Introduction to Fluon+™ Filled PTFE and Melt Processable Compounds
A world-leading fluorochemical manufacturer

US $14.1 billion net sales

56,200 employees

217 consolidated subsidiaries in 30 countries
Global Product Reach

Global Sales

- 44% Glass
- 20% Electronics
- 36% Chemicals/Other

- #1 global supplier of flat and auto glass
- #1 global supplier of ETFE
- Largest global glass supplier to NISSAN, HONDA, TOYOTA
Smart Chemistry Solutions

- U.S. headquarters & manufacturing near Philadelphia
- Custom compounds and formulations for high-quality fluorochemicals and specialty chemicals
- Short production lead times, system-controlled specifications, product consistency.
- Onsite physical, analytical and wear testing
- Compression and injection molding equipment to optimize product
Why Fluoropolymer Compounds?

- Fluoropolymer resins impart unique characteristics.
- Performance is further increased by the use of various fillers.
- AGC offers filled PTFE compounds and melt processable compounds.
Introduction to Filled PTFE Compounds

Free Flow - pelletized

Low Flow - non-pelletized
Filled PTFE Compounds

- High shear modulus fillers are encapsulated and bound by the low shear modulus PTFE resin.
- Addition of inorganic fillers can minimize deficiencies of PTFE while preserving many of its desirable properties.
- Fillers must be compatible with PTFE; they cannot dramatically diminish its desirable properties.
- Fillers are used to control unwanted creep, as well as improve wear, friction and tensile properties.
- Choice of filler is strongly application-dependent. No one filler addresses all deficiencies.
## Two Forms of Filled PTFE Compounds

<table>
<thead>
<tr>
<th>Low-Flow</th>
<th>Free-Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Produced by dry-blending virgin resin with filler</td>
<td>• Low-flow blend used as feed for free flow</td>
</tr>
<tr>
<td>• End product resembles cake flour</td>
<td>• Compound is wetted, pelletized and dried</td>
</tr>
<tr>
<td>• Used for simple compression molding such as bars and large billets</td>
<td>• End product is small pellets</td>
</tr>
<tr>
<td></td>
<td>• Physical properties of free-flow compounds are generally decreased compared to low-flow compounds</td>
</tr>
<tr>
<td></td>
<td>• Used for automatic compression and isostatic molding, such as sleeves</td>
</tr>
</tbody>
</table>
PTFE Filler Requirements

- Thermal stability of at least 750 degrees F to withstand PTFE processing temperatures
- Chemical resistance
- Particle size and distribution must be consistent with PTFE base (Typical: 325 mesh max)
- Ability to interrupt PTFE transfer during wear:
  - Modulus greater than PTFE
  - Reasonable lubricity
  - Non-abrasive
- Deformation resistance
## Potential Impact of Fillers

<table>
<thead>
<tr>
<th>Property</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wear Resistance</td>
<td>1000x Increase</td>
</tr>
<tr>
<td>Deformation Resistance</td>
<td>15x Increase</td>
</tr>
<tr>
<td>Tensile Properties</td>
<td>2x Increase</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>10x Increase</td>
</tr>
<tr>
<td>Thermal Expansion</td>
<td>5x Decrease</td>
</tr>
<tr>
<td>Chemical Resistance</td>
<td>Generally Decrease</td>
</tr>
<tr>
<td>Dielectric Strength</td>
<td>Generally Decrease</td>
</tr>
<tr>
<td>Friction</td>
<td>2x Increase</td>
</tr>
</tbody>
</table>
Filled PTFE Compounds - Fillers

- Fiberglass fibers and spheres
- Graphite powders and fibers
- Coke/carbon powders
- Molybdenum disulphide ("moly")
- Mineral powders and fibers
- Metal powders: bronze, stainless steel
- Blends (Glass/moly, bronze/moly, etc.)
- Polymers:
  - Polyphenylene sulfide (PPS)
  - Polyimide (PI)
  - Linear aromatic polyester (LAP, Ekonol®)
Filled PTFE Compounds: Markets Served

Transportation
• Automotive & Rail
• Heavy-duty Equipment
• Aerospace & Defense

Chemical Process Industries
• Fluid Control
• Industrial Equipment
• Pulp & Paper

Oil & Gas
• Exploration
• Production
• Refining

Appliances & HVAC
• Food & Beverage
• FDA Compliance
• Air Conditioning Systems

Your Dreams, Our Challenge
Filled PTFE Compounds: Applications

- Bearings
- Gaskets
- V-rings
- Chevron packings
- O-rings
- Back-up rings
- Hydraulic ring seals
- Non-lubricated compressor rings

- Self-lubricating bearings
- Valve seats
- Valve liners
- Swivel liners
- Thrust washers
- Lip seals
- Standoff and feed-through insulators
- Wear pads
Glass-filled PTFE Compounds

- Most common filler type – cost vs. performance
- Improve wear characteristics
- Improve compression strength
- Reduce creep relaxation
- Control billet discoloration by AGC proprietary treatment process
- Improve abrasion resistance by blending with graphite and/or moly
Glass-filled PTFE Compound Applications

Glass

- Hydraulic piston rings
- Gaskets
- Self-lubricating bearings
- Valve seats
- Big-billet skived sheet
- And more...
Moly-filled PTFE Compounds

- Increase hardness and stiffness
- Improve wear resistance
- Greatly reduce torque on start-up
- Lower coefficient of friction
- Good for dry, oil less applications
- Can be combined with glass or bronze
Moly-Filled PTFE Compound Applications

Moly

- Self-lubricating bearings
- Seals and gaskets
- Compressor rings
- V-rings, O-rings and backup rings
- Valve seats and liners
- And more...

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Glass/Moly PTFE Compound Applications

Glass/Moly

- Hydraulic seals
- Hydraulic piston rings
- Energized wipers
- Backup rings
- Single- and double-acting seals
- And more...
Graphite-Filled PTFE Compounds

- Excellent lubricity due to flaky structure
- Decrease wear, especially to soft metals
- Particularly good in wet environments for wear resistance
- Typically combined with carbon and glass to lower the coefficient of friction
Carbon-Filled PTFE Compounds

- Excellent compression strength (DuL)
- Excellent wear resistance
- Less abrasive than glass, but more abrasive than polymeric-filled compounds
- Good thermal conductivity
- Low permeability
- Often combined with graphite for enhanced wear and friction properties
Carbon/Graphite Compound Applications

Carbon/Graphite

- Gaskets – static-dissipating, etc.
- Compressor rings
- Valve seats and liners
- Piston rings and seals
- And more...

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Mineral-Filled PTFE Compounds

- Good wear resistance
- Low creep relaxation
- Good compressive strength
- Excellent chemical resistance
- Less abrasive than glass
- FDA compliant for food service
- 3A sanitary compliant
Mineral-Filled Compound Applications

Mineral

- Seals – all types
- Compressor rings
- Valve seats and liners
- Big-billet skived sheet
- Food & beverage applications
Bronze-Filled PTFE Compounds

- Excellent wear resistance
- Excellent thermal conductivity
- Improve creep resistance and deformation under load
- Less chemical resistance than other filled PTFE compounds
- Prone to acid and base attack
- Sometimes combines with moly or graphite to lower coefficient of friction
Bronze-Filled Compound Applications

Bronze

- Self-lubricating bearings
- Gaskets – static-dissipating/others
- Seals – all types
- Compressor rings
- Valve seats/liners
- Applications with high mechanical loads or high-speed rubbing contact where bronze filler supplies strength and conductivity to carry away unwanted heat
Stainless-Filled PTFE Compounds

- High wear resistance
- High load-bearing capability
- Improved chemical resistance over bronze-filled PTFE compounds
- Typically used in steam service
Stainless Steel-Filled Compound Applications

Stainless Steel

- Gaskets – all types
- Seals – all types
- Ball valve seats
PPS-Filled PTFE Compounds

- Polyphenylene sulfide
- Excellent dimensional stability
- Excellent thermal stability
- Improve wear and abrasion properties
- Excellent deformation and extrusion resistance
PPS-Filled Compound Applications

- Seals – all types
- Compressor rings
- Backup rings
- Hydraulic aircraft seals
- And more...

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Polyimide-Filled PTFE Compounds

- Improve wear and abrasion properties
  - Ideal for soft surfaces
- Lowest friction properties of all filled PTFE compounds
  - Provide great performance in non-lubricated applications
- Improve deformation and extrusion resistance
Polyimide-Filled Compound Applications

Polyimide

- Seals – all types
- Compressor rings
- Self-lubricating bearings
- Piston rings/seals
- And more...

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LAP-Filled PTFE Compounds

- Linear aromatic polyester (LAP) compounds
- Excellent dimensional stability
- Excellent thermal stability
- Excellent wear and abrasion resistance
  - Will not wear mating metal surfaces
  - Excellent for rotary applications
Polymide-Filled Compound Applications

Linear Aromatic Polyester

- Seals – all types
- Compressor rings
- Self-lubricating bearings
- And more...

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Introduction to Melt Processable Compounds

Fluon+™ MPC
Melt Processable Compounds

Fluon+™ ADHESIVE
Chemical Bonding Polymers

Fluon+™ mPLASTICS
Fluoropolymer Modification Science

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Introduction to Melt Processable Compounds

- Nine different groups of melt processable compounds
- Fillers: pigments, glass, fluoro resins, carbon, mineral, elastomers, etc.
- Fillers and content can be customized to precise specifications
- RoHS and REACH compliant: no lead, cadmium, etc.
- Resins used: ETFE & PFA vertically integrated through AGC; ECTFE, FEP, PEEK, PPS, PVDF
Product Groups

Concentrates
- Color
- Foam

Ready-to-Use
- Cross-link compounds
- Reinforced compounds
- Conductive compounds
- Lubricated compounds

Modified
- Flexible AR compounds
- Adhesive compounds
- Modified PEEK and PPS
### Concentrates

#### Color concentrates
- Resins used: ECTFE, ETFE, PFA, FEP, PVDF
- High-melt flow and low-melt flow types available
- Superb surface finish, color consistency and dispersion
- Consistent pellet size and integrity
- Standard colors and custom match to various color standards such as Munsell, RAL and Pantone

#### Foam concentrates
- Resins used: ECTFE, ETFE, FEP, PFA, PVDF
- High-melt flow and low-melt flow types available
- Can be customized to meet specifications
- Minimize signal loss, enhance high-speed transmission
- Save weight and material
Concentrates

Color concentrates
- Color-coded wire insulation, tubing
- Release films
- Injection-molded parts

Foam concentrates
- Thin-walled applications – LAN cable
- Thick-walled applications – Coaxial cable
### Reinforced & Cross-linkable Compounds

#### Reinforced compounds

- Resins used: ETFE, PFA, PFA
- Incorporate glass, carbon, mineral fillers
- Enhance dimensional stability
- Toughness, abrasion and shrinkage resistance
- Increase thermal conductivity

#### Cross-linkable compounds

- Resins used: ETFE, PVDF
- Processed through electron-beam or gamma radiation
- Withstand high temperatures
- Abrasion and cut-through resistance
Reinforced & Cross-linkable Compound Applications

Reinforced compounds

- Pump housings and valves
- Cable protection
- Distillation column packing
- And more...

Cross-linkable compounds

- Airframe wire insulation
- Industrial and shipboard wire insulation
- And more...

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## Conductive & Lubricated Compounds

### Conductive/anti-static compounds
- Resins used: ETFE, PFA, FEP, ECTFE, PVDF
- Carbon-filled, can customize melt flow and conductivity
- Control of heat and static electricity
- Consistency and processability are key factors

### Lubricated compounds
- Resins used: ETFE, ECTFE, FEP, PFA, PVDF
- Fillers include FEP or PTFE
- Low friction, abrasion resistance
Conductive & Lubricated Compound Applications

Conductive/anti-static compounds
- Heater cable
- Wrap/thaw frozen pipes or locate leaks
- Static dissipative fuel lines

Lubricated compounds
- Abrasion-resistant surfaces or linings
- Push-pull cable for car or truck brakes

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Flexible & Adhesive Compounds

Flexible AR compounds

- Resins used: ETFE and proprietary elastomer
- Maintains desired ETFE properties
- Flexible form
- Heat resistance can be enhanced by EB curing or cross-linking

Adhesive compounds

- Resins used: modified ETFE
- Strong adhesion properties
- Useful with many grades of polyamides such as nylon 12
- High permeation resistance to fluids and gases
Flexible & Adhesive Compounds Applications

Flexible AR compounds

• Wire and cable – industrial, auto/aero/rail, appliance
• Film and sheet
• Tubing and pipe
• Electronic components

Adhesive compounds

• Film and sheet
• Tubing and hose
• Electronic components
Modified PEEK and PPS Compounds

- Incorporates proprietary fluoropolymer and compounding technology
- Improves wear and impact resistance
- Improves physical and electrical properties
- Can be processed via extrusion, injection and pressure molding techniques
- Mid-high modification available in mPEEK compounds
- Low-high modification available in mPPS compounds
Modified PEEK and PPS Compounds Applications

- Extruded moldings
  - Film for electrical insulation
  - Wire and cable
  - Tubing
- Injection moldings
  - Gear member
  - Bearing retainer
  - Casing and case body
- Gaskets cutting and processing
  - Plate and sheet
  - Round and cylindrical bar