History of Packaging

• 6000 B.C. Clay vessels (Keramos=krukmakarlera)
• 2500 B.C.= Glass pearls in Babylonia
• 1500 B.C.= Glass vessels in Egypt
• 1000 B.C.= Blowing glass in Syria
• 1600 B.C.= Glass bottles in Sveden
• 0-500 A.D.=Wood barrels in the Roman empire
• 1300 century=""Laggade“ wood barrels in Sweden

The packaging history

• 1600’s = Paper in Sweden
• 1800’s = Paper machine
• 1850’s = Machine made bags
• 1871 = Corrugated board
• 1812= Canning technique, Napoleon (tin cans)

• 1950’s= Plastics in packagings

• New needs: 18000 manual stores (1950), 1000 in 1975
The packaging -the myth-
Material need for 500 g coffee

• Glass 470 g
• Plate 120 g
• Laminate 11 g

A car full of laminate packagings replaces three cars with glass packagings for the same amount of coffee

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Estimated end uses of plastics, by weight

- Packaging: 37%
- Building and construction: 23%
- Electrical and electronic: 10%
- Transport: 9%
- Furniture: 5%
- Housewares: 3%
- Agriculture: 2%
- Medical: 2%
- Sport: 2%
- Clothing: 1%
- Others: 3%
Materials

Polyethylene
Polypropylene
Polyamide
Polystyrene
PVC
PETP
Polycarbonate
Epoxy
PUR

Polyethylene
VLDPE, LDPE, LLDPE, MDPE, HDPE, UHMWPE

• $T_g \approx -70^\circ C$
• $T_m \approx 105-140^\circ C$

+ • high toughness
  • resistant to chemicals
  • low price
  • low water absorption

- • low creep resistance
  • high shrinkage
  • UV-sensitive
  • difficult to glue

• pipes, cables
• packaging
• housewares
**Polyethylene copolymers**

polar copolymers, E/VA, E/BA

- High toughness
- Transparent
- Easy to glue
- Higher water absorption
- Weaker than HDPE

- Tie-layer in laminates
- Packagings, cable insulations
- Emulsion paints

**Aseptic packaging**

Aseptic packaging with PE

Hydrogen peroxide
Extrusion Blow Molding

HDPE bottles for milk
Extrusion blow molding

Shrink film

PVC and polyolefins

Stretch film at softened state (but below melting T)

Tenter frame or bubble process to yield uni- or biaxial orientation

Heat will cause shrinkage
**Stretch film**

Elastic-plastic film
LLDPE, PVC or EVA
Cast (clear) or blown (hazy) films

Blown film with cling properties:
Polyisobutylene tackifier

"Clings only to itself"

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**Extrusion coating**
PE or PP bags

-30 µm films (bags/packagings)
-250 µm films (2 m wide LDPE, low MFI construction, extension max. 1:1.8)

Shrink films (1:3, 1:5)

"Bubble, tubular or blown film process"

Position of blowing equipment

Thin films 40 m/min

- Easy start, high melt strength
- Short distance for melt, PVC
- Large thick parts

Frostline

Important: temperature control (even thickness)
**Polypropylene**

![Chemical Structure of Polypropylene](image)

- $T_g \approx -10^\circ C$
- $T_m \approx 165^\circ C$

**Pros:**
- stiffer than HDPE
- low density
- steam sterilisation
- high fatigue strength

**Cons:**
- brittle below $-20^\circ C$
- UV-sensitive
- relatively difficult to glue

- car panels
- ropes, pipes
- chassis
- packagings

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**Blow-fill-seal (BFS)**

Blow-fill-seal (BFS) process flow diagrams and images of BFS products are shown.
Oriented PP

Hot filling

Kill microorganisms
Lower viscosity of food

Jam
Fruit juices
Tea
Ketchup

77-100°C
**Polyamide (PA)**

PA6, PA6,6

- T_g ≈ 50°C
- T_m ≈ 175°C

- abrasion resistant
- fatigue and creep resistant
- high chemical resistance
- can endure high T
- UV-sensitive
- high water absorption

- gears
- screws
- cable isolation
- oil-contact applications

**Polystyrene (PS)**

- T_g ≈ 100°C

- low mould shrinkage
- hard, stiff
- low price
- brittle (HIPS, ABS tough)
- low T_g
- low chemical resistance
- UV-sensitive

- Packaging (HIPS)
- Cellplastics (EPS)
- Cars, whitewares (ABS)
High impact polystyrene (HIPS)

Acrylonitrile-butadiene-styrene (ABS)
Thermoforming PS and others

Expanded polystyrene
Blowing agents

- Polymers in a cellular form are used in very large volumes for thermal insulation and "soft damping" (furnitures)
- Cells can be interconnected or not.
- Different gases can be housed in the cells

Blowing agents-mechanisms

- Chemical blowing agents: compounds decompose at some stage to yield volatile species (ex. Azocarbonamide yields CO, CO₂ and N₂)
- Incorporation of low boiling liquids which volatilise during processing (PS, PUR)
- Diffusion of gases into polymer under pressure with subsequent expansion at elevated temp. under decompression (a wide variety of polymers)
- Incorporation of solid CO₂ in plastic (plasticized PVC)
- Mechanical whipping of liquid - setting of whipped state (latex rubber foam)
PETP
Poly(ethylene terephthalate)

\[
\begin{array}{c}
\text{HOOC} \\
\text{O} \\
\text{CH}_2 \\
\text{C} \\
\text{H}_2 \text{O} \\
\text{Cl}
\end{array}
\]

\[n\]

+ • stiff, hard
• good chemical resistance
• UV-resistant
• creep resistant in dry conditions
-
• sensitive to hydrolysis
• high mould shrinkage/warping
• low ductility at cracks

PETP copolymers

1, 4 - Cyclohexane dimethanol
Isophthalic acid

PETP
\[\rightarrow\]
aPET

\[\rightarrow\]
CPET

High melt strength and amorphous material
Extruded sheet for blister-pack applications

QuickTime och en TIFF (LZW)-dekomprimerare krävs för att kunna se bilden.
PETP copolymers

CPET

Longer alkane part ("PBT")
Plasticisers
Nucleating fillers

PETP bottles

PETP bottles ("homopolymer")
Stretch blow molding

Biaxial orientation ≤40% crystallinity
Biaxially oriented PETP (tenter process)

Property: MD

<table>
<thead>
<tr>
<th>Property</th>
<th>MD</th>
<th>TD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate tensile strength (MPa)</td>
<td>200</td>
<td>240</td>
</tr>
<tr>
<td>Strength at 5% strain (MPa)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Modulus (GPa)</td>
<td>4.9</td>
<td>5.1</td>
</tr>
</tbody>
</table>
**Blister packs**

*aPET*

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**Foamed PETP**

**Low density**

*BLOWING AGENTS*

- HFC 134A
- HFC 152A
- Blend 152A/134A
- CO$_2$
- $n$-hexane
- $iso$-pentane
- $n$-heptane
- N$_2$

*Extrusion Foaming Line Scheme*
**PVC**

Poly(vinyl chloride)

- $T_g \approx 80^\circ C$

**Pros:**
- High chemical resistance
- Stiff
- Low price

**Cons:**
- Brittle at low $T$
- Low $T_g$

- Leather imitations
- Cables
- Pipes
- Construction

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**PVC Bags**

- Blow casing or calendering
- RF welding

QuickTime och en TIFF (LZW)-dekomprimerare krävs för att kunna se bilden.
Thermoformed rigid PVC as clam-shells

Polycarbonate (PC)

\[
\text{CH}_3 \quad \text{CH}_3 \quad \text{OC} \quad \text{OC} \quad \text{O} \quad \text{O} \quad \text{CH}_3 \quad \text{CH}_3
\]

- \( T_g \approx 150^\circ \text{C} \)
- \( + \)
  - excellent ductility (also at low T)
  - good weatherability
  - glassfiber
  - creep resistant in dry conditions
- 
  - sensitive to hot water
  - environmental stress cracking
  - scratch sensitive

- safety glass
- propellants
- helmets
- CD/DVD
Polycarbonate (PC)

- excellent adhesion
- abrasion resistant
- stiff, hard
- chemical resistance
- dimensional stability

\[
\text{HO C} \quad \text{CH}_3
\]

\[
\text{CH}_3
\quad \text{CH}_3
\]

crosslinked with a diamin

Epoxy

+ excellent adhesion
+ abrasion resistant
+ stiff, hard
+ chemical resistance
+ dimensional stability

- sensitive to alcohol
- monomers unhealthy

- paints, lacquers, glue
- coating of metals
- encapsulation of electric components
Aluminium cans

Epoxy coatings

**PUR**

polyurethane thermoset

- stiff, ductile, abrasion resistant
- chemical resistance
- large range in properties
- UV resistant

- smoke and dang. gases upon fire
- opaque

• electronic incapsulation, casings
• prototypes
**PUR**

polyurethane cellplastics (stiff)

- stiff, ductile, abrasion resistant
- chemical resistance
- low heat conduction
- low mold pressure
- UV-sensitive
- smoke and dang. gases upon fire

\[
\text{HO-CH} + \text{NCO-OR} \rightarrow \text{HOO} \quad \text{+ water = CO}_2 \text{ and cellplastic}
\]

- casings, covers
- furnitures