The CES EduPack Software

The CES EduPack

Level 1

- **1st year** students: Engineering, Materials Science, Design

64 materials, **75** processes

Level 2

- **2nd - 4th year** students of Engineering and Materials Science and Design.

94 materials, **107** processes

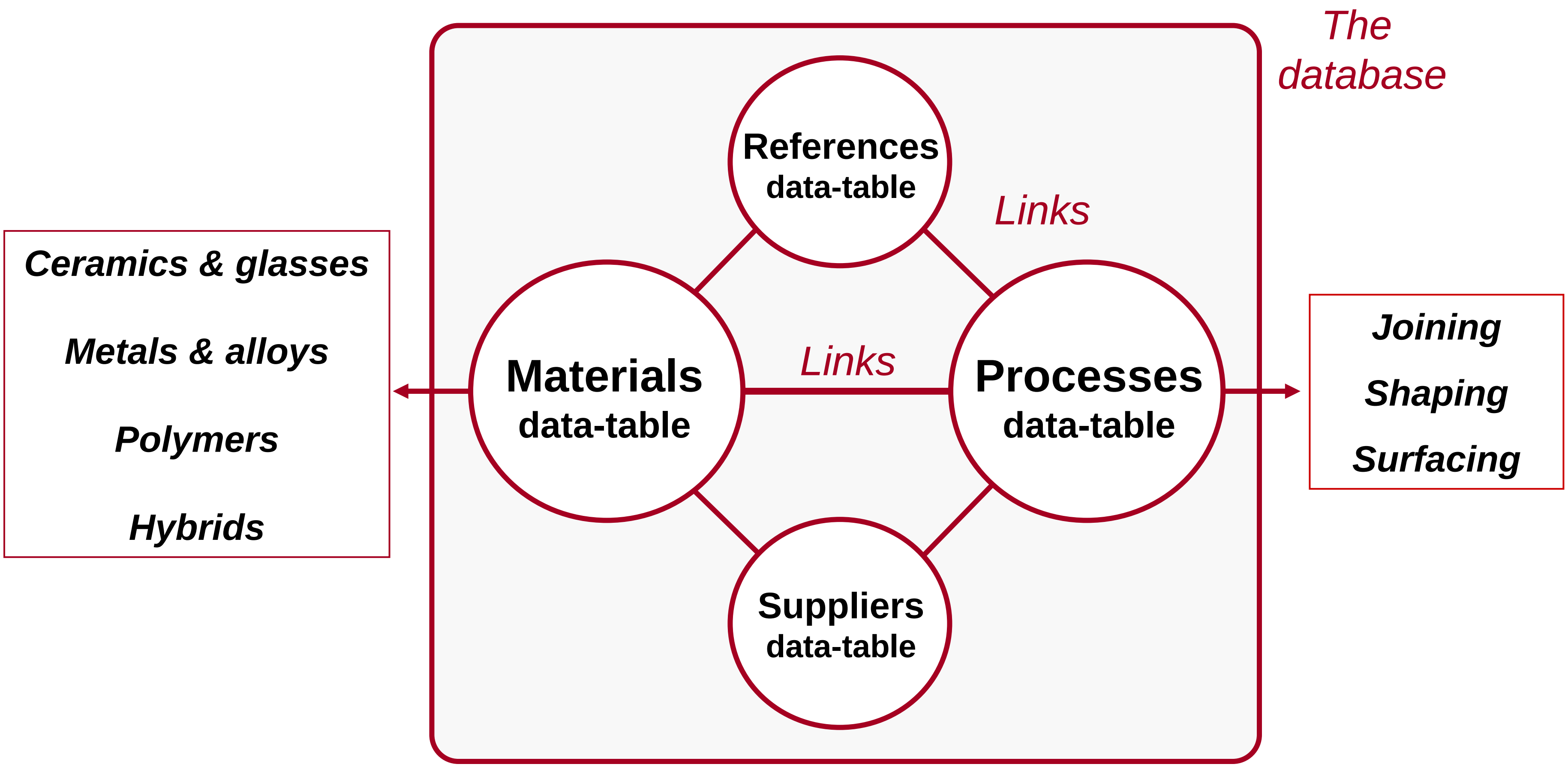
Level 3

- **4th year**, **masters** and **research** students of Engineering Materials and Design.

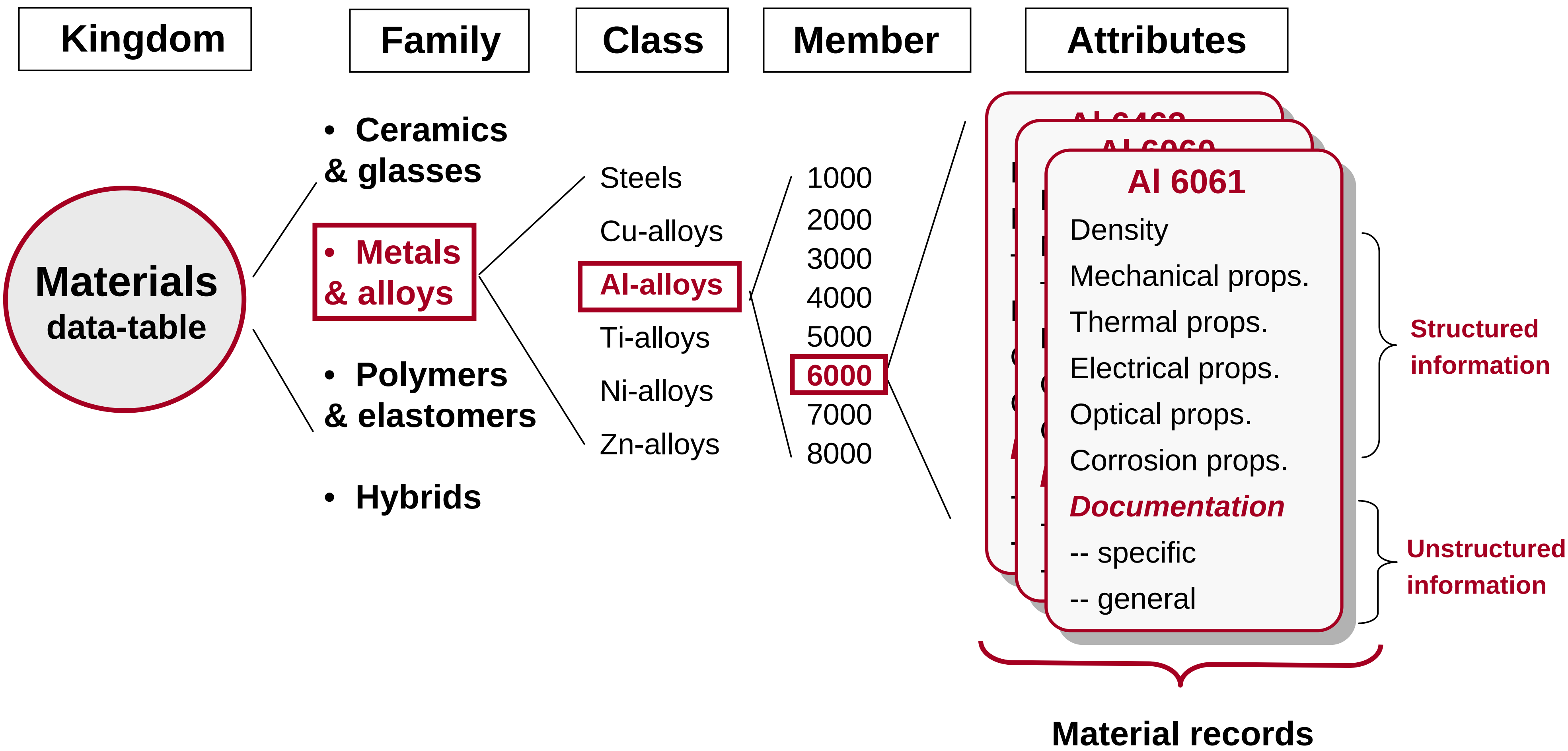
2916 materials, **233** processes

Materials science | **Polymer engineering** | **Mechanical engineering** | **Aeronautical engineering** | **Architecture & civil eng**

The structure of the CES Edu database



Organizing information: the MATERIALS TREE



Structured information for ABS*

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

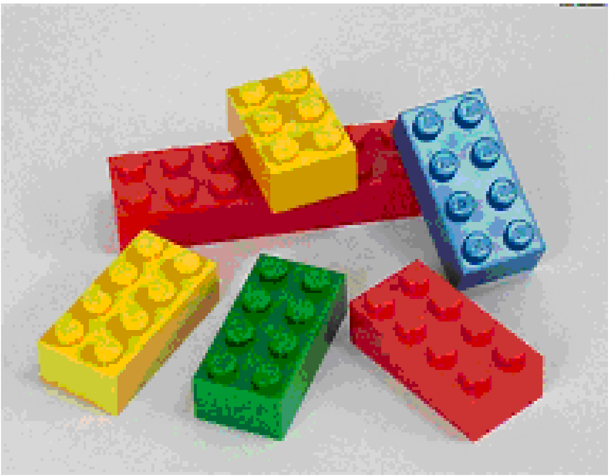
Corrosion and Wear Resistance

Flammability	Average
Fresh Water	Good
Organic Solvents	Average
Oxidation at 500C	Very Poor
Sea Water	Good
Strong Acid	Good
Strong Alkalis	Good
UV	Good
Wear	Poor

+ links to processes

Unstructured information for ABS*

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.

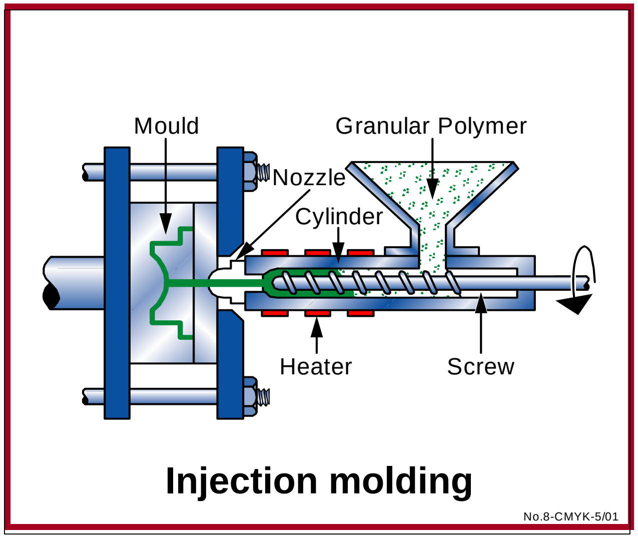
Technical notes. ABS is a terpolymer - one made by copolymerising 3 monomers: acrylonitrile, butadiene and syrene. The acrylonitrile gives thermal and chemical resistance, rubber-like butadiene gives ductility and strength, the styrene gives a glossy surface, ease of machining and a lower cost. In ASA, 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.

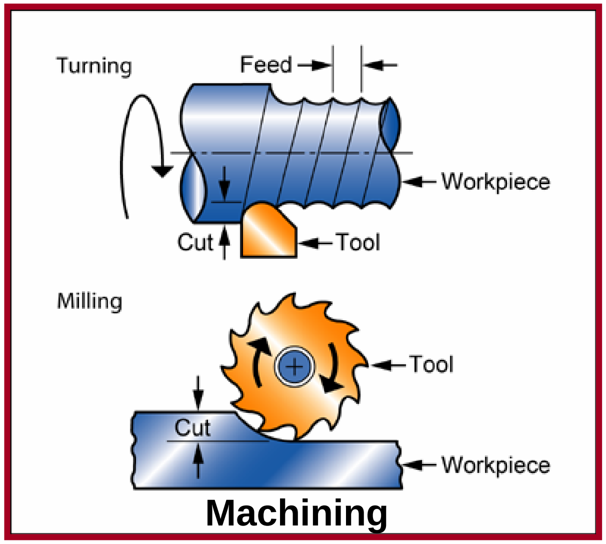
The world of manufacturing processes

Primary shaping



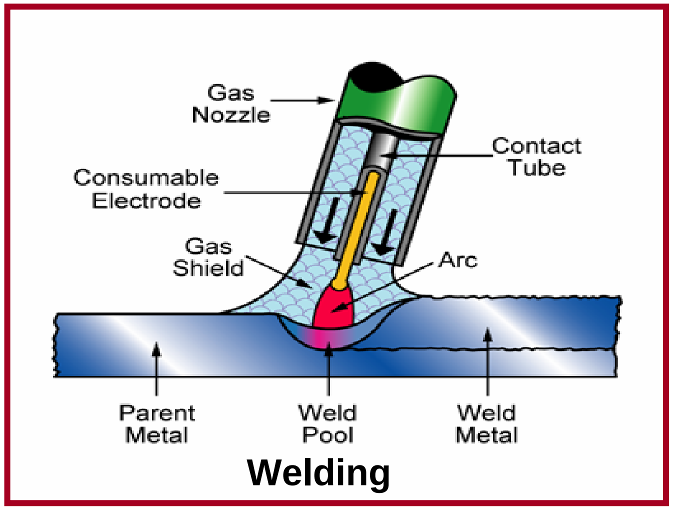
Injection molding

Secondary shaping



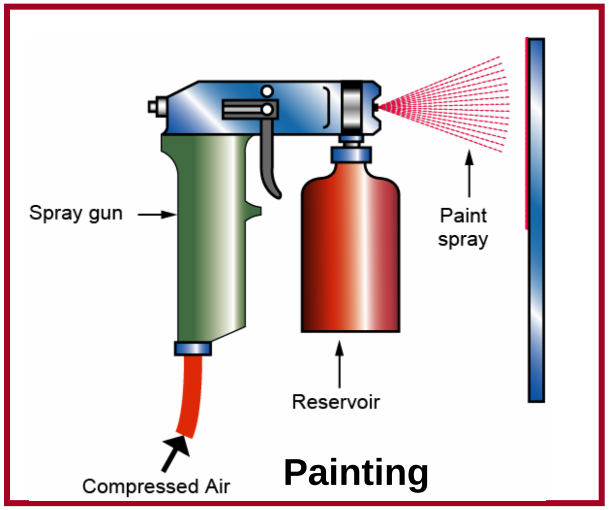
Machining

Joining



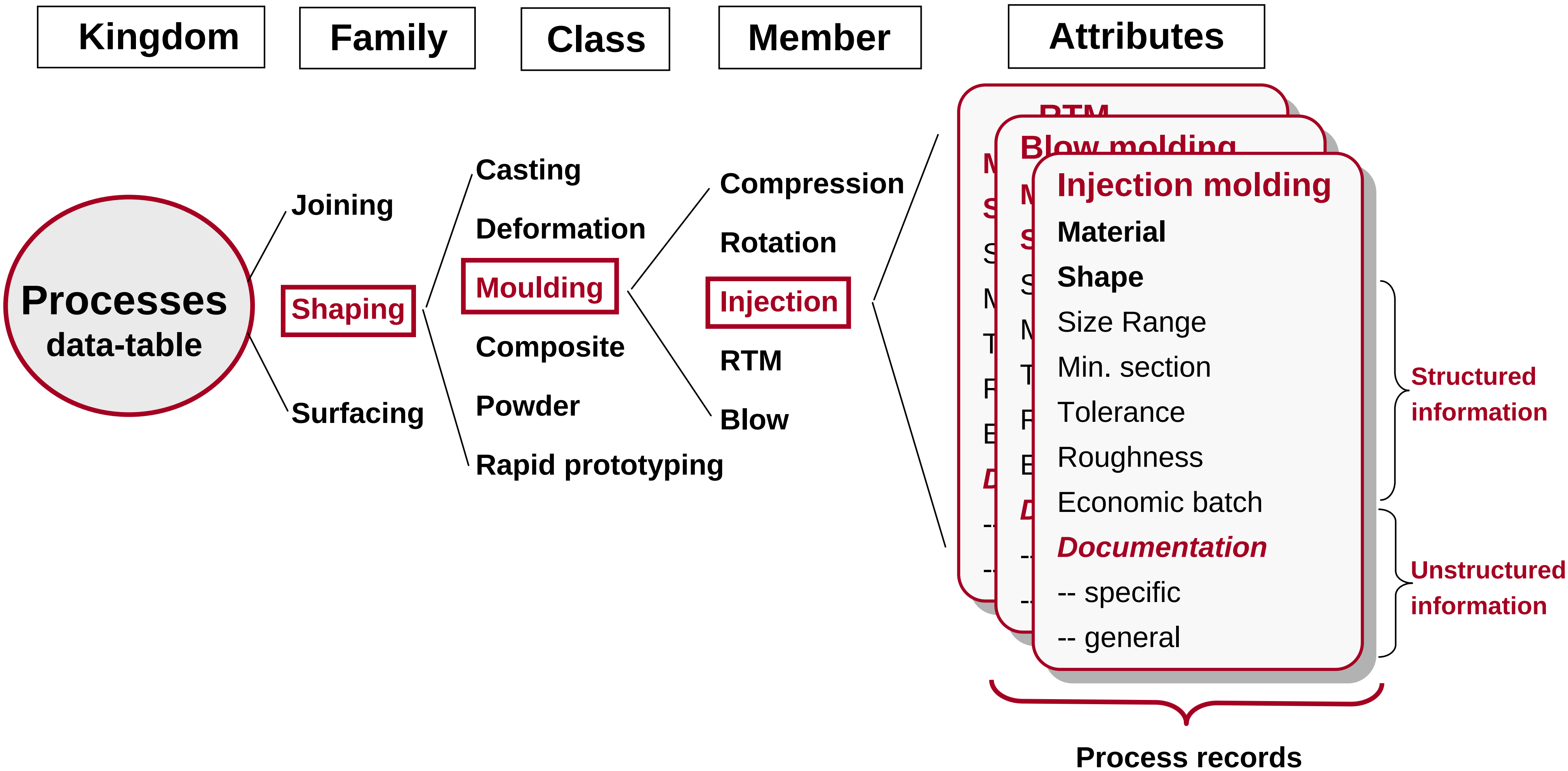
Welding

Surface treating



Painting

Organizing information: the PROCESS TREE



Structured information for Injection Molding

Physical Attributes

Mass range	0.001 – 25	kg
Section thickness	$4e^{-4}$ – $6.3e^{-3}$	m
Tolerance	$7e^{-5}$ – 1e-3	m
Roughness	0.2 – 1.6	µm
Surface roughness (A=v. smooth)	A	

Process Characteristics

Discrete	✓

Economic Attributes

Economic batch size (units)	$1e^{4}$ – $1e^{6}$
Relative tooling cost	very high
Relative equipment cost	high
Labor intensity	low

Cost Modeling

Relative cost index (per unit) *421.4-6625

Parameters: Material Cost = 10USD/kg, Component Mass = 1kg, Batch Size = 1000, Overhead Rate = 110USD/hr, Capital Write-off Time = $1.577e^{8}$s, Load Factor = 0.5

Capital cost	*$2e^{4}$-$4.5e^{5}$ USD
Material utilization fraction	*0.6-0.9
Production rate (units)	*0.01667-0.2778/s
Tooling cost	*2000-$2e^{4}$USD
Tool life (units)	*$1e^{4}$-$1e^{6}$

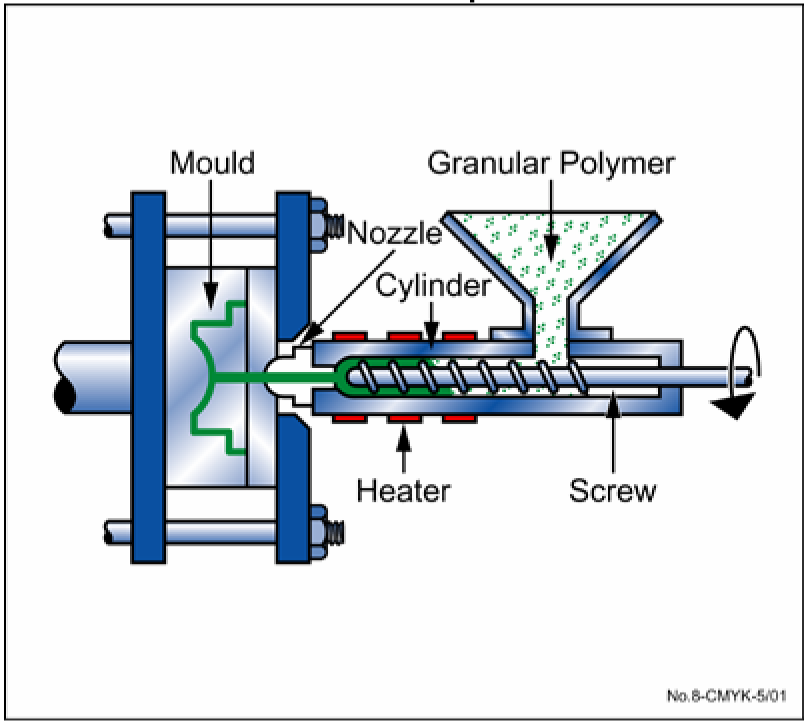
Shape

Circular prismatic	✓
Non-circular prismatic	✓
Solid 3-D	✓
Hollow 3-D	✓

Unstructured information about Injection Molding

Design guidelines

Injection molding is the best way to mass-produce small, precise, polymer components with complex shapes. The surface finish is good; texture and pattern can be easily altered in the tool, and fine detail reproduces well. Decorative labels can be molded onto the surface of the component (see In-mold Decoration). The only finishing operation is the removal of the sprue.



Unstructured information about Injection Molding

Technical notes

Most thermoplastics can be injection molded, although those with high melting temperatures (e.g. PTFE) are difficult. Thermoplastic-based composites (short fiber and particulate filled) can be processed providing the filler-loading is not too large. Large changes in section area are not recommended. Small re-entrant angles and complex shapes are possible, though some features (e.g. undercuts, screw threads, inserts) may result in increased tooling costs. The process may also be used with thermosets and elastomers. The most common equipment for molding thermoplastics is the reciprocating screw machine, shown schematically in the figure. Polymer granules are fed into a spiral press where they mix and soften to a dough-like consistency that can be forced through one or more channels ('sprues') into the die. The polymer solidifies under pressure and the component is then ejected.

Typical uses

Extremely varied. Housings, containers, covers, knobs, tool handles, plumbing fittings, lenses, etc.

The economics

Capital cost are medium to high, tooling costs are usually high - making injection molding economic only for large batch sizes. Production rate can be high particularly for small moldings. Multi-cavity molds are often used. Prototype moldings can be made using single cavity molds of cheaper materials. Typical products. Housings, containers, covers, knobs, tool handles, plumbing fittings, lenses.

The environment

Thermoplastic sprues can be recycled. Extraction fans may be required for volatile fumes. Significant dust exposures may occur in the formulation of the resins. Thermostatic controller malfunctions can be hazardous.

Finding information with CES

File   Edit   View   Select   Tools

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

Table: ***MaterialUniverse***

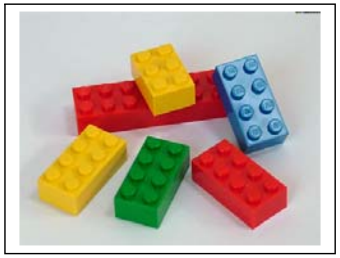
Subset: ***Edu Level 1***

MaterialUniverse
- + **Ceramics and glasses**
- + **Hybrids: composites etc**
- + **Metals and alloys**
- + **Polymers and elastomers**

Find what ***Plexiglas***

Look in table ***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	1e3	-	1.2e3	kg/m^3
Price	2	-	2.7	USD/kg

Mechanical properties

Young's modulus	1.1	-	2.9	GPa
Hardness - Vickers	5.6	-	15	HV
Elastic limit	19	-	51	MPa
Tensile strength	28	-	55	MPa
Compressive strength	31	-	86	MPa
Elongation	1.5	-	1e2	%
Endurance limit	11	-	22	MPa
Fracture toughness	1.2	-	4.3	MPa.m$^{1/2}$

Thermal properties

Thermal conductivity	0.19	-	0.34	W/m.K
Thermal expansion	85	-	230	µstrain/°C
Specific heat	1400	-	1900	J/kg.K
Glass Temperature	88	-	130	°C
Max service temp.	62	-	90	°C

Electrical properties

Resistivity	2.3e21	-	3e22	µohm.cm
Dielectric constant	2.8	-	2.2	

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.

Finding information with CES

File   Edit   View   Select   Tools

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

Table: ***ProcessUniverse***

Subset: ***Edu Level 1***

ProcessUniverse

- [+] **Joining**
- [+] **Shaping**
- [+] **Surface treatment**

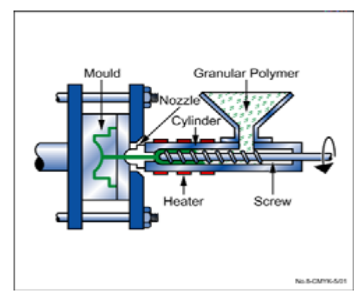
Find what ***RTM***

Look in table ***Process***

Injection molding molding, thermoplastics

The process

No other process has changed product design more than INJECTION MOULDING. Injection molded products appear in every sector of product design: consumer products, business, industrial, computers, communication, medical and research products, toys, cosmetic packaging and sports equipment. The most common equipment for molding thermoplastics is the reciprocating screw machine, shown schematically in the figure. Polymer granules are fed into a spiral press where they mix and soften to a dough-like consistency that can be forced through one or more channels ('sprues') into the die. The polymer solidifies under pressure and the component is then ejected.



Shape

Circular Prismatic	True
Non-circular Prismatic	True
Solid 3-D	True
Hollow 3-D	True

Physical Attributes

Mass range	1e-3-25kg
Range of section thickness	0.4-6.3mm
Surface roughness	(A=v. smooth) A

Physical Attributes

Mass range1e-	3-25kg
Range of section thickness0.	4-6.3mm
Surface roughness (A=v. smooth)	A

Economic Attributes

Economic batch size (units)	1e4-1e6
Relative tooling cost	very high
Relative equipment cost	high
Labor intensity	low

Typical uses

Extremely varied. Housings, containers, covers, knobs, tool handles, plumbing fittings, lenses, etc.

Adding the science

Age hardening ALUMINUM ALLOYS

The material

The high-strength aluminum alloys rely on age-hardening: a sequence of heat treatment steps that causes the precipitation of a nano-scale dispersion of intermetallics that impede dislocation motion and impart streng

General properties

Density	2500	-	2900	kg/m^3
Price	1.423	-	2.305	USD/k

Mechanical properties

Young's modulus	68	-	80	GPa
Elastic limit	95	-	610	MPa
Tensile strength	180	-	620	MPa
Elongation	1	-	20	%
Hardness - Vickers	60	-	160	HV
Fatigue strength at 10^7 cycles	57	-	210	MPa
Fracture toughness	21	-	35	MPa.m

Thermal properties

Thermal conductor or insulator?	Good conductor			
Thermal conductivity	118	-	174	W/m.K
Thermal expansion	22	-	24	µstrain
Specific heat	890	-	1020	J/kg.K
Melting point	495	-	640	°C
Maximum service temperature	120	-	170	°C

Electrical properties

Electrical conductor or insulator?	Good conductor

Young's modulus

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Fatigue strength at 10^7 cycles

Definition……

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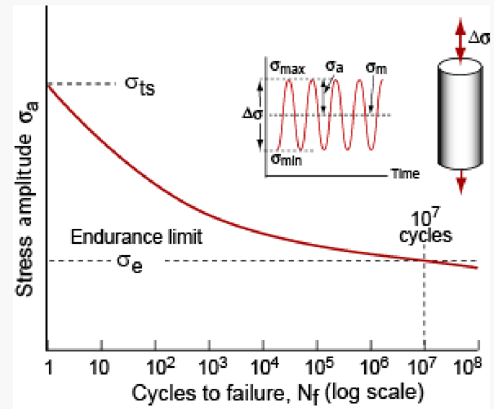

Measurement

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Origins

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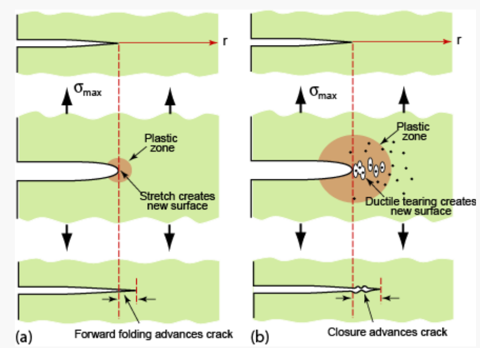


The main points

- **Classification** allows materials data to be organized and retrieved

- The data take two broad forms:

  (a) **numeric, non-numeric data** that can be **structured** in a uniform way for all materials

  (b) **documentation,** usually in the form of text and images

- **CES allows** rapid access to information by
  - **Browsing**
  - **Searching**
  - **Exploring the science**

Pause for demo

Exercises: Browsing

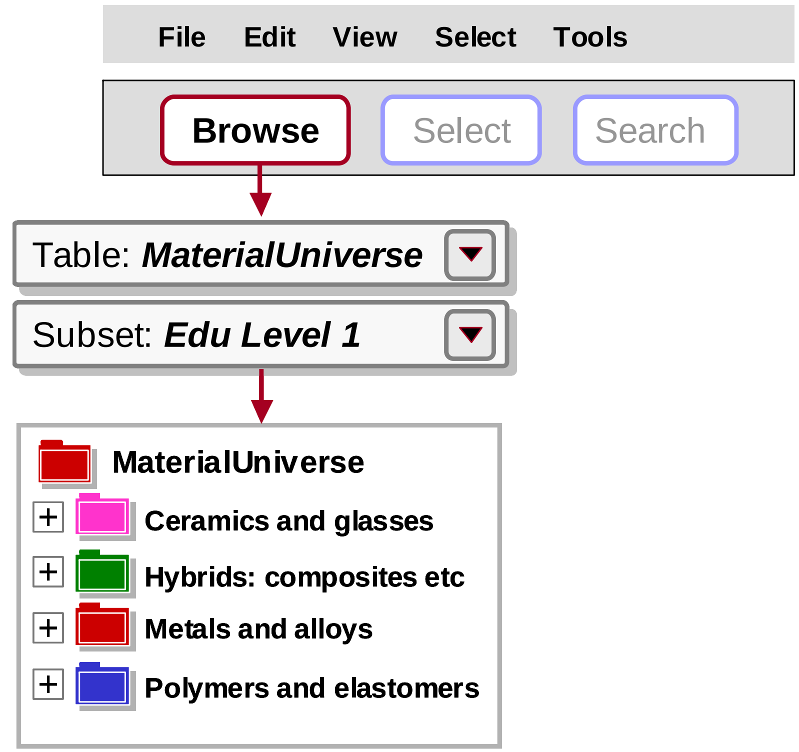
1.1 Find, by browsing, the *Level 1* record for ***Titanium alloys*** in Metals and alloys: Non-ferrous

1.2 Find the *Level 1* record for ***Phenolics*** in Polymers and elastomers: Thermosets

1.3 Find the *Level 1* record for ***Alumina*** in Ceramics and and elastomers: Technical ceramics

1.4 Find the *Level 2* record for ***Age-hardening wrought aluminum alloys*** in in Metals and alloys: Non-ferrous: Aluminum alloys

1.5 Find the *Level 2* record for ***Plywood*** in in Hybrids: Natural materials



Exercises: Searching

1.6 Find, by searching, the record for ***Polylactide***: what is it?

Answer: Polylactide, PLA, is a biodegradable thermoplastic derived from corn.

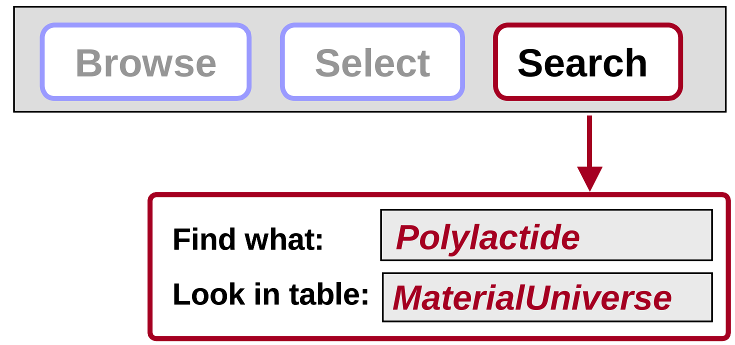
1.7 Find records for materials that are used for ***Lenses***: what are they?

Answer: Silicon, Polyamides (PA), Polycarbonate (PC) and Acrylic (PMMA).

1.8 Find records for any material that is a ***Biopolymer.***

Answer:

- Natural rubber (NR);
- Cellulose polymers (CA);
- Polylactide (PLA);
- Poly_something_unpronounceable (PHA, PBA);
- Starch-based thermoplastics (TPS)



Exercises: Exploring the science

1.9 How is *Fracture toughness* measured?

Answer: ***Definition and measurement.*** The fracture toughness, , (units: MPa $m^{1/2}$ or $MN/m^{1/2}$) measures the resistance of a material to the propagation of a crack. It is measured by loading a sample containing a deliberately-introduced contained crack of length or a surface crack of length (Figure 1), recording the tensile stress or the bending load at which the crack suddenly propagates.

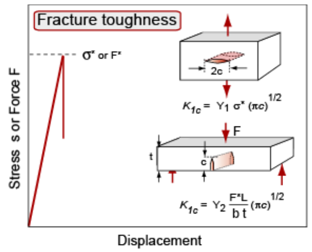
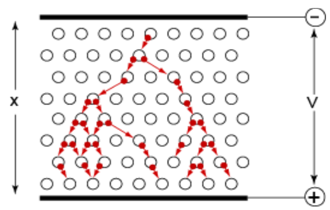


Figure 1. Measuring fracture toughness, K_{1C}.

1.10 What does *Dielectric breakdown* mean?

Answer: ***Definition and measurement.*** The *breakdown potential gradient* or *dielectric strength* (units: MV/m) is the electrical potential gradient at which an insulator breaks down and a damaging surge of current like a lightning strike flows through it.



Breakdown involves a cascade of electrons like a lightning strike.

1.11 What is meant by the *CO_2 footprint* of a material?

Answer: The CO_2 footprint per unit weight, using PET as an example, is

$$(CO_2)_{PET} = \frac{\sum Mass\ \ of\ \ CO_2\ directly\ arising\ from\ PET\ production\ \ per\ \ year}{Mass\ \ of\ \ PET\ \ shipped\ \ per\ \ year}$$

Mechanical properties

- Young's modulus
- Fracture toughness
- ……..

Thermal properties

- Thermal conductivity
- Maximum use temperature
- ……..

Electrical properties

- Electrical conductivity
- Dielectric strength
- ……..

Eco properties

- Embodied energy
- CO_2 footprint
- ……..

Young's modulus

Definition……………………………
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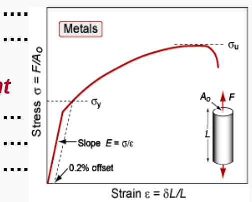

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