A partner in innovation:

	PVC	TPE	TPU	SILICONE	Engineering Plastics	FEP	PFA	PTFE	PVDF	ETFE	HDPE	PP
Extrusion	●	●	●	●	●	●	●	●	●	●	●	●
Molding		●	●	●	●		●		●	●	●	●
Braided Extrusion	●	●	●	●		●	●	●				
Assemblies	●	●	●	●	●	●	●	●	●	●	●	●
Machining								●	●	●		

Diverse Manufacturing Capabilities

- **Silicone Compounding (HCR, LSR)**
  - Silicone properties and performance can be optimized for specific applications whether an extruded or molded product. Tear resistance, purity, clarity, organoleptic properties, meeting regulatory requirements, pump performance, and compression set resistance are just some examples of properties which can be optimized for specific applications.

- **TPE Compounding**
  - Using thermoplastic elastomer compounding, one can custom tailor physical properties and performance of materials to specific applications. For example in PVC compounding, it is critical to add the correct plasticizers, stabilizers, and other ingredients in order to meet certain product requirements.

- **Injection Molding**
  - Silicone Molding
    - Silicone molding allows the performance benefits of using a silicone material in a complex molded product. Developing tooling designs, process controls, and automation are critical to providing high quality, high performing products.
  - 2K and Micro-molding
    - 2K and micro-molding take silicone molding to the next step. Using micro-molding one can design a product used in “micro” applications where features can be on the micron level. 2K molding combines the benefits of silicone with thermoplastics to create a two component product in one process. This guarantees perfect fit and good adhesion between materials to excel in certain applications.
  - Thermoplastic and Fluoropolymer Molding
    - Thermoplastics can provide varying physical properties from flexible thermoplastic elastomers, to chemically resistant fluoropolymers, to high strength engineer resins. Selecting the correct resin, creating an optimized design, and developing a high quality process are all key to a successful product.

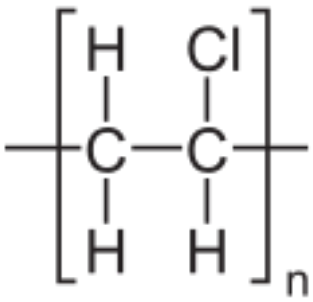
- **Extrusion**
  - Thermoplastic and Fluoropolymer Extrusion
    - Saint-Gobain has the ability to extrude single and multi-material/multi-layered thermoplastic and fluoropolymer tubes and profiles. This capability combined with custom compounding results in a product that has the optimized physical properties at the customer desired shape.
  - Silicone Tube and Profile Extrusion
    - Silicone extrusion requires much different theory and controls compared to thermoplastic extrusion. Saint-Gobain has developed and optimized silicone extrusion to create consistent product with high accuracy for tubing and profiles.
  - Braided Tubing
    - Developing multilayered tubes and hose with reinforcement allows the products to maintain flexibility but gain a significant increase in working pressure and burst pressure. Braiding can be performed on all thermoplastic elastomers and silicone to create higher pressure performance on tubing and hose.

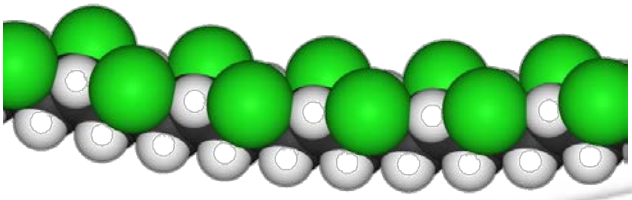
- **Film Extrusion and Bag Assembly**
  - In house film extrusion (up to 3 different layers) allows us to create new film constructions to develop new polymer bags.

<u>Multi-material science formulation expertise</u>

Polyvinyl Chloride (PVC)

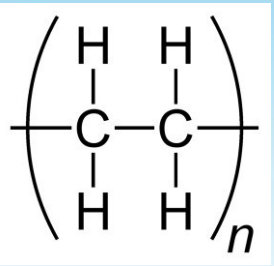
- **Highly versatile and cost-effective family of polymers**
- **Both rigid and flexible PVC formulas**
  - **Rigid formulas used in piping – water, sewer**
  - **Flexible formulas used in packaging films, toys, household items, flexible tubing, water hoses**
- **Flexible PVC (fPVC) is very versatile**
  - **Industrial, Food, and Medical grades of fPVC**
  - **Wide range of hardness (durometers)**
    - **Shore A 40, 55, 65, and 80**
  - **Use plasticizers (oils) in the formula to soften the PVC**
    - **Softer grades typically have more plasticizer**

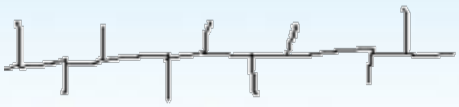




Polyolefin-based formulations

- **Polymers contain only hydrogen and carbon Polyethylenes – simplest of polymers**
  - **High Density Polyethylene (HDPE)**
    - **Very crystalline and hard**
  - **Low-Density Polyethylene (LDPE)**
    - **Low crystallinity**
  - **Linear Low-Density Polyethylene (LLDPE)**
    - **Combines the strength of HDPE with flexibility of LDPE**

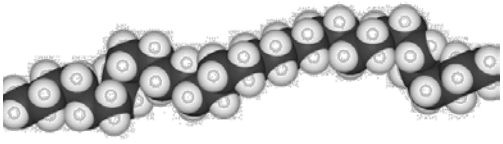




LLDPE has short-chain branching

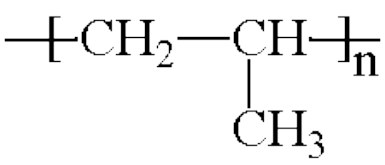
HDPE has almost no branching which makes it crystalline

LDPE has long-chain branching which makes it amorphous



Polyolefins

- **Polypropylene**
  - **Has extra methyl (CH_3)group on backbone**
  - **Very hard and crystalline structure**
  - **High melting point**
- **EPDM (ethylene-propylene diene monomer)**
  - **Rubber made of ethylene and propylene**
  - **Typically soft and gum-like**
  - **Has ethylidene norbornene (ENB) to aid crosslinking**



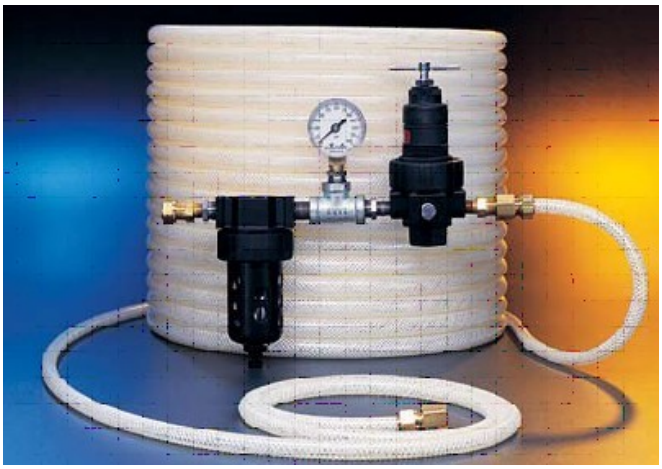
SAINT-GOBAIN

Thermoplastic Polyurethane (TPU)

Polyurethane that can be melted

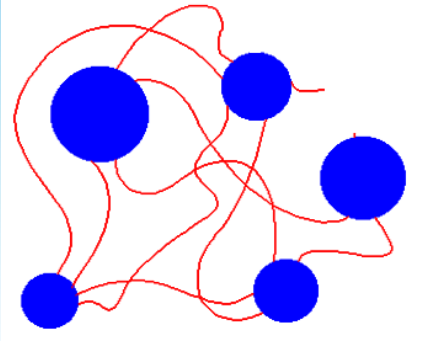
- **Structure is more complex than vinyl polymer**
- **More complex extrusion process**
- **Polymer has hard and soft sections**
  - **Hard (crystalline) sections give strength**
  - **Soft (amorphous) sections provide durability and flexibility**
- **Typically harder and stiffer than PVC**
  - **Shore A 80 and above**
  - **Custom grades down to 60 Shore A**

- **Polyether vs. Polyester Polyurethanes**
  - **Both are fuel/lube/oil resistant**
  - **Polyether TPUs are more water-resistant**
    - **Formula C-544-A and C-544-A I.B**
  - **Polyester TPUs are more oil and lube resistant**
    - **Stronger than polyether TPUs**
    - **Not recommended for contact with aqueous solutions**
    - **Formula C-210-A**

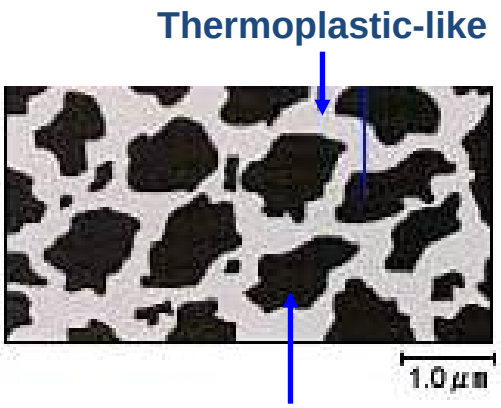


Thermoplastic Elastomers (TPE)

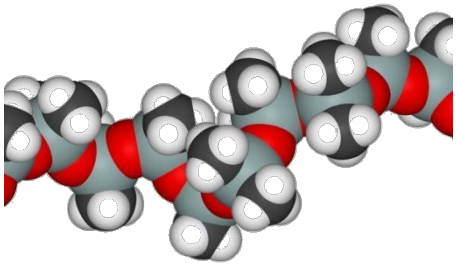
- Chemistry
  - Small domains of rubber in a thermoplastic matrix
  - TPEs are elastic (like rubber) but process like a thermoplastic
  - May contain oil to soften the polymer
  - Cleaner than most rubbers



Silicone Rubber



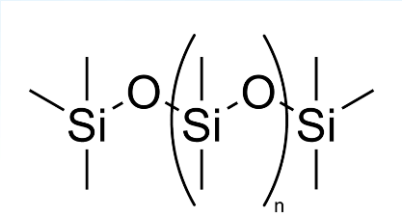
- Chemistry
  - Silicone rubber has a backbone of repea
  - Large bond angles and bond lengths allc
  - Formulations contain
    - Silicone gum-rubber
    - Curing package (either peroxide c
    - Additives to “tweak” properties
- Crosslinking
  - Crosslinking connects silicone chains
  - The silicone essentially becomes one giant molecule
  - High temperature resistance – the cured polymer does not melt
- Processing
  - Extruder is chilled rather than heated
  - Vertical extrusion is common
  - Tubes pass through an in-line oven to cure the polymers



<u>Rubber Type</u>: High Consistency Rubber (HCR) vs Liquid Silicone Rubber (LSR)

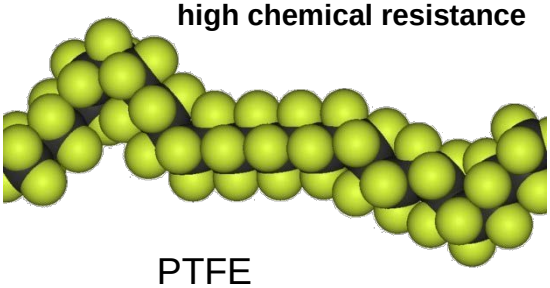
- **HCR is a soft gum-like material whose curing package is milled into the rubber before processing.**
- **HCR can be molded or extruded.**
- **LSR is a 2-part A/B liquid system. When the 2 liquids combine, curing begins.**
- **LSR can only be molded, not extruded**

- **<u>Cure Package:</u> Peroxide vs. Platinum**
- **Peroxide-cured silicone is typical for industrial uses**
- **Platinum-cured is cleaner and better for use in high-purity applications (medical, pharmaceutical)**
- **Platinum-cured has lower extractables and odor**
- **Platinum-cured typically costs more although Saint-Gobain has platinum silicones competitive to peroxide silicones**

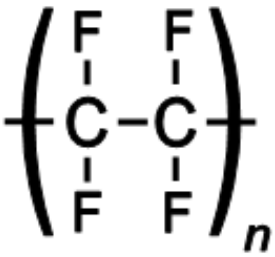


Fluoropolymers

- **The most chemical resistant of polymers**
  - **Fluorine-Carbon bond is very strong**
  - **Fluorine is also very small so it creates a very tight structure that protects the carbon backbone**
- **PTFE (commonly known as Teflon)**
  - **Fully fluorinated – no hydrogen**
  - **Highest chemical resistance**
  - **Very good temperature resistance**
  - **Cannot process by melting**
- **FEP, PFA, PVDF, ETFE**
  - **Differing properties because of different chemical structures**
  - **PFA is typically used for high-purity applications**
- **FKM and fluorinated silicones**
  - **Crosslinking allows these rubbers to have very high flexibility while maintaining high chemical resistance**



PTFE



PTFE