The Global Petrochemical Industry:
Understanding the Complex Interactions Between Technology, Economics and Markets

Manuel Asali
Vice President
masali@nexant.com
Section 3

Propylene and derivatives
Cumene, phenol and acetone
The cumene value chain

BENZENE AND PROPYLENE → CUMENE → ACETONE → PHENOL → CAPROLACTAM → NYLON 6

CYCLOHEXANONE\(^{(1)}\) → PHENOL → PHENOLIC RESINS

METHYL METHACRYLATE → SOLVENTS

BISPHENOL A → EPOXY RESINS → POLYCARBONATES

\(^{(1)}\) Most cyclohexanone is made from benzene
Cumene and phenol top producers, 2018

The top 10 represents 52 percent of cumene and 60 percent of phenol

Source: Nexant
Cross-linked phenol–formaldehyde resin (bakelite)

Leo Baekeland

GPO 300 Series – Bakelite Black

Phenol-Formaldehyde Resin

\[
\text{Phenol} + 3 \text{H}_2\text{C}=\text{O} \xrightarrow{\text{heat}} \text{Phenol-Formaldehyde Resin} \]

Bakelite (a cross-linked solid)
Bakelite (phenol-formaldehyde resin)
“The material for a thousand uses”
Bisphenol A formation

\[
2 \text{PHENOL} + \text{CH}_3\text{C-CH}_3 \rightarrow \text{HO} - \text{C} = \text{C} - \text{CH}_3 \text{CH}_3 + \text{HO} - \text{C} = \text{C} - \text{CH}_3 \text{CH}_3
\]

The mixture is useful for most epoxy resin grades. The \( p, p' \) - isomer is necessary for polycarbonates and the lesser volume engineering resins such as polysulfones, polyarylates, and poly(ether imides).
BPA under pressure for toxicity reasons

Feb 27, 2007 11:37 am US/Pacific
Report: Plastic Baby Bottles Leach Toxic Chemical
Chemical Used To Make Plastic Released Into Liquid

Critics claim BPA mimics the female hormone estrogen, is linked to:
birth defects in boys, heart disease in adults, lower sperm counts, diabetes,
hyperactivity, miscarriage and breast cancer in animals

Many Industry sponsored studies dispute these findings.
BPA free photo

GO BPA FREE™
BABY BOTTLE SAMPLER
Epoxy resins - a value chain

- Propylene
- Allyl chloride
- Cumene
- Benzene
- Phenol
- Acetone
- Epichlorohydrin
- Bisphenol A
- Epoxy resins
Epoxy – two-part formulation
Global epoxy resin demand, 2018

**Demand by End-Use**

- Coatings: 54%
- Electrical/Electronics: 18%
- Composites: 10%
- Construction: 8%
- Adhesives/Sealants: 7%
- Others: 3%

Global Demand = 2.6 Million Tons

**Demand by Region**

- Asia Pacific: 62%
- Western Europe: 18%
- North America: 15%
- ROW: 5%

Source: Nexant
Epoxy coatings

- Powder coating
- UV inks
- Marine coatings
- Coil and can coatings
- Automotive coatings
- Seamless Flooring
Epoxy resin applications

- Composites
- Electrical Encapsulation
- Electronic Laminations
- Adhesives
- Civil engineering
- Carbon Fiber / Epoxy Composite
New Boeing 787 constructed of 50% carbon/epoxy composite
The Big 3 have been evolving

Dow
Shell Chemical Company
Ciba

Olin EPOXY
HEXION Specialty Chemicals
Huntsman
Polycarbonate formation

Phase Transfer Catalyst

\[ \text{Bisphenol A (Water)} \quad \overset{\text{Phosgene}}{\longrightarrow} \quad \text{Polycarbonate} \]

\[ n \text{NaO} - \text{CH}_3 - \text{C} - \text{CH}_3 - \text{ONa} + n\text{COCl}_2 \rightarrow [\text{O} - \text{C} - \text{CH}_3 - \text{CH}_3 - \text{O}_\text{C} - \text{O} - \text{C} - \text{O}]_n + 2n\text{NaCl} \]
<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>Impact resistance</td>
<td>Poor solvent resistance</td>
</tr>
<tr>
<td>Ductility</td>
<td>Poor abrasion resistance</td>
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<tr>
<td>Clarity</td>
<td>Limited UV resistance</td>
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<tr>
<td>Dimensional stability</td>
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<tr>
<td>Creep resistance</td>
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<tr>
<td>Rigidity</td>
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<td>High temperature resistance</td>
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<tr>
<td>Electrical properties</td>
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<td>Inherent fire resistance</td>
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Polycarbonate innovation timeline

1953: Dr. Daniel Fox invents PC

1962: Astronaut helmet

1968: PC sheets

1978: Auto light lenses

1980: Auto instrument panels

1984: Compact discs (CDs)

1990: Eye lenses

1994: Flip phones

1996: DVDs

1998: Consumer electronics
Polycarbonate end-use products

Kartell chair
The polymer industry evolves with music

Phenolic resins

PVC (Vinyl)

PS case, PET tape

1980s: CD (Polycarbonate)

From 2001… Multiple polymers (PMMA, PC/ABS, etc.)
Global polycarbonate producers 2018

Top 10 Represents 85 percent of Global Capacity
Global polycarbonate demand, 2018

**Demand by End-Use**

- Electrical & Electronics: 28%
- Construction: 12%
- Automotive: 15%
- Optical media: 11%
- Others: 27%

**Global Demand = 4.4 Million Tons**

**Demand by Region**

- AP: Asia Pacific (59%)
- WE: Western Europe (16%)
- NA: North America (14%)
- SA: South America (2%)
- ME: Middle East (2%)
- CE/EE: Central/Eastern Europe (7%)
- Africa (0.5%)
Many routes to MMA

Conventional Route

Japanese Route

BASF, Lucite
One of the first uses for PMMA (PLEXIGLAS)

In 1943 alone, the U.S. produced 86 000 warplanes and R&H sold 22 million dollars of Plexiglas
PMMA in the Battle of Britain!

MESSERSCHMITT (Plexiglas)

ICI

SPITFIRE (Perspex)
Polymethylmethacrylate (PMMA)
Thank you!

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