MEC-E1070
Selection of Engineering Materials

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Learning objectives for this Lecture

Knowledge and Understanding

Understanding of the potential of **hybrid materials**

Skills and Abilities

Ability to use the **synthesizer** to explore **material combinations**

Values and Attitudes

Inspiration to combine properties to create **new materials**

Resources

- Text: *"**Materials Selection in Mechanical Design**", 4th edition by M.F. Ashby, Butterworth Heinemann, Oxford, 2016, Chapters 11-12.*
- Software: GRANTA EduPack Hybrid synthesizer tool (Grantadesign.com)

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Lecture outline

Cellular structures

Composites

Sandwich structures

Multi-layers

Part cost estimator

❑ **Hybrid materials** – expanding the filled space

❑ **Example** – **Sandwich structures**

❑ New developments – **Part cost estimator**

❑ **Next-generation** material design

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Advanced systems use hybrid materials

Sails – Kevlar + Nylon mixed weave
With thermally bonded PET skin

Mast and boom –
CFRP, filament wound

Hull – sandwich construction,
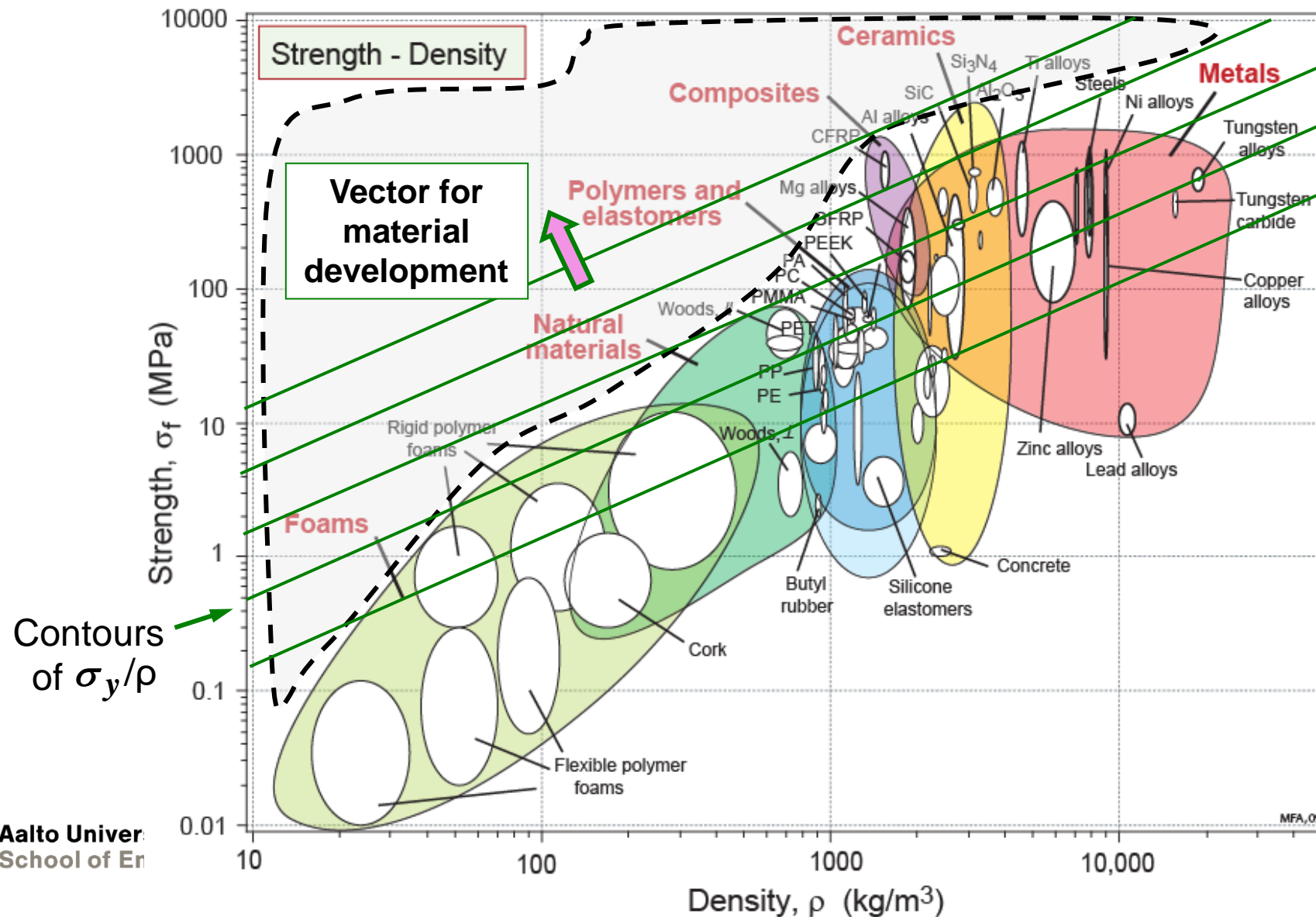carbon fibre/PMAA foam core

Criteria of excellence: material indices

- **Material index** = combination of material properties that limit performance

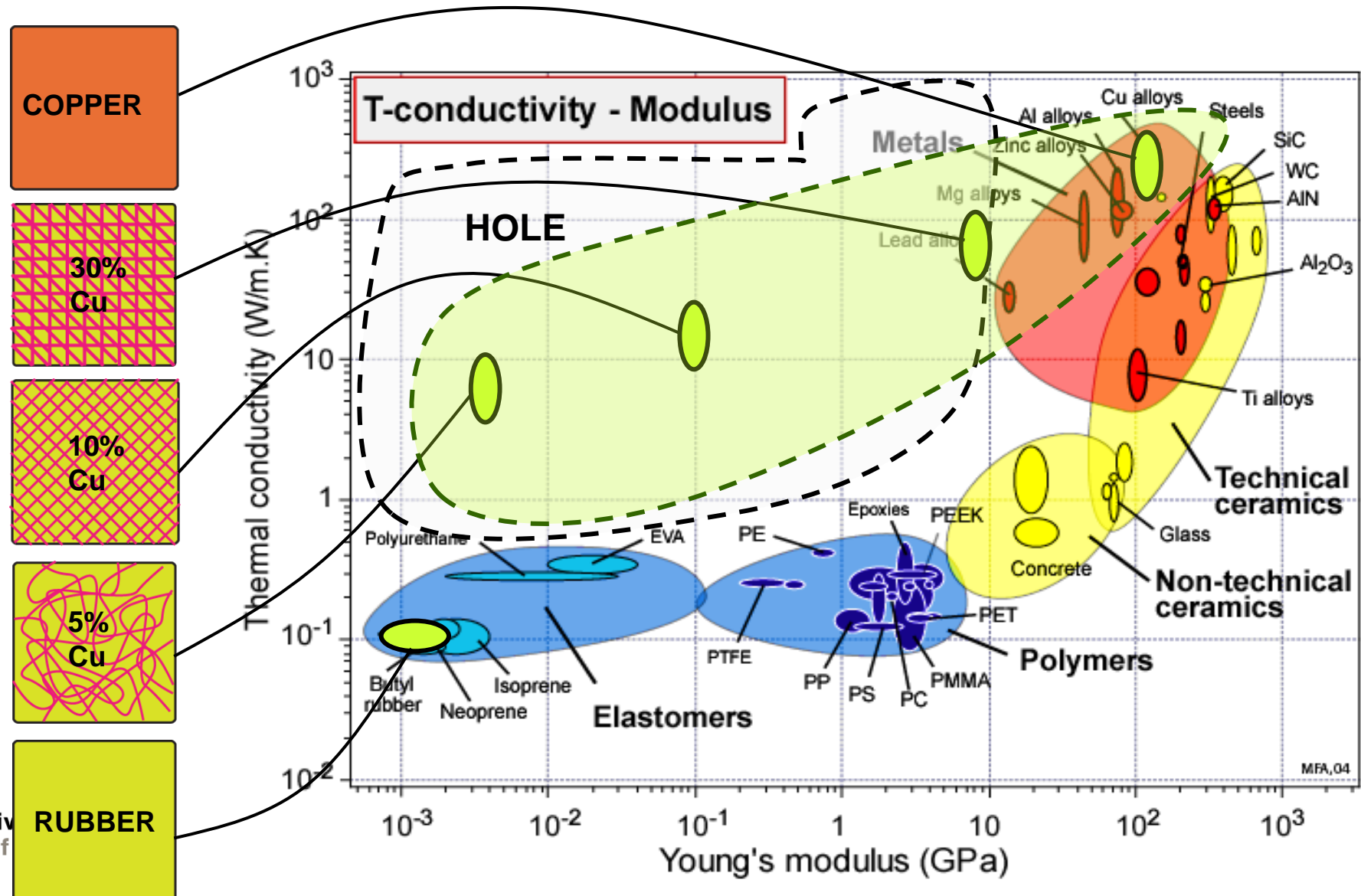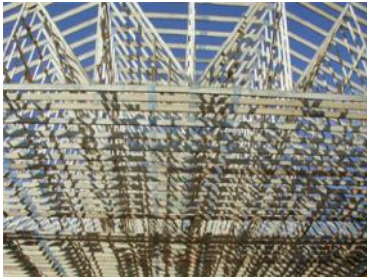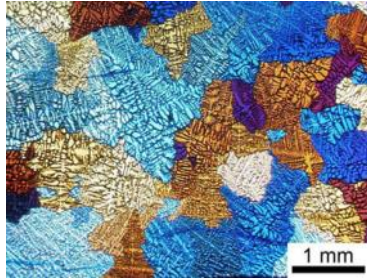| Objective minimise **mass**	Constraints	
	Stiffness	Strength
Tension (tie)	E/ρ	σ_y/ρ
Bending (beam)	$E^{1/2}/\rho$	$\sigma_y^{2/3}/\rho$
Bending (panel)	$E^{1/3}/\rho$	$\sigma_y^{1/2}/\rho$

Modulus and Density
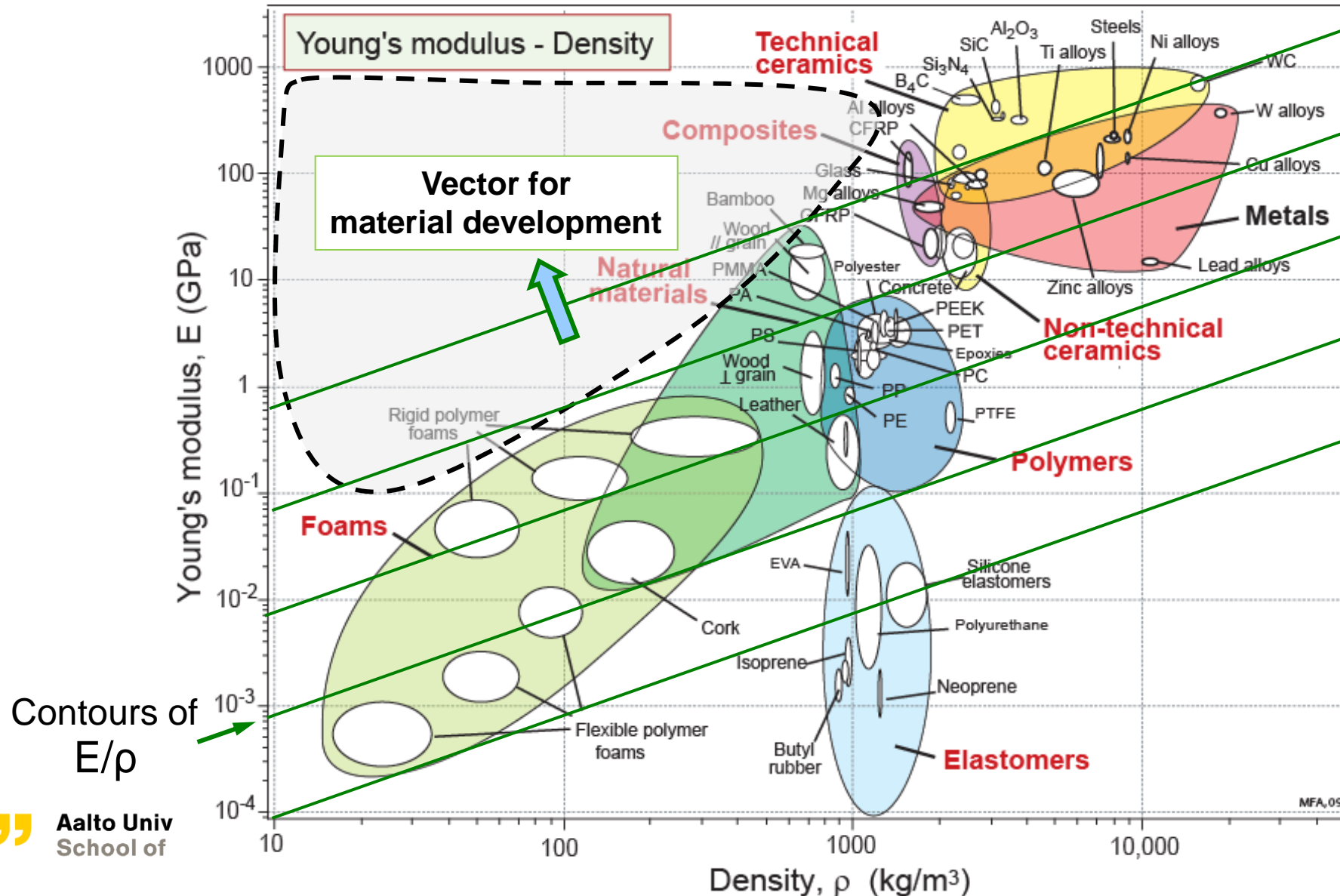
Strength - Density

Using Hybrids to fill holes

Designing hybrid materials

Combine:

- **Materials – relate properties to microstructure: controlled nature, scale through alloy design and processing.**

- **Mechanics – accept properties as "given", optimise the geometry**

- **Textile technology – exploit unique strength and blending properties of fibers**
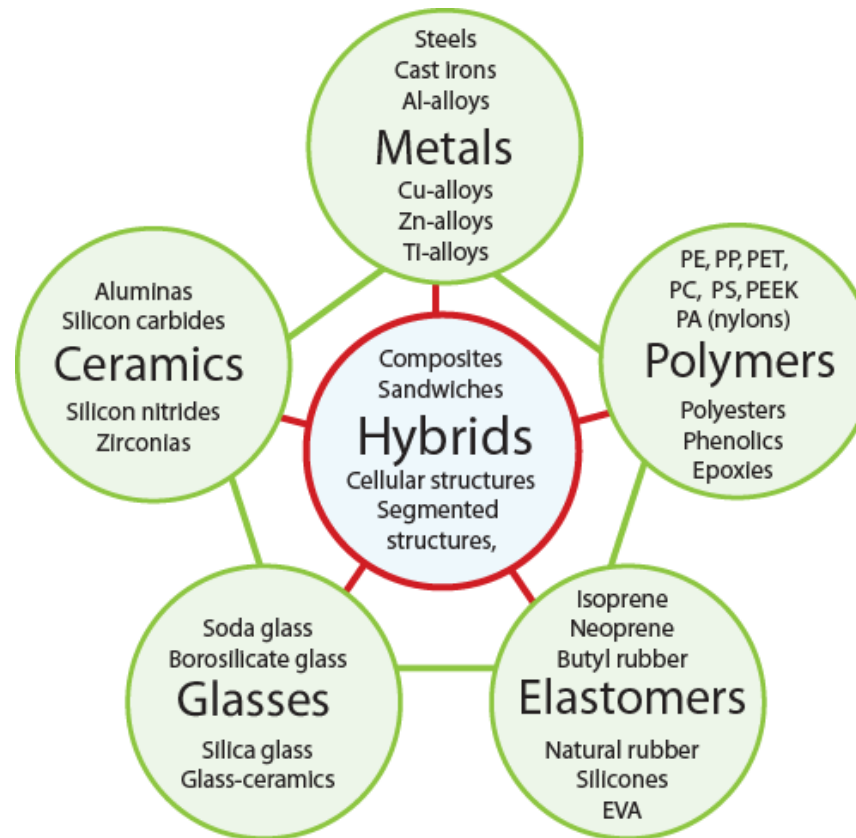
Hybrid materials

Cellular structures

Composites

Sandwich structures

Multi-layers

Metals
Steels
Cast Irons
Al-alloys
Cu-alloys
Zn-alloys
Ti-alloys

Polymers
PE, PP, PET,
PC, PS, PEEK
PA (nylons)
Polyesters
Phenolics
Epoxies

Ceramics
Aluminas
Silicon carbides
Silicon nitrides
Zirconias

Hybrids
Composites
Sandwiches
Cellular structures
Segmented structures,

Elastomers
Isoprene
Neoprene
Butyl rubber
Natural rubber
Silicones
EVA

Glasses
Soda glass
Borosilicate glass
Silica glass
Glass-ceramics

Design variables:

- Choice of materials
- Volume fractions
- Configuration
- Connectivity
- Scale

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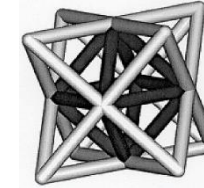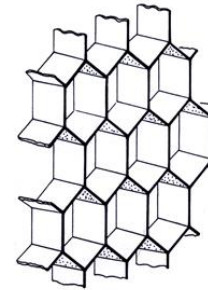School of Engineering

10

Familiar Architectures

Composites
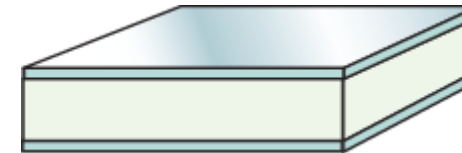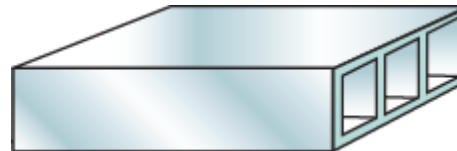- *Unidirectional*
- *Quasi-isotropic*
- *Particulate*
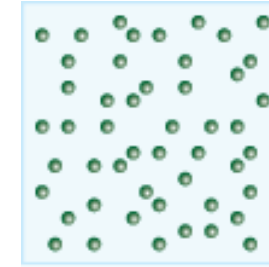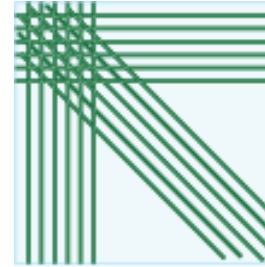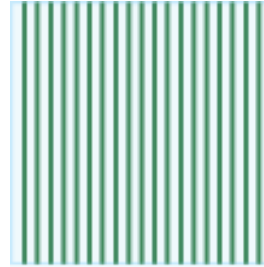
Cellular structures
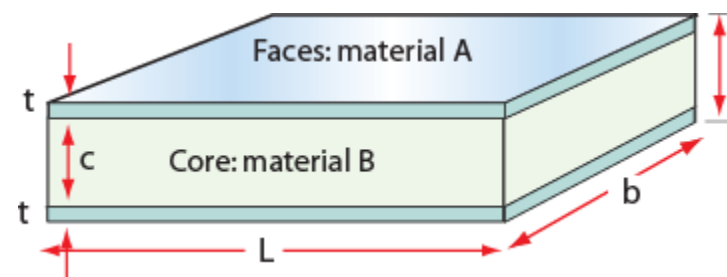- *Foams*
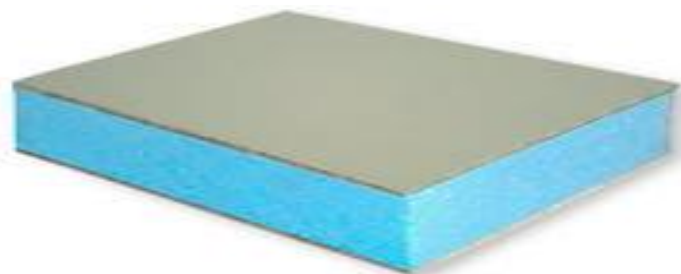- *Honeycombs*
- *Triangulated lattices*

Sandwich structures
- *Symmetric sandwiches*

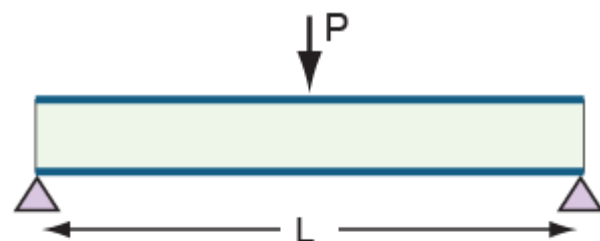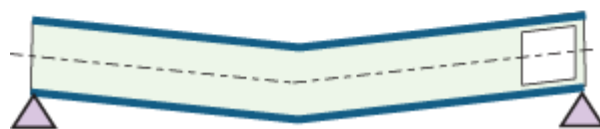**Many more**

Example: Sandwich panel – property models

Faces: material A

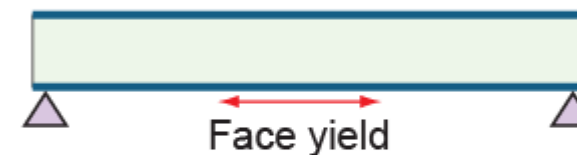Core: material B

Elastic response

P

Bending

Core shear

Collapse response

P
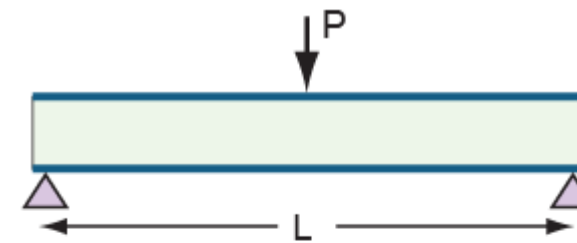
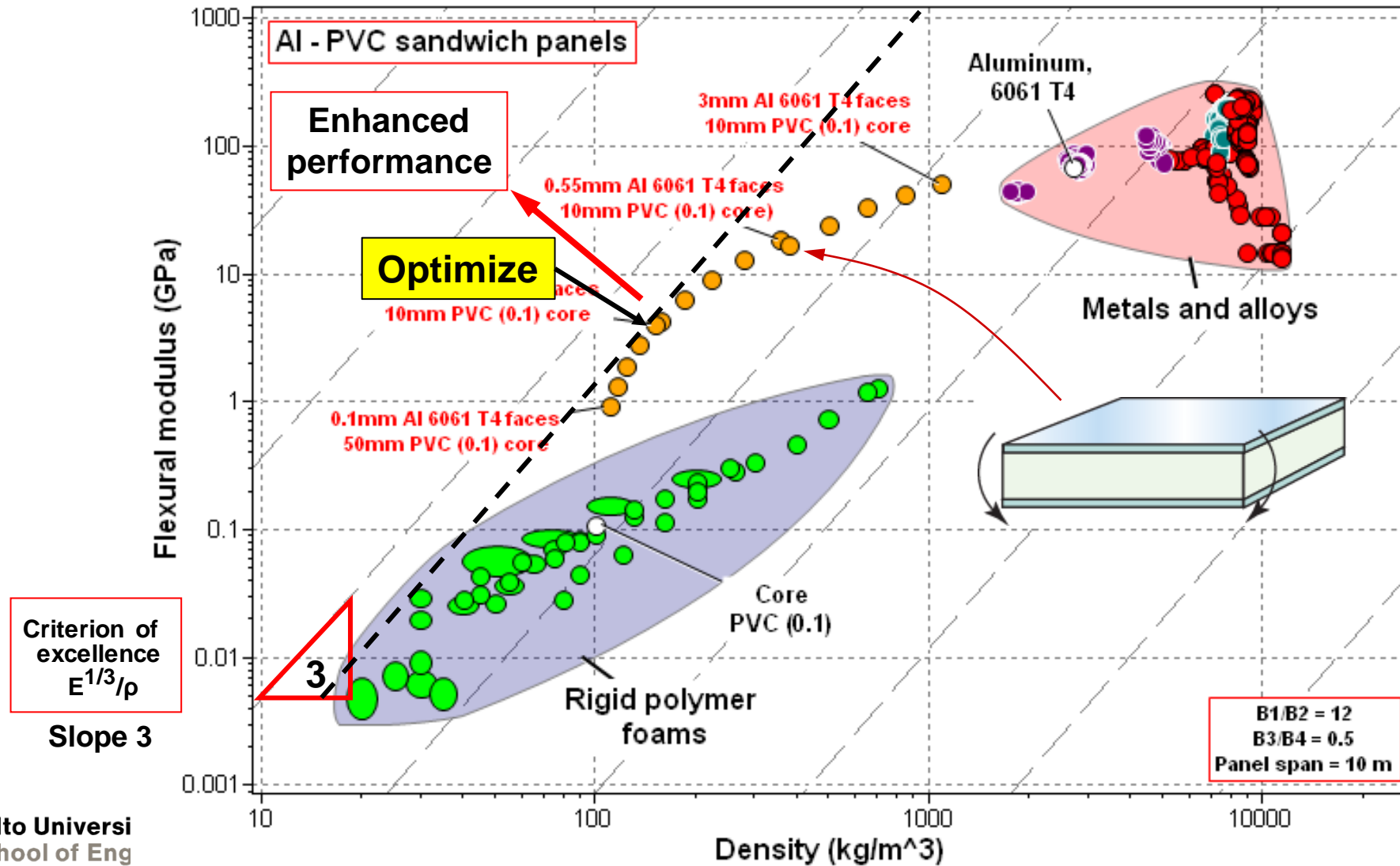Face yield

Face buckling

Core failure

Plus **thermal** and **electrical properties**
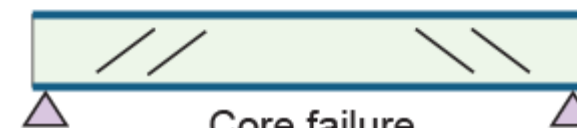
Stiff sandwich panels

The good and the bad about Hybrids

Hybrid corn

Hybrid cars

Improved yield, hardiness

Low fuel consumption, emissions

…… but…   Infertile

…… but…   Expensive

Synthesizer model for part cost

Cost per part

Cost contributors

Raw material | Forming process | Surface treatment | Assembly method

■ Material 1
■ Material 2

Total Part
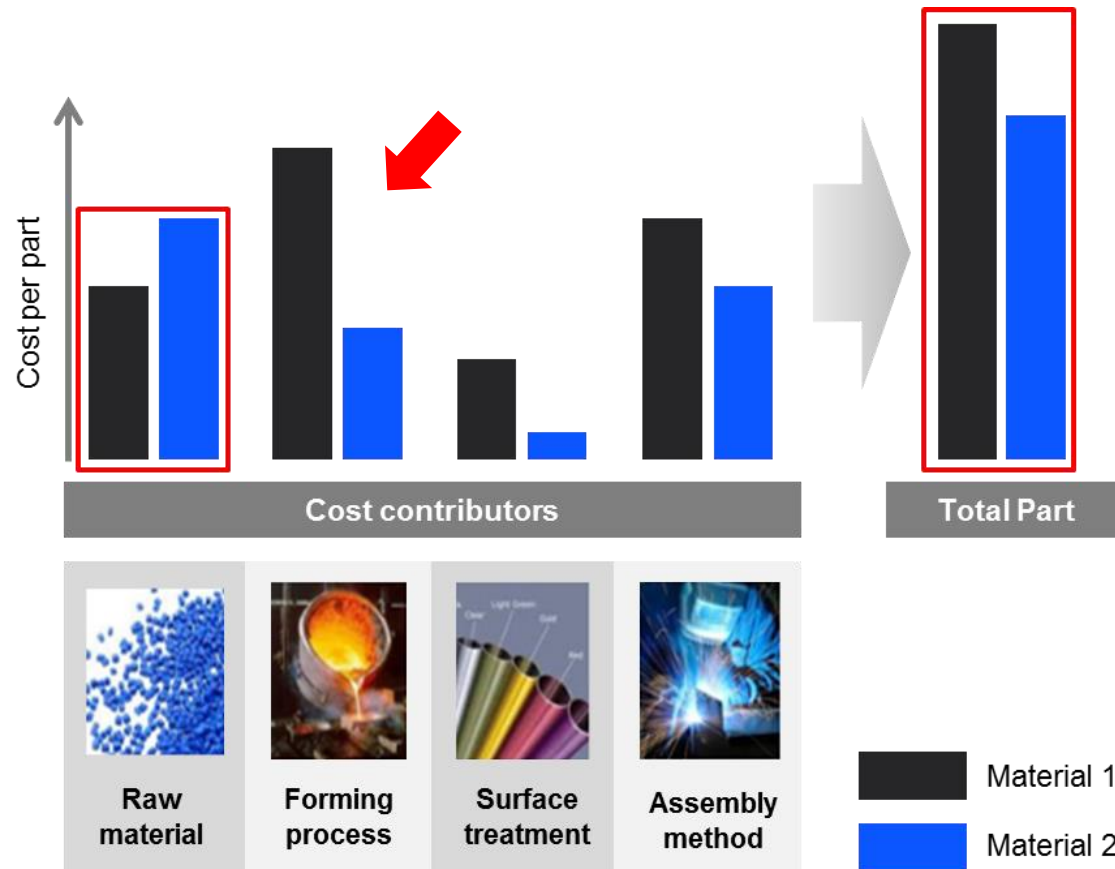
- *PP-20% mineral filled door panel*
- *15% saving in vehicle weight, but what about cost?*

- Quickly estimate the **cost to manufacture a component**
- **Compare different classes** of materials *and* processing routes

Part cost comparison: Door panel

Cost estimate vs Batch size

Steel YS140
rolled, pressed

PP (20% talc)
molded

Part cost (USD)

120
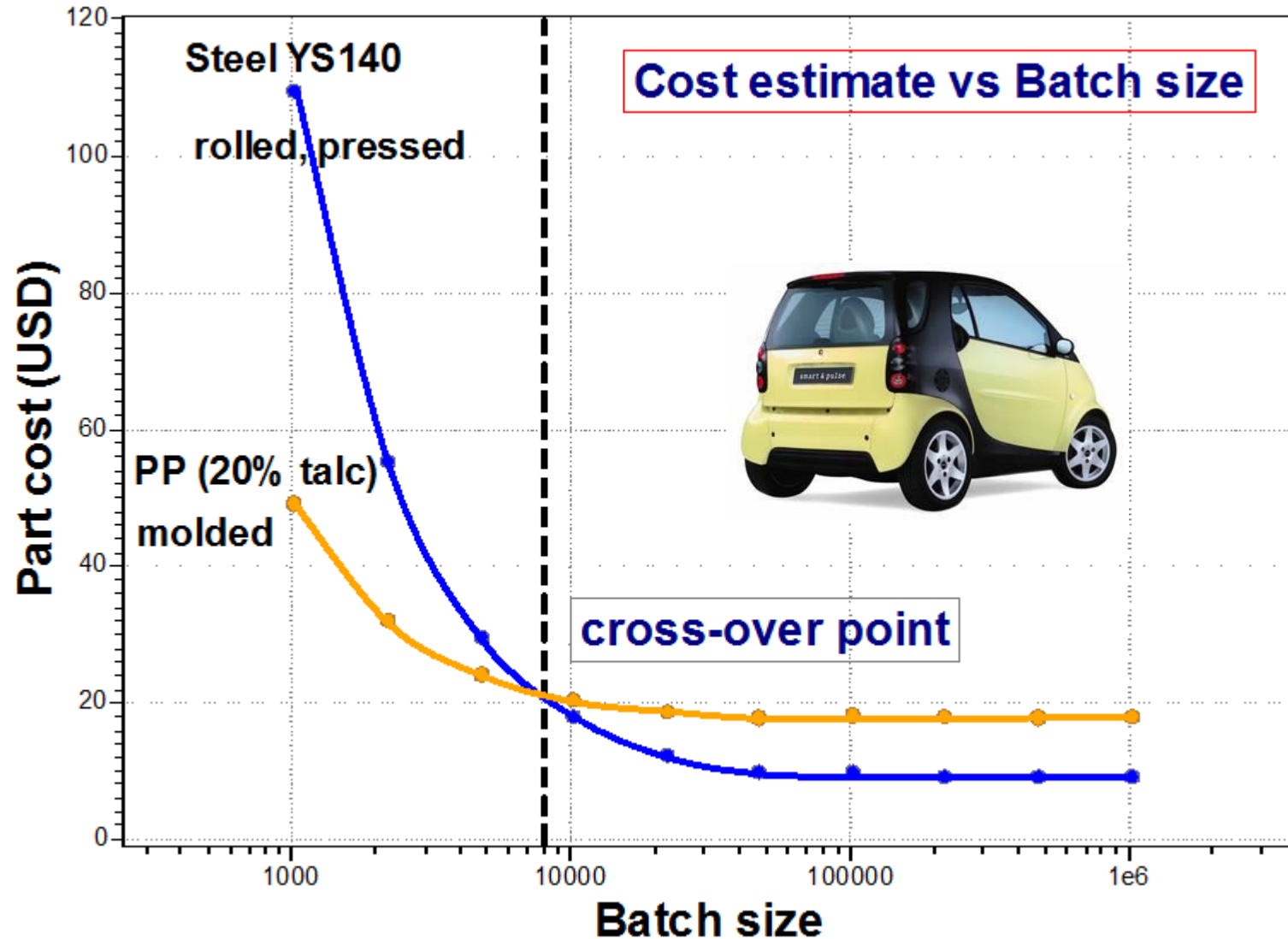100
80
60
40
20
0

cross-over point

Batch size

1000   10000   100000   1e6

Accelerating new material development

Current internationally:

ICME - *Integrated Computational Materials Engineering*

MGI - *The Materials Genome Initiative*

AMD - *Accelerated Material Development.............* more

Vision: Materials Informatics

*Use today's ability to store, process and retrieve information
to accelerate material development*

Almost all "bottom-up": *sub-atomic $\longrightarrow$ nano $\longrightarrow$ micron $\longrightarrow$ mm scale*

Can envisage "top-down": *Design requirements $\longrightarrow$ Architecture*

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