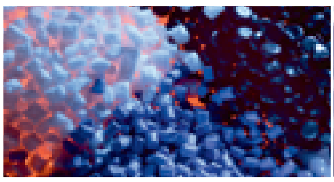
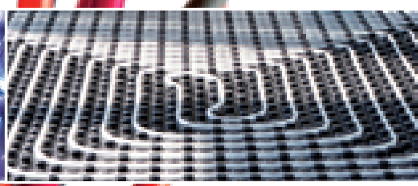
MOMENTIVE™
inventing possibilities

# Silox*, Silcat*, Silquest* Silanes and XL-PEarl* Liquid Silanes for Crosslinking





## 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, this technology 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 improves chemical resistance (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

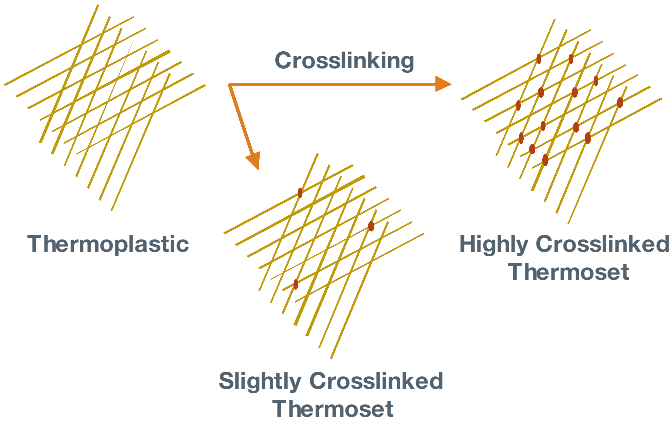
## Silane Crosslinking Technologies for Polyethylene

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

- Silcat* Silane Crosslinking Chemicals: for the One-Step Process, originally commercialized as Monosil[1]
- Silox* Silane Grafting Chemicals: for the Two-Step Process, originally commercialized as Sioplas[2]
- Silquest* Silanes High Purity Silanes: for copolymerization in reactor
- XL-PEarl* Liquid Crosslinking Chemicals

## Concepts of Crosslinking

- Process which forms bonds between polymer chains
- Creates 3-dimensional macro-molecular crosslinked structure
- Material changes from thermoplastic compound to an elastomer (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

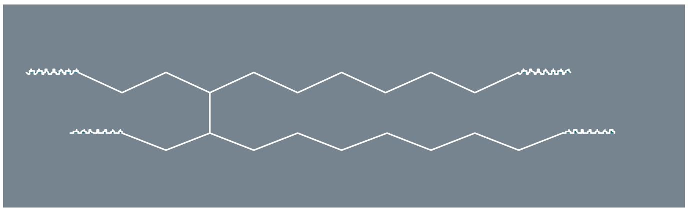



## Silane Crosslinking Technology

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.

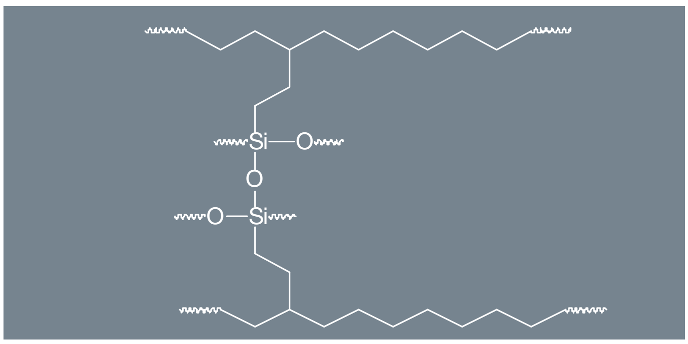
### Peroxides/Radiation

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




(1) Maillefer SA and BICC Ltd.
(2) Midland Silicones (Dow Corning)

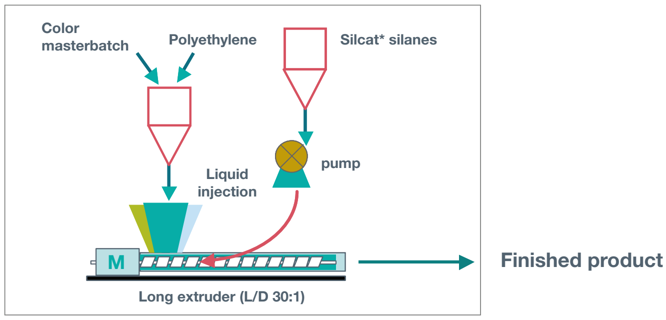
## Moisture Curing

- 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



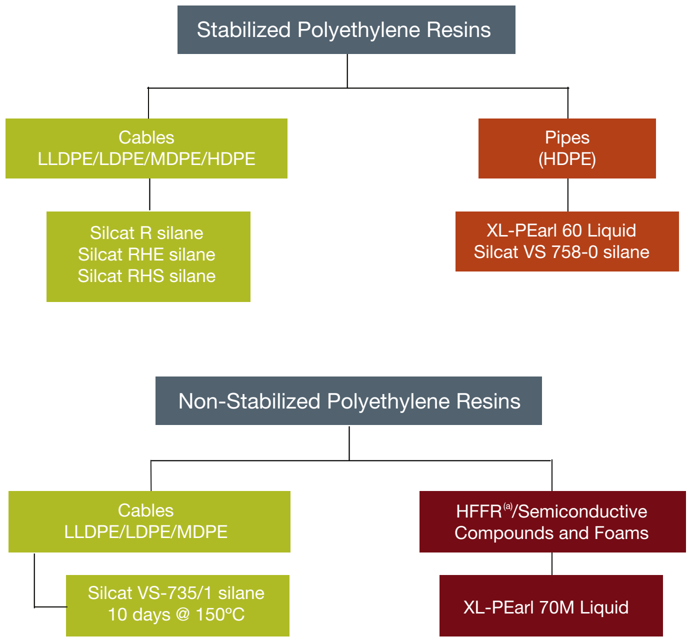

## Advantages

- 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

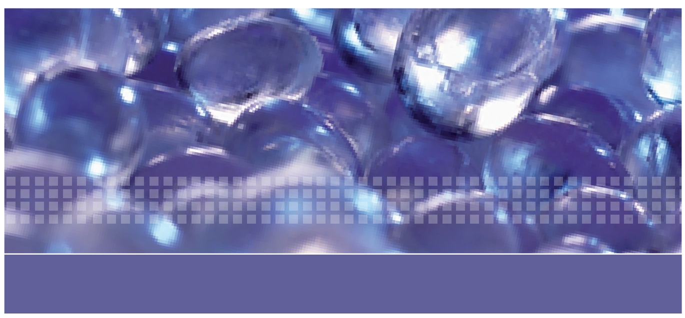
## Disadvantages

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

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




a) Halogen-Free Flame Retardant Compounds



(1) Maillefer SA and BICC Ltd.

*Silcat is a trademark of Momentive Performance Materials Inc.

## Silane Crosslinking Two-Step Process - Sioplas[2]

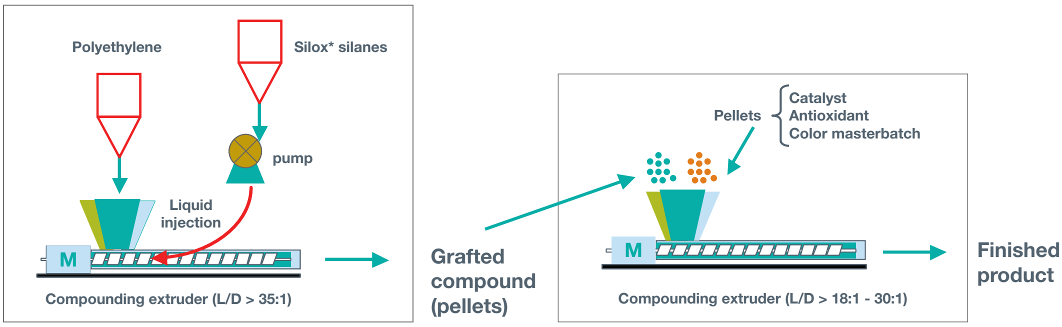
- Separates the process into two steps
- Silane and peroxide are added in the first step for grafting
- Grafting is usually done on a twin screw extruder, pelletized and isolated as the Silane Grafted Polymer (Sioplas compound)
- End-user buys Sioplas compound and Tin catalyst to add to extrude into 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)

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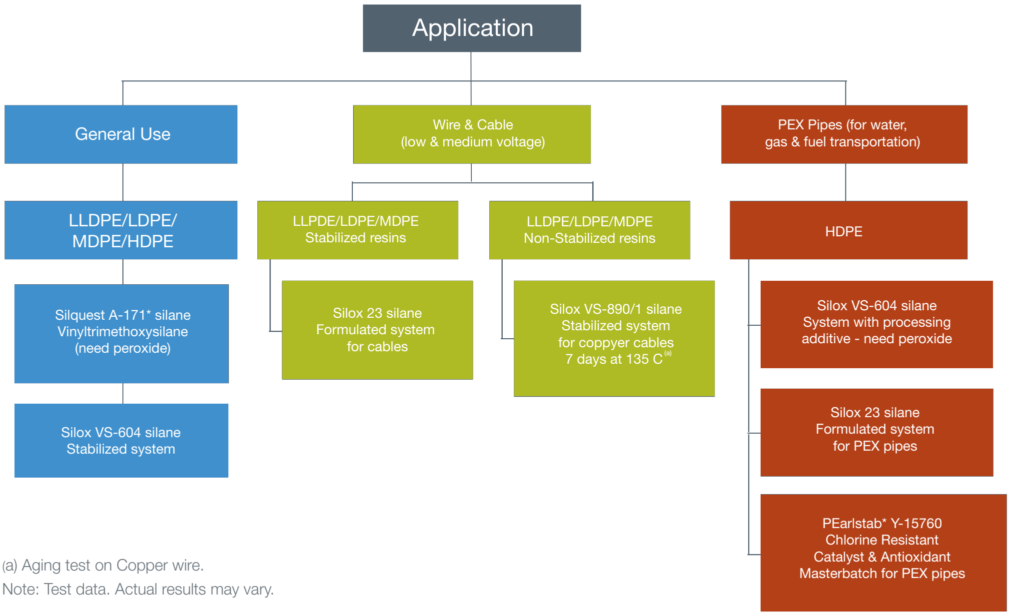
## Silox* and Silquest* Silanes Selection Chart for Two-Step Process - Sioplas[2]



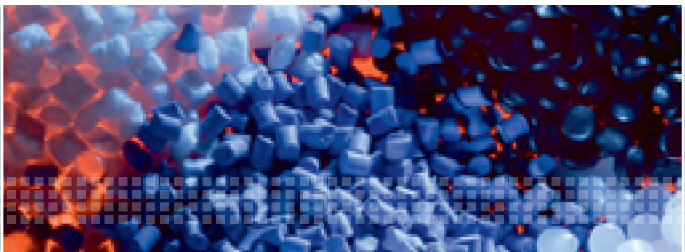

(a) Aging test on Copper wire.
Note: Test data. Actual results may vary.

(2) Midland Silicones (Dow Corning)

## XL-PEarl* Crosslinking Chemicals and PEarlstab* grades:

| Grade | Application |
|---|---|
| XL-PEarl 31 Liquid | Crosslinking system to be used with LLDPE, MDPE and HDPE resins for cables insulation. Must be used in combination with resins that contains stabilizers or with a suitable antioxidant masterbatch. |
| XL-PEarl 35 Liquid | The product is designed for crosslinking high density polyethylene (HDPE) for manufacturing PEX pipes. |
| PEarlstab Y-15760 Masterbatch | It is a multi-component chlorine resistant antioxidant and catalyst masterbatch. |
| XL-PEarl 60 Liquid | The product is designed for crosslinking medium and high density polyethylene (HDPE) for manufacturing PEX pipes. Additional stabilizer package might be required. |
| XL-PEarl 70M Liquid | Crosslinking system for Halogen-Free Flame Retardant cable compounds, semiconductive cable compounds and polyethylene foams. |





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