SILOX*, SILCAT*, SILQUEST* Silanes and XL-PEarl* Liquid Silanes for CROSSLINKING

*Silox, Silcat, Silquest and XL-PEarl are trademarks of Momentive Performance Materials Inc.
Silane Crosslinking of Polyolefins

Polyethylene has been crosslinked for many years by a number of proven methods. The initial goal was to extend the maximum service temperature. However, especially Silane crosslinking can help deliver many important advantages to non-crosslinked polymers like polyethylene and PVC:

- Typically improves Temperature Resistance [e.g. Long-Term Service Temperature (XLPE = 90°C) and Short-Time Peak Temperature (XLPE up to 250°C)]
- Can help increase Aging Resistance
- Can reduce drip phenomena when burning
- Can reduce deformation under load, improved creep, and for pipe, improved stress rupture performance (Environmental Stress)
- Typically can help to improve resistance against certain chemicals (e.g. against solvents)
- Can help increase abrasion resistance
- Memory effect (e.g. for shrink tubing, shrink film and stretch wrap)
- Typically improves Flexural Modulus and Low Temperature Impact Strength
**Silane Crosslinking Technologies for Polyethylene**

Momentive Performance Materials supply silane chemicals to two well-established methods that employ silanes in crosslinking polyethylene

- **Silcat** Silane Crosslinking Chemicals: for the One-Step Process, originally commercialized as Monosil
- **Silox** Silane Grafting Chemicals: for the Two-Step Process, originally commercialized as Sioplas

**Concepts of Crosslinking**

- Process which forms bonds between polymer chains
- Creates 3-dimensional macro-molecular crosslinked structure
- Material changes from thermoplastic compound to a thermoset
- Network translates into better hot-set or permanent set properties than peroxide crosslinking
- Unlike radiation or peroxide crosslinking, silane systems need a curing cycle immersed in hot water or exposed to steam

**Silane Crosslinking Technology**

Utilizing Silane crosslinking is a flexible and economical process. Silane crosslinked polyolefins are linked through an Si-O-Si moiety rather than a C-C bond.

**Peroxides/Radiation**

Direct carbon bond provides a rigid structure

**Silane technology (Silquest Silanes, Silox Silane, Silcat Silane, XL-PEARL Liquids)**

Siloxane bonds providing enhanced chemical resistance and mechanical flexibility

---

*Silox, Silcat, Silquest and XL-PEARL are trademarks of Momentive Performance Materials Inc.*

(1) Maillefer SA and BICC Ltd.
(2) Midland Silicones (Dow Corning)
Moisture Curing
- Curing involves providing moisture and heat to the grafted polymer
- Organotin compounds (catalyst) accelerate cure
- Rate of curing:
  - Proportional to temperature and the quantity of moisture
  - Inversely proportional to thickness
- Curing Options
  1. Sun bath: Expose to open air for 7 to 14 days (ambient curing)
     - depends on weather and humidity
     - slow and may require 15 days or longer
  2. Steam bath: Place in steam room for 4 or more hours
     - may be used for cables or pipes in huge coils
  3. Water bath: Immerse at 80 ~ 95°C for 4 or more hours
     - may be used for all products

Silane Crosslinking
One-Step Process - Monosil(1)
- Monosil is a one-step process
- Polyethylene, silane, peroxide, catalyst and other compatibles additives are added in a continuous extrusion step
- The one-step process combines the raw materials, accomplishes the grafting reaction and continuously forms a finished part such as a wire and cable insulation or a PEX pipe
- The technically sophisticated extrusion system employs an extruder with a long barrier screw (L/D = 30) and an injection system for the liquid silane blend
- As in all silane crosslinking methods, the finished part is moisture-cured

Advantages
- Can be cost effective on larger scale
- Single step - high speed
- May be lowest variable cost
- Wide formulation latitude
- Custom formulation flexibility
- No additional heat history

Disadvantages
- Extruder modification/purchase required
- Care in handling of chemicals

Silcat* Silanes Selection Chart for One-Step Process - Monosil(1)

(1) Maillefer SA and BICC Ltd.
*Silcat is a trademark of Momentive Performance Materials Inc.
Silane Crosslinking Two-Step Process - Sioplas (2)

- Separates the process into two steps
- Silane and peroxide are added in the first step for grafting
- Grafting is usually done on a twin screw extruder, pelletized and isolated as the Silane Grafted Polymer (Sioplas compound)
- End-user buys Sioplas compound and Tin catalyst to add to extrude into cable or pipe (the second step) on a conventional single screw extruder L/D = 24
- Antioxidant or stabilizer, metal deactivator, processing aid and color master batch may be added

Advantages

- Can be lowest investment as existing extruders can be used
- Very high speed and output
- Silane Grafted Polymer is more stable over time than any silane soaking processes
- System generally requires less technical expertise and has fewer problems

Disadvantages

- Higher cost for Sioplas compounds
- Need to mix catalyst prior to production (requiring second compounding step)
- Additional heat history in polymer
- Silane Grafted Polymer has a more stable shelf life over time

---

(2) Midland Silicones (Dow Corning)

*Silox is a trademark of Momentive Performance Materials Inc.*
Silox* and Silquest* Silanes Selection Chart for Two-Step Process - Sioplas

Application

General Use

Wire & Cable (low & medium voltage)

PEX Pipes (for water, gas & fuel transportation)

Silquest A-171* silane
Vinyltrimethoxysilane
(need peroxide)

Silox*23 silane
Formulated system for cables

Silox VS-890/1 silane
Stabilized system for copper cables
7 days at 135 C

Silox 23 silane
Formulated system for PEX pipes

LLDPE/LDPE/MOPS/HDPE

Silquest A-171* silane
Vinyltrimethoxysilane
(need peroxide)

Silox VS-890/1 silane
Stabilized system for copper cables
7 days at 135 C

Silox 23 silane
Formulated system for PEX pipes

LLDPE/LDPE/MDPE

Silox VS-604 silane
System with processing additive - need peroxide

HDPE

Note: Test data. Actual results may vary.
**XL-PEARL* Crosslinking Chemicals and PEARLSTAB* grades:**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>XL-PEARL 35 Liquid</td>
<td>The product is designed for crosslinking high density polyethylene (HDPE) for manufacturing PEX pipes.</td>
</tr>
<tr>
<td>XL-PEARL 60 Liquid</td>
<td>The product is designed for crosslinking medium and high density polyethylene (HDPE) for manufacturing PEX pipes. Additional stabilizer package might be required.</td>
</tr>
<tr>
<td>XL-PEARL 70M Liquid</td>
<td>Crosslinking system for Halogen-Free Retardant cable compounds, semiconductive cable compounds and polyethylene foams.</td>
</tr>
</tbody>
</table>

*XL-PEARL and PEARLSTAB are trademarks of Momentive Performance Materials Inc.*
Patent Status
Nothing contained herein shall be construed to imply the nonexistence of any relevant patents or to constitute the permission, inducement or recommendation to practice any invention covered by any patent, without authority from the owner of the patent.

Product Safety, Handling and Storage
Customers should review the latest Safety Data Sheet (SDS) and label for product safety information, safe handling instructions, personal protective equipment if necessary, emergency service contact information, and any special storage conditions required for safety. Momentive Performance Materials (MPM) maintains an around-the-clock emergency service for its products. SDS are available at www.momentive.com or, upon request, from any MPM representative. For product storage and handling procedures to maintain the product quality within our stated specifications, please review Certificates of Analysis, which are available in the Order Center. Use of other materials in conjunction with MPM products (for example, primers) may require additional precautions. Please review and follow the safety information provided by the manufacturer of such other materials.

Limitations
Customers must evaluate Momentive Performance Materials products and make their own determination as to fitness of use in their particular applications.

Customer Service Centers

<table>
<thead>
<tr>
<th>Worldwide</th>
<th>Americas</th>
<th>Latin America</th>
<th>Europe, Middle East, Africa and India</th>
<th>Asia Pacific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email: <a href="mailto:commercial.services@momentive.com">commercial.services@momentive.com</a></td>
<td>+1 800 295 2392</td>
<td>+55 11 4534 9660</td>
<td>00800 4321 1000 +40 213 044229</td>
<td>800 820 0202</td>
</tr>
<tr>
<td>Email: <a href="mailto:commercial.services@momentive.com">commercial.services@momentive.com</a></td>
<td>+1 614 986 2495</td>
<td></td>
<td></td>
<td>+60 3 9206 1543</td>
</tr>
<tr>
<td>Email: <a href="mailto:commercial.services@momentive.com">commercial.services@momentive.com</a></td>
<td></td>
<td></td>
<td></td>
<td>+81 276 20 6182</td>
</tr>
</tbody>
</table>

Disclaimer

DISCLAIMER: THE MATERIALS, PRODUCTS AND SERVICES OF Momentive Performance Materials Inc. and its subsidiaries and affiliates DOING BUSINESS IN LOCAL JURISDICTIONS (collectively “SUPPLIERS”) ARE SOLD BY THE RESPECTIVE LEGAL ENTITY OF THE SUPPLIER SUBJECT TO SUPPLIERS’ STANDARD CONDITIONS OF SALE, WHICH ARE INCLUDED IN THE APPLICABLE DISTRIBUTOR OR OTHER SALES AGREEMENT, PRINTED ON THE BACK OF ORDER ACKNOWLEDGMENTS AND INVOICES, AND AVAILABLE UPON REQUEST. ALTHOUGH ANY INFORMATION, RECOMMENDATIONS, OR ADVICE CONTAINED HEREIN IS GIVEN IN GOOD FAITH, SUPPLIERS MAKE NO WARRANTY OR GUARANTEE, EXPRESS OR IMPLIED, (i) THAT THE RESULTS DESCRIBED HEREIN WILL BE OBTAINED UNDER END-USE CONDITIONS, OR (ii) AS TO THE EFFECTIVENESS OR SAFETY OF ANY DESIGN INCORPORATING SUPPLIERS’ PRODUCTS, MATERIALS, SERVICES, RECOMMENDATIONS OR ADVICE. AFOREMENTIONED EXCLUSIONS OR LIMITATION OF LIABILITY ARE NOT APPLICABLE TO THE EXTENT THAT THE END-USE CONDITIONS AND/OR INCORPORATION CONDITIONS CORRESPOND TO THE RECOMMENDED CONDITIONS OF USE AND/OR OF INCORPORATION AS DESCRIBED BY SUPPLIER IN ITS PRODUCT DATA SHEET AND/OR PRODUCT SPECIFICATIONS. EXCEPT AS PROVIDED IN SUPPLIERS’ STANDARD CONDITIONS OF SALE, SUPPLIERS AND THEIR REPRESENTATIVES SHALL IN NO EVENT BE RESPONSIBLE FOR ANY LOSS RESULTING FROM ANY USE OF ITS MATERIALS, PRODUCTS OR SERVICES DESCRIBED HEREIN. Each user bears full responsibility for making its own determination as to the suitability of Suppliers’ materials, services, recommendations, or advice for its own particular use. Each user must identify and perform all tests and analyses necessary to assure that its finished parts incorporating Suppliers’ products, materials, or services will be safe and suitable for use under end-use conditions. Nothing in this or any other document, nor any oral recommendation or advice, shall be deemed to alter, vary, supersede, or waive any provision of Suppliers’ Standard Conditions of Sale or this Disclaimer, unless any such modification is specifically agreed to in a writing signed by Suppliers. No statement contained herein concerning a possible or suggested use of any material, product, service or design is intended, or should be construed, to grant any license under any patent or other intellectual property right of Suppliers or any of its subsidiaries or affiliates covering such use or design, or as a recommendation for the use of such material, product, service or design in the infringement of any patent or other intellectual property right.

*Silox, Silcat, Silquest, PEarlstab and XL-PEarl are trademarks of Momentive Performance Materials Inc.

**Maillefer SA and BICC Ltd.

**Midland Silicones (Dow Corning)

Momentive and the Momentive logo are trademarks of Momentive Performance Materials Inc.