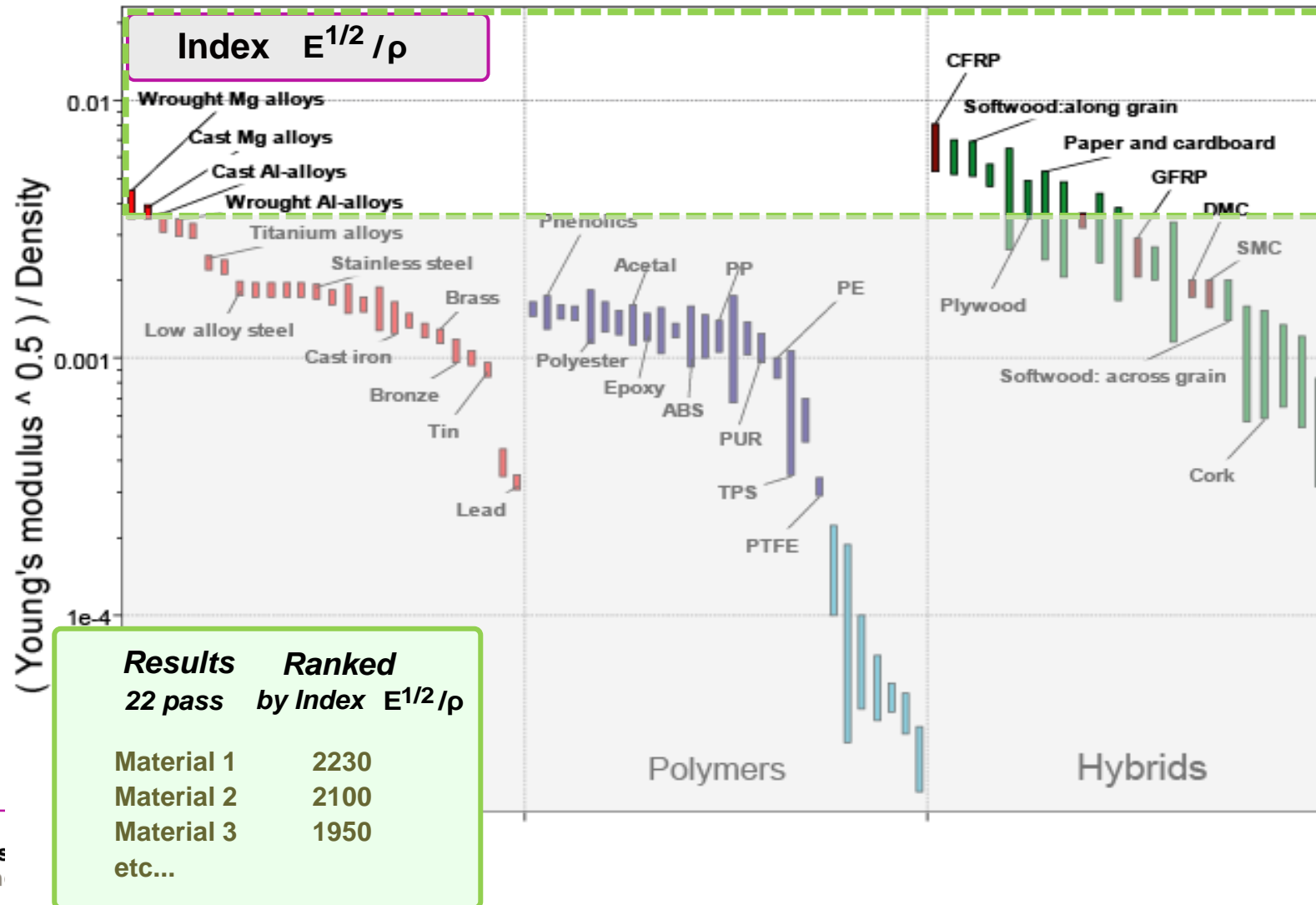




# Selection using index in a bubble chart



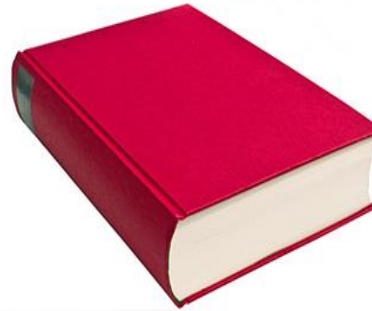
# Selection using index directly on chart axis



# Documentation

**Documentation:** “now the number of candidates is small, explore their character in depth”

**Handbooks**



**Specialized  
databases**



**Suppliers'  
data sheets**



**The Internet**

# Videos for Exercise

## Materials Selection with Granta EduPack

### Lesson 1: Creating Charts

[https://youtu.be/oVH2r8tJrp8?list=PLtt6-ZgUFmMK4aApOUoA85CvaJ\\_udGDCE](https://youtu.be/oVH2r8tJrp8?list=PLtt6-ZgUFmMK4aApOUoA85CvaJ_udGDCE)

### Lesson 2: Formatting Charts

[https://www.youtube.com/watch?v=hNA5DBNwm1I&list=PLtt6-ZgUFmMK4aApOUoA85CvaJ\\_udGDCE&index=2](https://www.youtube.com/watch?v=hNA5DBNwm1I&list=PLtt6-ZgUFmMK4aApOUoA85CvaJ_udGDCE&index=2)

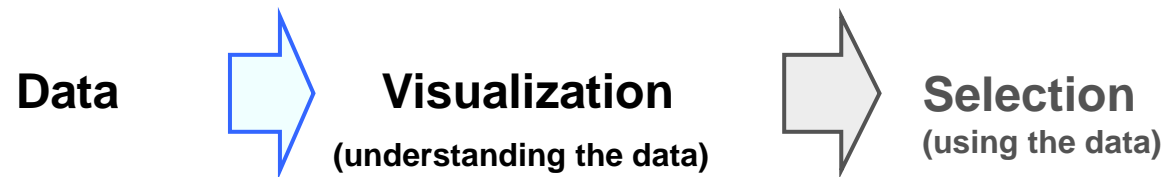
# Summary

- **The selection strategy:**

Translate - Screen - Rank - Documentation

- EduPack allows Screening using **‘Limit – Chart – Tree stages’** in any number and sequence

- **The progression:**



# Questions?

- **Contact: MyCourses 'General discussion' channel**