How we develop the best process for methyl methacrylate
What methacrylates are used for

**Construction**
- Chemical dowels
- Cement additives

**Electronics**
- Optical specialty products for LED applications

**Automotive**
- Rear lights
- Car body panels

**Aerospace industry**
- Cabin windows

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**MMA and derivatives**

**Pharmaceuticals and medical tech**
- Tablet coatings
- Implants

**Raw-material extraction**
- Flow improver for oil and gas transportation

**Paints and coatings**
- Gloss effects
- Brilliant depth effect

**Communication**
- Light-guiding PMMA films
How MMA is produced

**SHARE OF GLOBAL PRODUCTION CAPACITY (2017)**

- **C3 ACH sulfo process**
  - Acetone
  - 60%
  - MMA (Methyl-Meth-Acrylate)

- **C4 Direct oxidation**
  - Isobutene
  - 30%

- **C2 ALPHA process**
  - Ethylene
  - <10%

Petroleum Natural gas → Cracker
LiMA combines proven technology and our own development

Development goals

- Higher efficiency
- Less environmental impact
- Higher supply reliability

LiMA (Leading in MethAcrylates) process overview

Proven technology

- Ethylene ($\text{C}_2\text{H}_4$)
- Synthesis gas ($\text{CO}/\text{H}_2$)
- Natural gas
- Air ($\text{O}_2$)
- Methanol ($\text{CH}_3\text{OH}$)

Evonik’s development

- Propionaldehyde ($\text{C}_3\text{H}_6\text{O}$)
- Formalin ($\text{CH}_2\text{O}$)
- Methacrolein
- Direct Oxidative Esterification (DOE)
- MMA

October 5, 2017 | R&D Press Briefing | How we develop the best process for methyl methacrylate
LiMA uses an intelligent process and an efficient catalyst

- Higher efficiency
- Less environmental impact
- Higher supply reliability
LiMA is best in class for production of MMA

- Higher efficiency
- Less environmental impact
- Higher supply reliability

- Fewer emissions
  - High raw-material efficiency
  - High plant availability
  - Improved raw-material availability
  - Simplified process

- Intelligent process
- Efficient catalyst
How LiMA increases efficiency

**INTELLIGENT PROCESS**
- Robust technology: All steps in the liquid phase under moderate reaction conditions
- This leads to increased availability and minimizes technical complexity

**EFFICIENT CATALYST**
- High selectivity leads to almost complete raw material yield
- This increases the overall yield to more than 90%

Yields of the various processes

<table>
<thead>
<tr>
<th>Process</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4 process</td>
<td>65%</td>
</tr>
<tr>
<td>C3 process</td>
<td>87%</td>
</tr>
<tr>
<td>C2 ALPHA</td>
<td>~90%</td>
</tr>
<tr>
<td>LiMA</td>
<td>&gt;90%</td>
</tr>
</tbody>
</table>

Source: PERP08/09-07, Nexant Inc.
How LiMA decreases environmental impact

**INTELLIGENT PROCESS**
- Low wastewater streams, reduced recycle streams
- This simplifies the overall process and minimizes energy and steam requirements

**EFFICIENT CATALYST**
- Catalyst is highly active at moderate temperatures
- This minimizes by-products and reduces wastewater volumes and thus CO₂ emissions

Metric tons CO₂ equivalent per metric ton of MMA (industry average)

<table>
<thead>
<tr>
<th>Process</th>
<th>CO₂ Emission (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4 process</td>
<td>4.5</td>
</tr>
<tr>
<td>C3 process</td>
<td>3.7</td>
</tr>
<tr>
<td>C2 ALPHA</td>
<td>3.8</td>
</tr>
<tr>
<td>LiMA</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Source: CEFIC, internal calculation
How LiMA improves supply reliability

INTELLIGENT PROCESS
- Ethylene and methanol can be used highly efficiently as raw-material sources
- Their excellent availability ensures sustainable supply and economy of scale

EFFICIENT CATALYST
- New catalyst accesses C2 raw-material sources for MMA production
- LiMA complements Evonik’s range of raw materials

Global annual production in millions of metric tons

Source: IHS Markit

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Global Annual Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4 - Isobutene</td>
<td>15</td>
</tr>
<tr>
<td>C3 - Acetone</td>
<td>5</td>
</tr>
<tr>
<td>C2 - Methanol</td>
<td>75</td>
</tr>
<tr>
<td>C2 - Ethylene</td>
<td>150</td>
</tr>
</tbody>
</table>
LiMA shows outstanding results in pilot operation

ROBUST TECHNOLOGY
More than 8,000 hours of pilot production prove that all development goals were reached

PRODUCT QUALITY
MMA produced with LiMA can be used even for most demanding optical applications

BEST IN CLASS
in efficiency, environmental impact, and raw-material availability

EFFICIENCY
High raw-material efficiency
High plant availability
Improved raw-material availability

ENVIRONMENTAL IMPACT
Lower emissions

SUPPLY RELIABILITY
Simplified process