ACRYLIC IMPACT MODIFIERS FOR RIGID PVC COMPOUND: COMPOSITE AIM TECHNOLOGY

D. CHAN, A. VERMOGEN, K. YCCA

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Acrylic Impact Modifiers

- Core / Shell impact modifier design
- Modes of failure and formulation
- Arkema technology

Durastrength® Acrylic Impact Modifier (AIM) Performance

- PVC formulation and application specifics
- Durastrength® AIM product range
- Arkema composite impact modifier technology
- New Durastrength® 367
**ACRYLIC PROCESSING AID**

- High molecular weight ACRYLIC copolymers
- PVC fusion promotion and rheology enhancer

**Main applications:** PVC Flooring, Foam, Film & Sheet, Pipe and Profiles, Vinyl cladding, and Fence and Rail

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**MBS IMPACT MODIFIERS**

- Core shell based on METHYL METHACRYLATE / BUTADIENE / STYRENE
- Excellent cold impact performance
- Best balance of transparency / impact performance
- Main applications: PVC film & sheet, CPVC pipes & fittings, and engineering resins

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**ACRYLIC IMPACT MODIFIERS**

- Core-shell based only on ACRYLIC monomers
- Best balance of impact performance / weathering properties
- Main applications: PVC window profiles, pipe and fittings, fencing, siding, roofing membranes

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**Clearstrength**

**Durastrength**

**Plastistrength**
# CORE / SHELL TECHNOLOGIES

<table>
<thead>
<tr>
<th>Methacrylate – Butadiene – Styrene (MBS)</th>
<th>Acrylic Impact Modifiers (AIM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>pBd core (Tg ~ -80°C)</td>
<td>pBA core (Tg ~ -45°C)</td>
</tr>
<tr>
<td>pMMA shell</td>
<td>pMMA shell</td>
</tr>
<tr>
<td><strong>• Excellent low temperature impact</strong></td>
<td><strong>• Good low temperature impact</strong></td>
</tr>
<tr>
<td><strong>• Excellent colorability</strong></td>
<td><strong>• Good colorability</strong></td>
</tr>
<tr>
<td><strong>• Non-weatherable</strong></td>
<td><strong>• Excellent UV stability</strong></td>
</tr>
<tr>
<td><strong>• Acceptable thermal stability</strong></td>
<td><strong>• Excellent thermal stability</strong></td>
</tr>
</tbody>
</table>

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**MBS Impact Modifiers**

**Acrylic Impact Modifiers**

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ACRYLIC IMPACT MODIFIERS
ARKEMA CORE-SHELL TECHNOLOGY
CORE/SHELL ACRYLIC IMPACT MODIFIER (AIM) SYNTHESIS, STRUCTURE, AND KEY PARAMETERS

Monomers → AIM Latex → Spray-drying

- Rubber content
- CS particle size (80-500 nm)
- Core X-linking level
- Chemistry improving PVC compatibility

AIM Latex → AIM Powder

- Cross-linked rubbery PBA core
- Grafted rigid PMMA shell

AIM Powder grain
CORE/SHELL VS POWDER GRAIN PARTICLES

AIM CS primary particle

Ideal schematisation

More realistic view

Cross-linked rubbery PBA core

Grafted rigid PMMA shell

Cross-linked rubbery PBA core

Grafted rigid PMMA shell

Rubber content can vary from 60 to > 90% and remain a free-flowing powder → improved shell chemistry improves anti-blocking properties

AIM CS primary particle

D50≈ 200 nm

AIM Powder grain

D50≈ 200 µm

There are about 1 billion of active AIM CS particles into a single AIM powder grain! → Easily released and dispersed into the PVC matrix during the extrusion step

PVC Window Profile
CORE/SHELL AIM SIDE EFFECTS: OTHER KEY APPLICATION PROPERTIES

- Fusion promotion
- Corner Weld Strength (CWS)
- Plate-out resistance
- Surface gloss
- Dehydrochlorination (DHC)
  - Small amounts of acidic species can be released without any effect on real thermo-stability of PVC profiles

AIM acts as rheology modifier (particulate system + shell processing aid effect)

These differences between AIM grades generally remain within the technical specifications…
APPLICATIONS PERSPECTIVE: PROCESSING AND RHEOLOGY

★ PVC mechanical properties and melt rheology are correlated:
- Transition from a brittle to ductile PVC material is highly dependent on impact modifier content
- Increasing modifier levels generally improves fusion and mechanical properties
- Cost-efficiency gains possible due to improved fusion at higher filler loading levels while maintaining mechanical properties

![Graph showing melt temperature, gelation level, and impact strength](chart.png)

(a)=4.5 phr; (b) = 5.5 phr; (c)=6.5 phr; (d)=7.5 phr; (e)=8.5 phr
DURASTRENGTH® IMPACT MODIFIER PERFORMANCE
TARGETED PERFORMANCE FOR PVC BUILDING PRODUCTS
## TYPICAL RIGID PVC FORMULATIONS (OPAQUE)

<table>
<thead>
<tr>
<th>Function</th>
<th>Ingredient</th>
<th>Window Profile / Siding Capstock</th>
<th>Siding Substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Resin</td>
<td>PVC Resin</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Heat Stability</td>
<td>Organotin Heat Stabilizer // Stabilizer / lubricant one-pack</td>
<td>1.0 – 1.2 (&gt;18% Sn) // 3.5 – 4.0 (Ca/Zn or other)</td>
<td>0.8 – 1.2 (6% - 12% Sn) // 3.0 – 5.0 (Ca/Zn or other)</td>
</tr>
<tr>
<td>Internal Lubricant</td>
<td>Calcium Stearate (Sn only)</td>
<td>1.0 – 1.5</td>
<td>1.0 – 1.5</td>
</tr>
<tr>
<td>External Lubricant</td>
<td>Paraffin Wax (Sn only)</td>
<td>0.8 – 1.2</td>
<td>0.8 – 1.2</td>
</tr>
<tr>
<td>External Lubricant</td>
<td>PE / OPE Wax (Sn only)</td>
<td>0 – 0.2</td>
<td>0 – 0.2</td>
</tr>
<tr>
<td>Fusion Promotion</td>
<td>Process Aid (PLASTISTRENGTH® process aid)</td>
<td>0 – 1.0</td>
<td>0.3 – 2.0</td>
</tr>
<tr>
<td>Melt Strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact Resistance</td>
<td>Impact Modifier (DURASTRENGTH® AIM)</td>
<td>4.5 – 6.0</td>
<td>3.5 – 5.0</td>
</tr>
<tr>
<td>Filler</td>
<td>Calcium Carbonate (0.7 µm)</td>
<td>2.0 – 18.0</td>
<td>12.0 – 22.0</td>
</tr>
<tr>
<td>Pigment / UV Protection</td>
<td>Titanium Dioxide</td>
<td>3.5 – 9.5</td>
<td>0.5 – 1.0</td>
</tr>
<tr>
<td>Color</td>
<td>Pigments / Colorants</td>
<td>As Needed</td>
<td>Regrind addition</td>
</tr>
</tbody>
</table>

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**DURASTRENGTH® ACRYLIC IMPACT MODIFIER PRODUCT RANGE**

**Highest impact requirements:**
- High gloss and ultimate impact strength

**Standard performance AIM**

**New cost-efficient / high-performance alternative AIM for Rigid PVC**

**Injection Molding AIM - Rheology**

**OVERALL Performance**

- **D382**
- **D350**
- **D365s**
- **D36X**
- **D320**
- **D367**
- **D4000**
- **D200**

**R&D and innovation leading to dosage reduction by more than 2phr**

**New Arkema Technology**
- Based on proprietary Arkema innovation
- Moderate performance with optimized cost
- Alternative to CPE and CPE blends,
  (with improved process stability), in rigid PVC profiles and highly filled applications / substrate

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**ARKEMA COMPOSITE IMPACT MODIFIER TECHNOLOGY**

**“Outside” type**

- **Standard AIM**
  - Powder grain
  - Mineral fillers & additives

**Performance with optimized cost-efficiency**

**“Inside” type**

- **Patented technology**
  - Innovative association of highly efficient AIM & inorganic additive

- **Why encapsulation?**
  - No segregation
  - Homogeneity of the mixture
  - Excellent flowability and powder properties
  - Mineral/Rubber synergy: larger energy dissipation (cavitation and shear yielding)
  - Minimal abrasion on metal tooling
  - High reward with optimized cost

- Fillers and impact modifier are physically blended powders
- Risk of segregation
- Heterogeneity of the mixture
*Example of mineral / AIM synergy*

SEM Morphology investigations after impact testing (ductile break)

- Dewetting of inorganic/PVC interfaces leads to cavitation that promotes shear yielding
- Larger energy dissipation
# Impact Modifier Technology Comparison

<table>
<thead>
<tr>
<th>Chlorinated polyethylene (CPE)</th>
<th>Acrylic Impact Modifiers (AIM)</th>
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<tbody>
<tr>
<td><img src="image" alt="CPE particle" /> No defined core-shell particle (Tg ~ -10°C)</td>
<td><img src="image" alt="AIM particle" /> pBA core (Tg ~ -45°C) pMMA shell</td>
</tr>
<tr>
<td>Poor powder properties</td>
<td></td>
</tr>
</tbody>
</table>

- Poorer UV Stability
- Shrinkage (swelling)
- Lower environmental resistance
- Plate-out deposit
- Melt flowability

*CPE no longer has improved welding strength as a technical advantage in current grades

- Excellent UV stability
- Good thermal stability
- Best-in-class impact performance
- Improved plate-out resistance
- Higher melt strength development
- Broad process window
CPE SOLUTIONS: NEAT CPE AND CPE BLENDS

CPE and CPE blends
- Today CPE is used in combination with AIM products or with high loading levels of fillers and inorganic content

- Today’s CPE materials: more caking / blocking CPE requires more mineral fillers
  - Extra cost: minimum extra dosage of AIM to maintain properties
  - More complex to handle: physical mixture of multiple IM components
  - Unstable processing: heterogeneous modifier & PVC blend
  - Poorer weatherability / UV resistance vs. AIM products
NEW DURASTRENGTH® 367

Focusing on Fusion

DURASTRENGTH® 367
- Faster fusion than CPE/AIM blends regardless the AIM ratio
- Same observation vs CPE/AIM ready blend

Pure CPE, CPE/AIM blends and ready blends
- Different fusion speed = f(source) for CPE quality ⇔ different CPE product
- Faster fusion requires higher modifier dosage ⇔ extra cost
- Same CPE source gives larger fusion fluctuations than DURASTRENGTH® acrylic impact modifier
- Pure CPE even slower (incomplete) fusion

Lab. Scale extrusion - Window Profile Ca/Zn
5.5phr of IM and 8 phr of CaCo3 fillers
50/50 AIM/CPE ratio
NEW DURASTRENGTH® 367

Focusing on process stability: 3h lab-scale extrusion

Lab-scale Extrusion Measurements

- CPE and CPE blends lead to instability:
  - poor homogeneity
  - risk of segregation
  - poor quality stability

- Durastrength® AIM provides processing stability

Lab. Scale extrusion - Window Profile Ca/Zn 5.5phr of AIM and 8 phr of CaCo3 fillers

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NEW DURASTRENGTH® 367

Focusing on melt fracture resistance

- Melt fracture resistance influenced by type of impact modifier in the formulation
- DURASTRENGTH® 367 shows improved melt fracture resistance versus CPE-based PVC formulations
- Typically, melt fracture resistance is decreased with higher CaCO₃ content – Durastrength® 367 helps maintain higher overall melt strength
NEW DURASTRENGTH® 367 – IMPROVED TECHNICAL SOLUTION VS. CPE

PVC Window Profile & Siding application perspective

DURASTRENGTH® 367 vs CPE / CPE blends
- Improved flowability and powder properties
- Same improved, stable processing conditions offered by Durastrength® products
- Improved melt fracture resistance
- Acrylic technology offers improved UV resistance
- Faster fusion
- Similar notched impact resistance
- DURASTRENGTH® quality consistency
- Global production in North America and Europe

Performance & Savings without processing inconsistencies and lot-to-lot variability attached to CPE and CPE blends

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