Topic #3: Materials Selection Charts

M. F. Ashby "Materials Selection in Design", Ch. 4

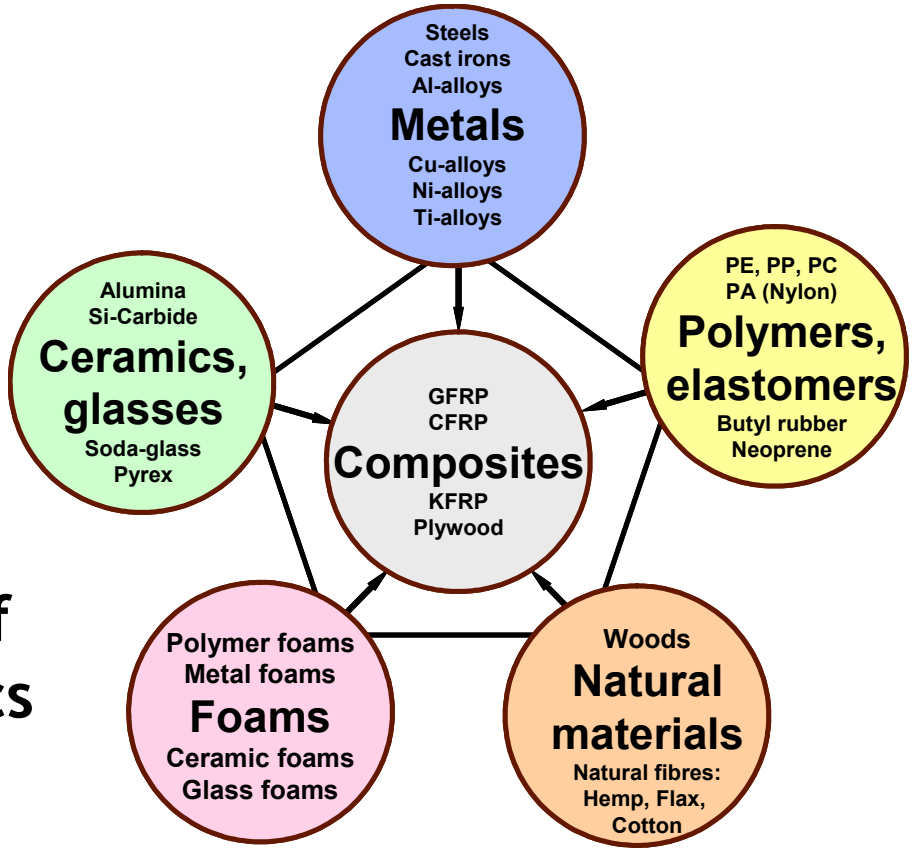
- Methods for displaying material properties
- Simple use of materials selection charts
- Approaching Systematic Materials Selection

Review: Materials Kingdom

Engineering Materials

- The materials kingdom
- Advantages / disadvantages of each
- Range of properties available for each class

Qualitative Overview of Material Characteristics



Material Properties

Class	Property	Symbol	SI Units
General	Cost	C_m	\$/Kg
	Density	ρ	Kg/m^3
Mechanical	Elastic Moduli	E, G, K	GPa (10^9 J/m^3)
	Strength	σ_f	MPa
	Toughness	K_{IC}	MPa $m^{1/2}$
	Damping Capacity	η	--
	Fatigue Endurance Limit	σ_e	MPa
Thermal	Thermal Conductivity	λ	W/mK
	Thermal Diffusivity	α	m^2/s
	Specific Heat Capacity	C_p	J/KgK
	Melting Point	T_m	K
	Glass Temperature	T_g	K
	Thermal Expansion Coefficient	α	K^{-1}
	Thermal Shock Resistance	ΔT	K
	Creep Resistance	--	--
Wear	Archard Wear Constant	k_A	MPa^{-1}
Corrosion	Corrosion rate	K	mm/year
Oxidation	Parabolic Rate Constant	k_p	m^2/s

We know “materials kingdom”...

we know important materials properties …

How do we use this information to *systematically* select materials?

How do we select materials?

- From problem we identify key material properties e.g.

Method #1: Data "Browsing"

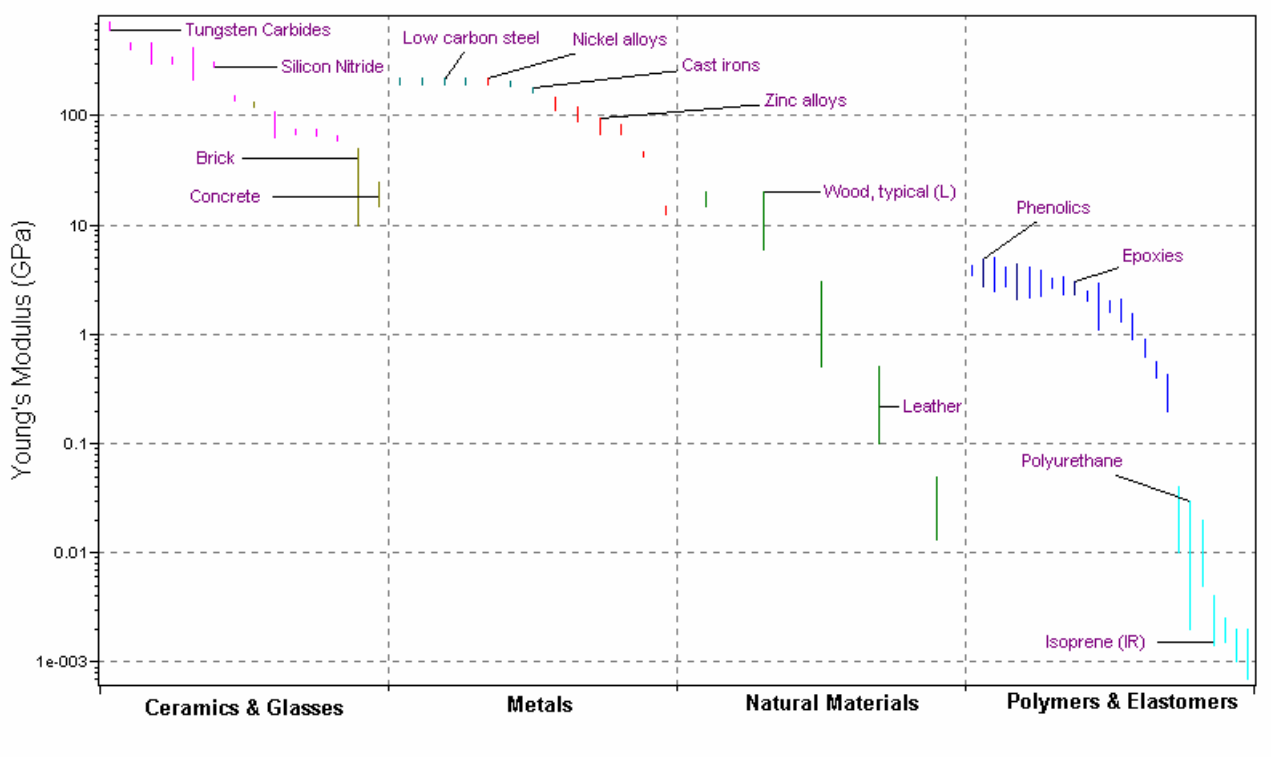
- Find material data by canvassing reference books, software and/or internet

Example: Typical properties of wrought Al-alloys (extract)

Alloy and temper	Tension				Hardness	Shear	Fatigue	Modulus
	Strength, ksi		Elongation, % in 2 in.					
	Ultimate	Yield	1/16 in. thick specimen	1/2 in. dia. specimen	Brinnell number 500 kg load 10 mm ball	Ultimate shearing strength, ksi	Endurance[3] limit, ksi	Modulus[4] of elasticity, ksi × 10^3
5652-HO	28	13	25	30	47	18	16	10.2
5652-H32	33	28	12	18	60	20	17	10.2
5652-H34	38	31	10	14	68	21	18	10.2
5652-H36	40	35	8	10	73	23	19	10.2
5652-H38	42	37	7	8	77	24	20	10.2
5657-H25	23	20	12	. .	40	12	. .	10.0
5657-H38, H28	28	24	7	. .	50	15	. .	10.0
6061-O	18	8	25	30	30	12	9	10.0
6061-T4, T451	35	21	22	25	65	24	14	10.0
6061-T6, T651	45	40	12	17	95	30	14	10.0
Alclad 6061-O	17	7	25	. .	. .	11	. .	10.0
Alclad 6061-T4, T451	33	19	22	. .	. .	22	. .	10.0
Alclad 6061-T6. T651	42	37	12	. .	. .	27	. .	10.0

Method #2: Property Bar Charts

- Plot property data as bar charts showing range of properties for a given material



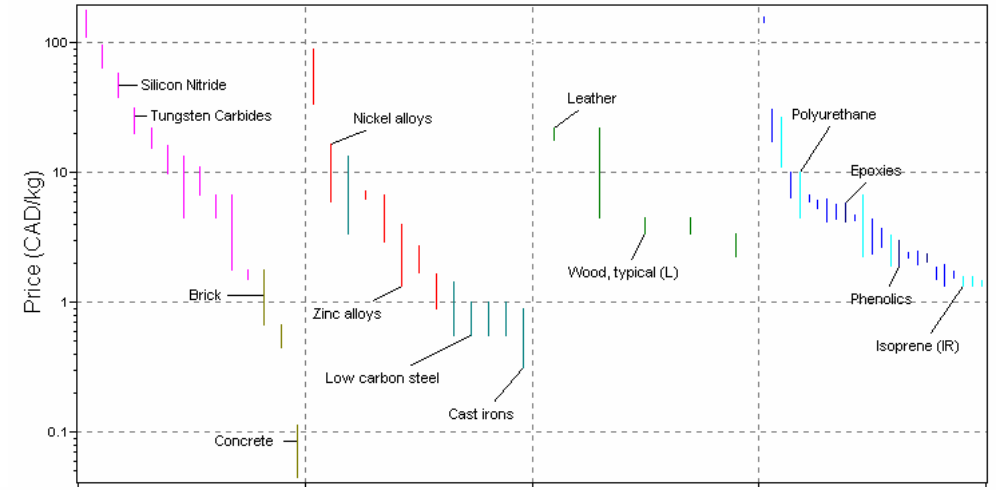
e.g. need stiff material (E > 100 GPa)

Method #2: Property Bar Charts (cont.)

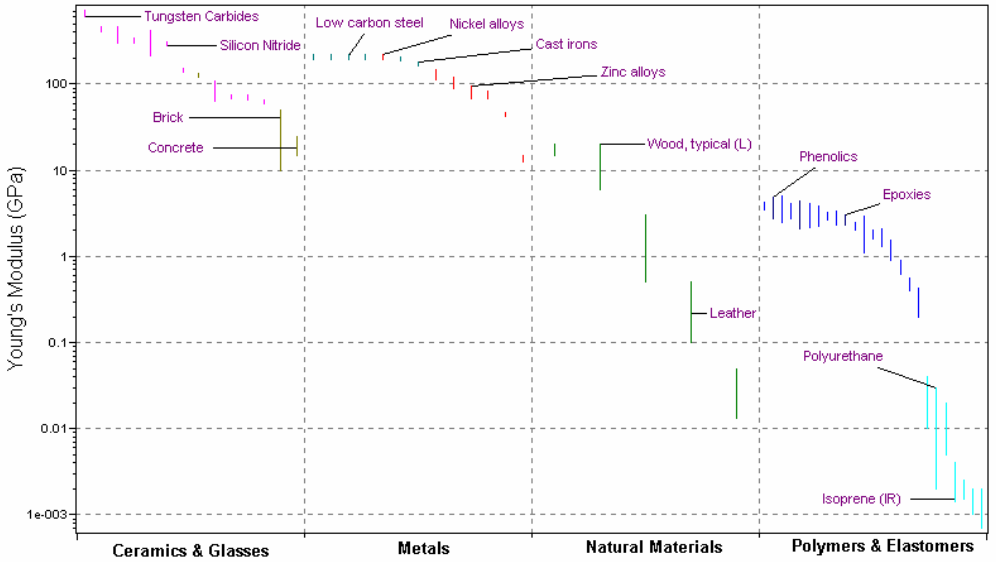
A design requires a stiff & cheap component

Potential Candidates

Better

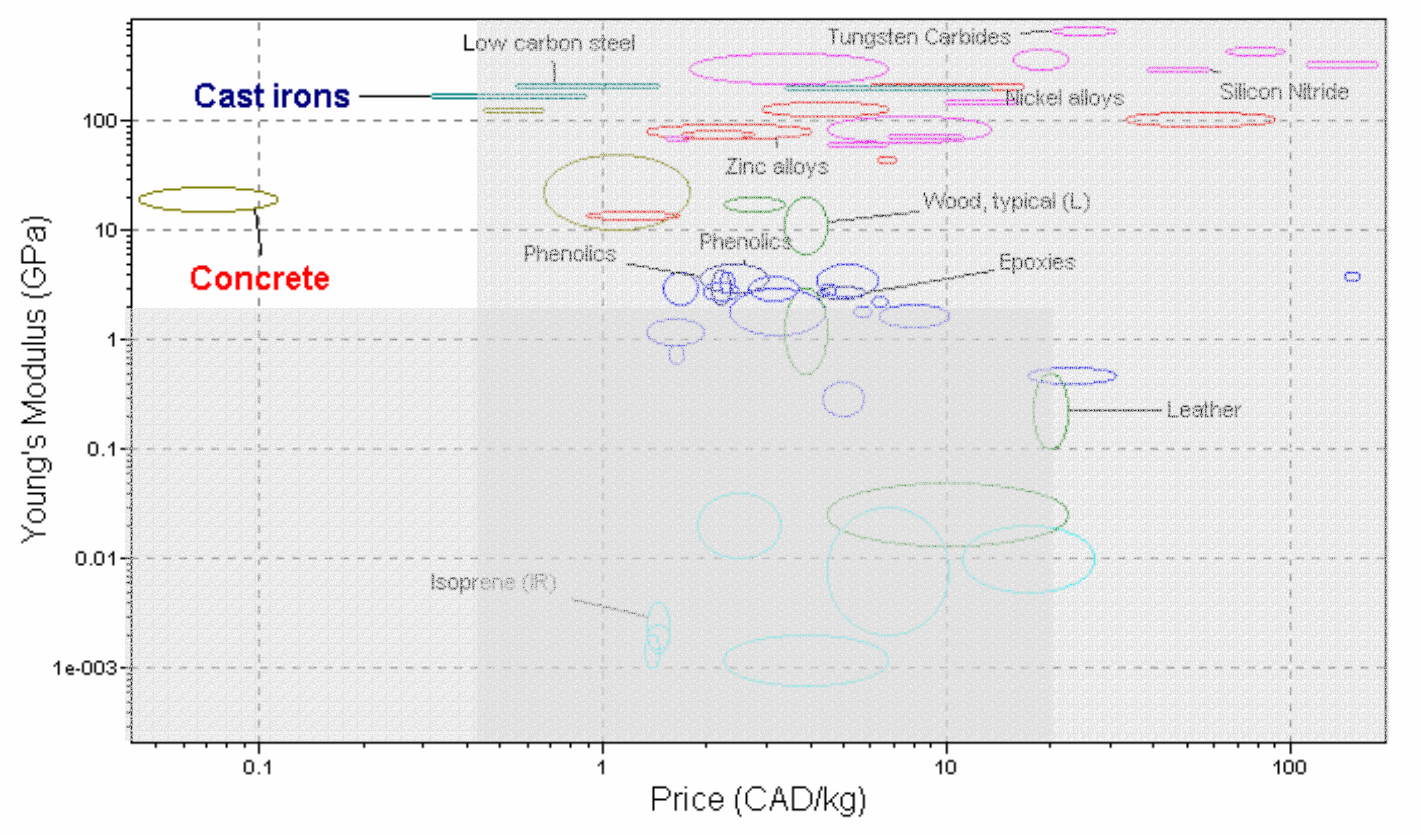


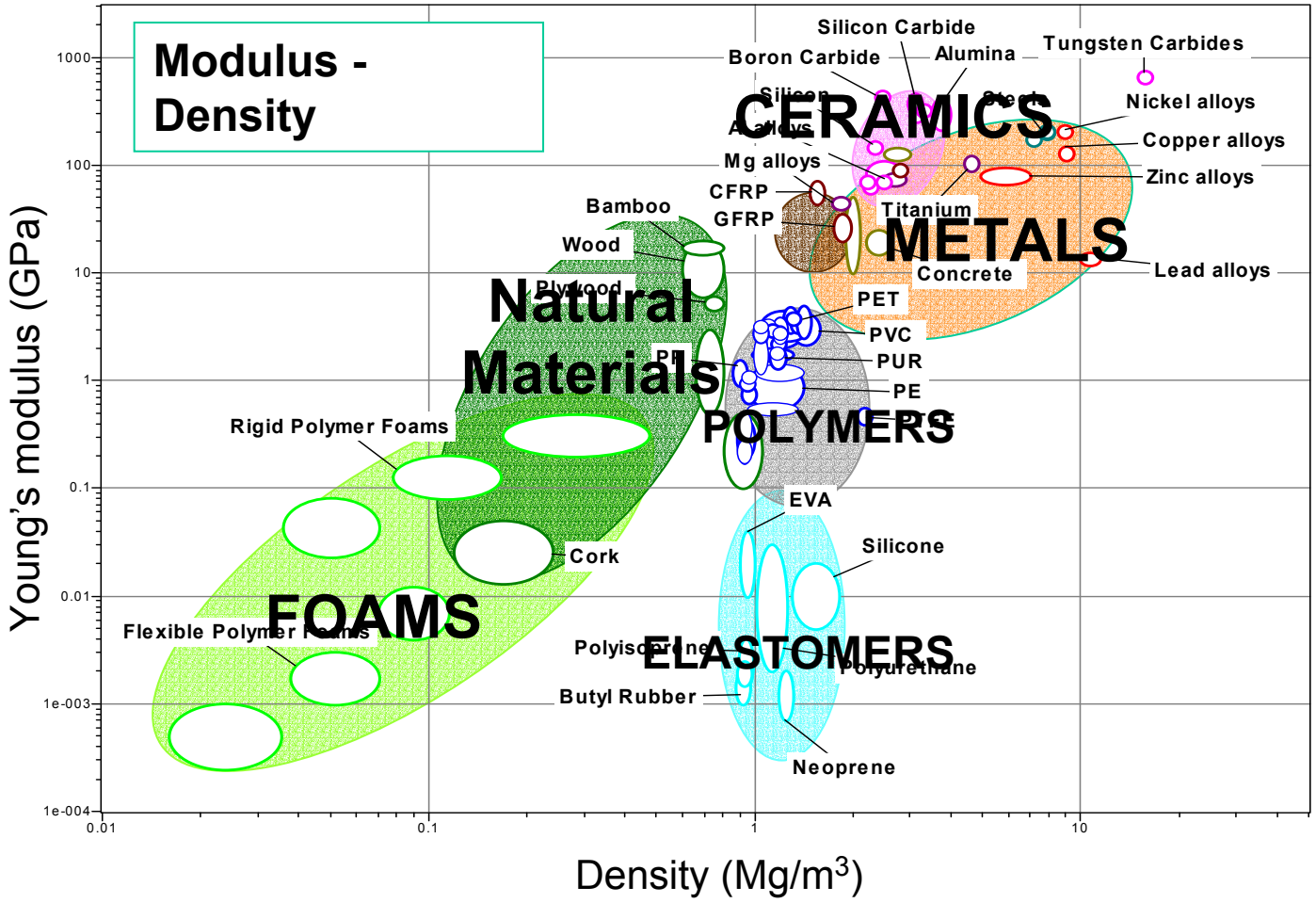
Better



Method #3: Materials Selection Charts

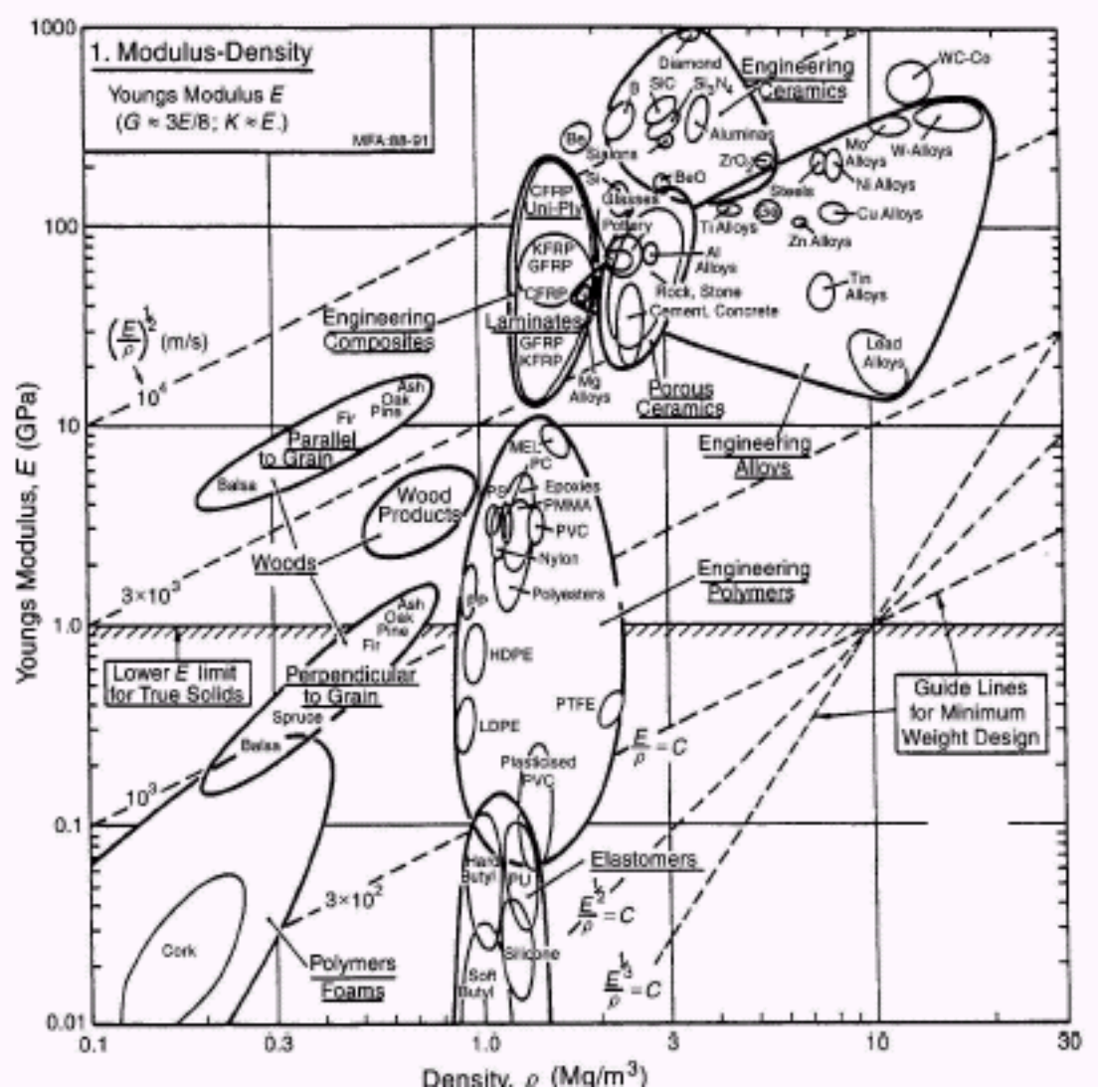
- For designs requiring the optimization of two (or more) attributes plot one property versus the another




Modulus - Density
CERAMICS
METALS
Natural Materials
POLYMERS
FOAMS
ELASTOMERS
Silicon Carbide
Boron Carbide
Alumina
Tungsten Carbides
Nickel alloys
Copper alloys
Zinc alloys
Mg alloys
CFRP
GFRP
Titanium
Bamboo
Wood
Concrete
Lead alloys
PET
PVC
PUR
PE
EVA
Silicone
Rigid Polymer Foams
Cork
Flexible Polymer Foams
Polyisoprene
Polyurethane
Butyl Rubber
Neoprene
Young's modulus (GPa)
Density (Mg/m3)
1000
100
10
1
0.1
0.01
1e-003
1e-004
0.01
0.1
1
10

Where to find materials selection charts?

1. Ashby Ch. 4 & Appendix C
2. MMAT280 Website
3. CES Software (CWS)



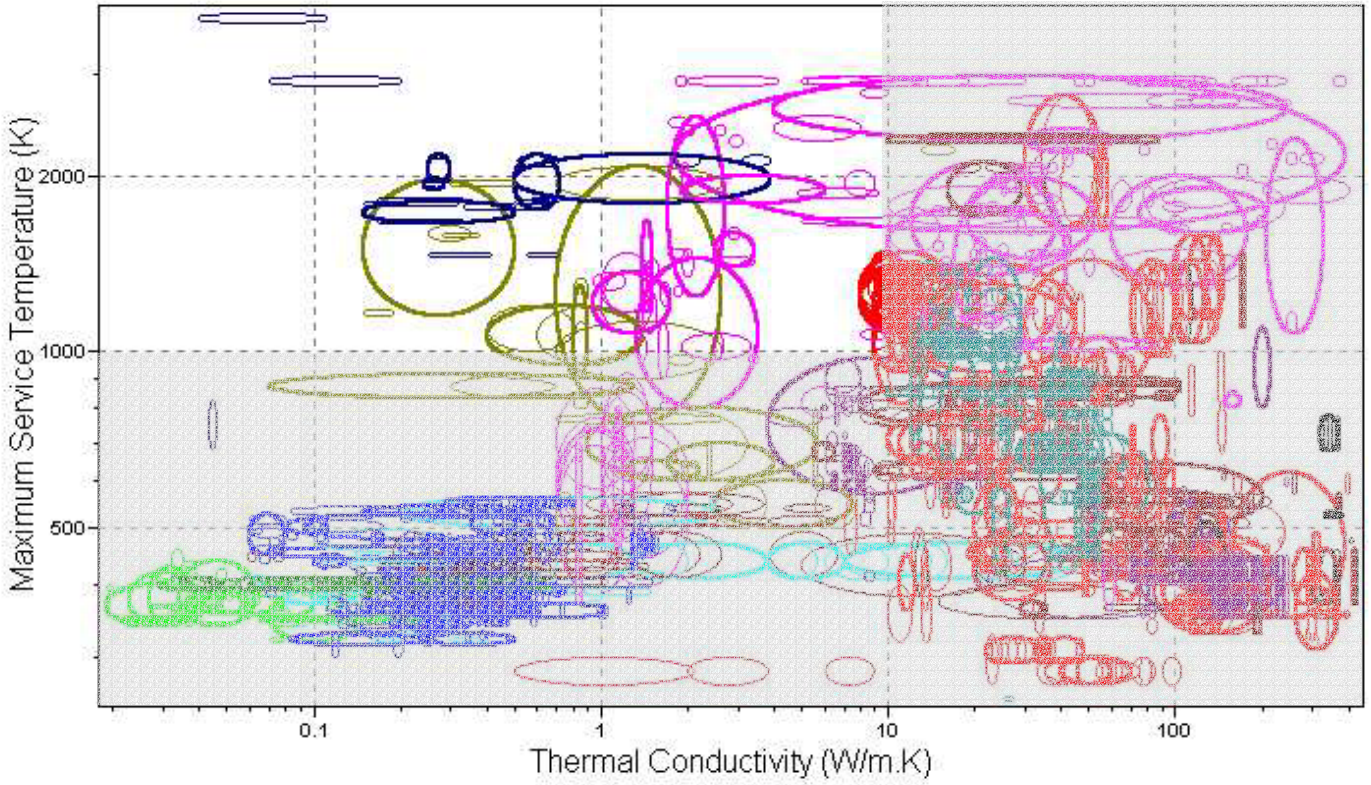
Simple Use of Property Charts in Materials Selection

First Step in Materials Selection: *Screening*

- **Can be qualitative or yes/no, e.g.**
  - material must be transparent
- **Often quantitative, e.g.**
  - material must be able to operate above 1000^{o}C
  - material must be less dense than water
  - material must have a Young's modulus > 100 GPa
- **Can use Property charts to find subset of materials that satisfy screening criteria**

Screening Criteria:

$T_s > 1000^oC$, $\lambda < 10$ W/mK



Now have screened materials to reduce the number of candidates - formed a "subset"

Problem

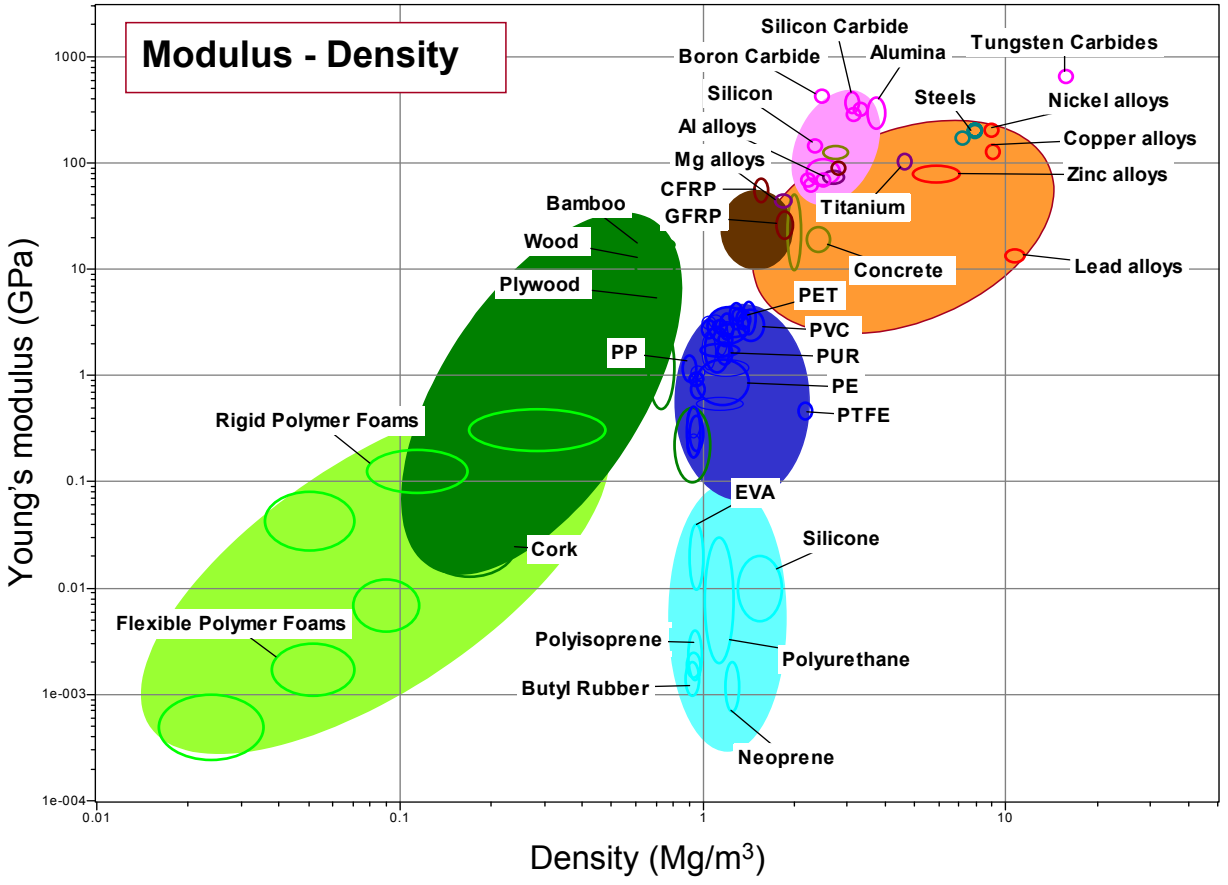
How do we *quantitatively* compare materials within the active subset?

Example

→ Need a light, "stiff" component

Need to know the relative design "**cost**" of each property:

How many units of ρ am I willing to give up to gain one unit of E?



How can we compare two material properties?

You are asking us to compare apples and oranges?!?!?

Need More Information!

Performance Indices

Review

- Three ways to perform materials selection
  - Data browsing
  - Property Bar Charts
  - Materials Selection Charts
- Materials selection charts have the advantage of immediately identify materials suited for a given application based on *material properties*
- Selection Charts good for screening of materials
- Once selected we must be able to quantitatively compare materials