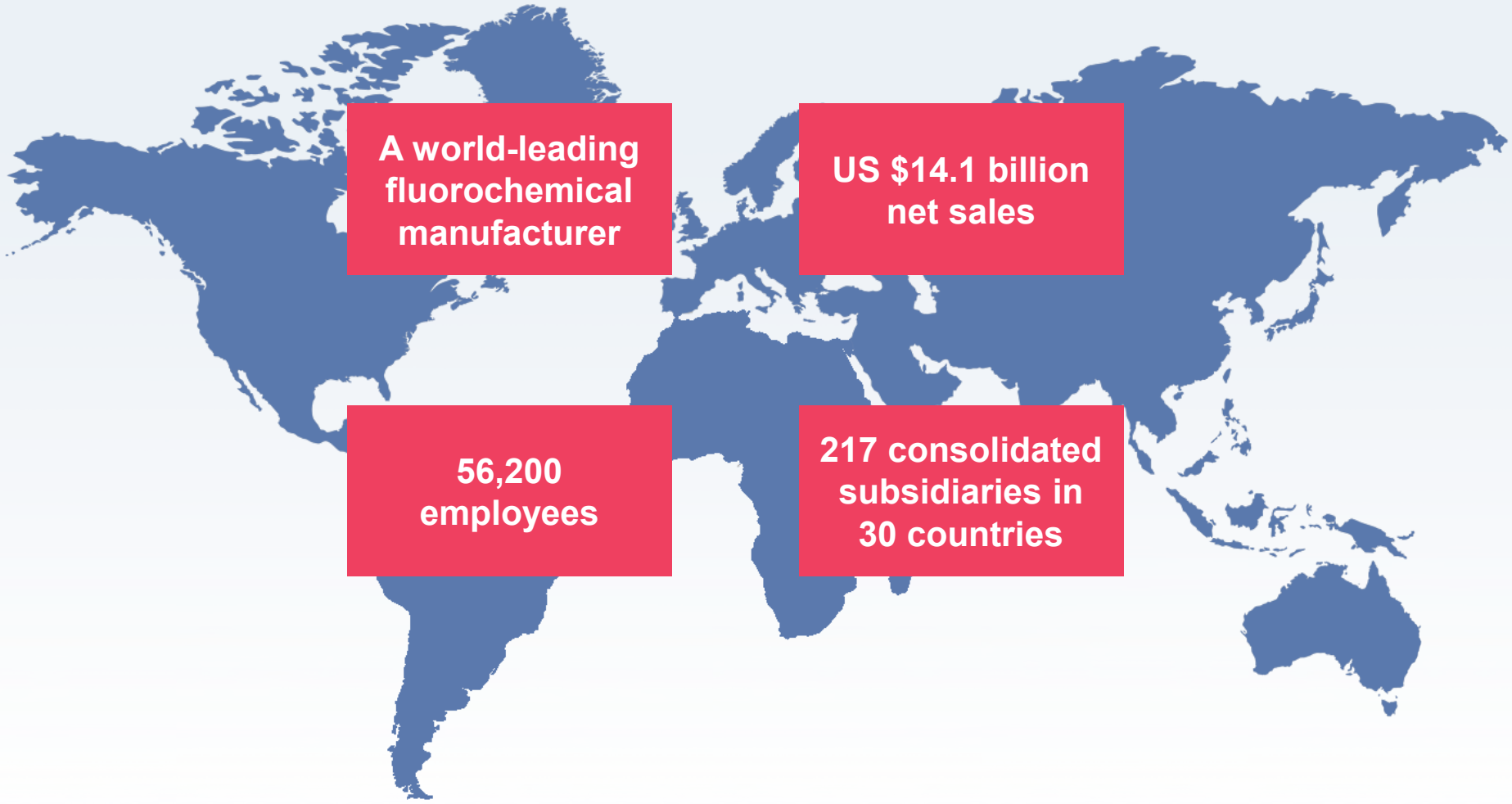
Introduction to Fluon+™ Filled PTFE and Melt Processable Compounds

AGC

Fluon+™
Enhanced Material Science

Your Dreams, Our Challenge

AGC Global Operations



A world-leading fluorochemical manufacturer

US $14.1 billion net sales

56,200 employees

217 consolidated subsidiaries in 30 countries

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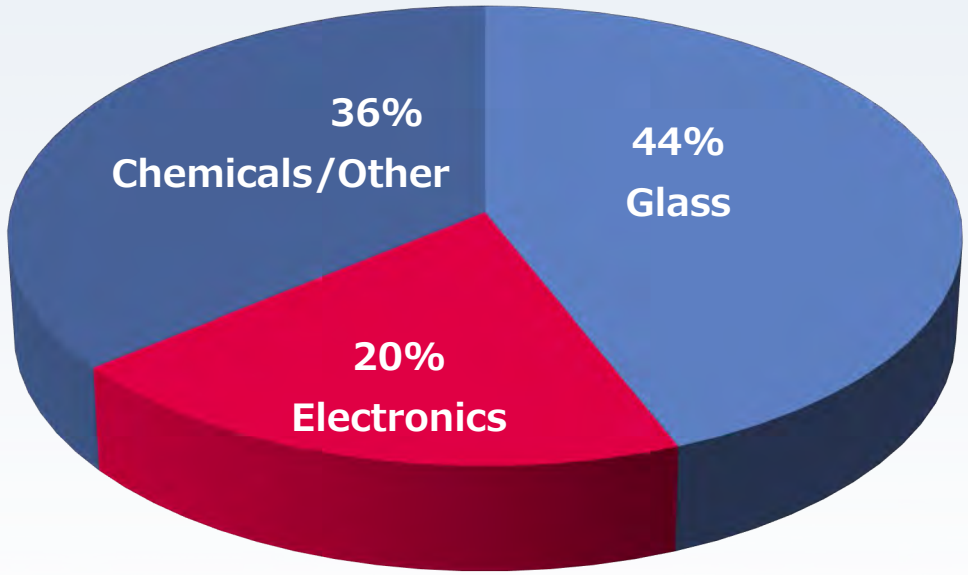
Global Product Reach

Global Sales



- #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
- Certified ISO 9001:2015 and 14001:2015.
- 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.

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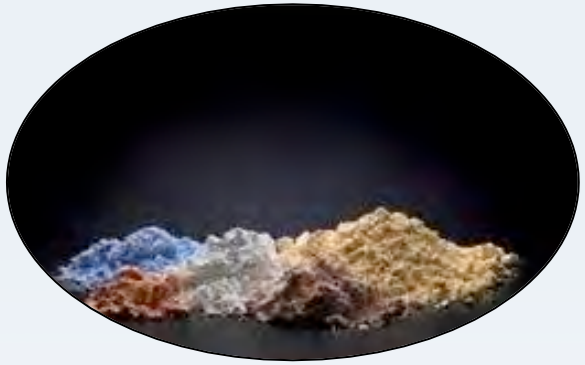
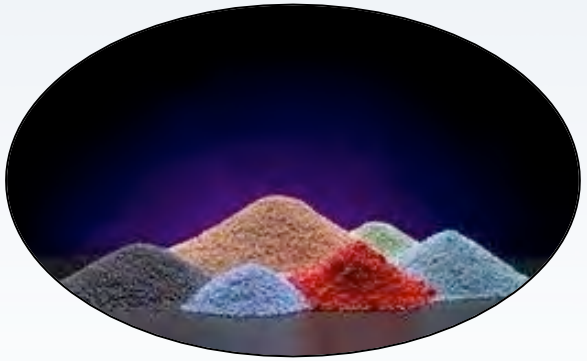
Introduction to Filled PTFE Compounds



Low Flow - non-pelletized



Free Flow - pelletized

Fluon+ FPC
Filled PTFE Compounds

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

Low-Flow

- Produced by dry-blending virgin resin with filler
- End product resembles cake flour
- Used for simple compression molding such as bars and large billets

Free-Flow

- Low-flow blend used as feed for free flow
- Compound is wetted, pelletized and dried
- End product is small pellets
- Physical properties of free-flow compounds are generally decreased compared to low-flow compounds
- Used for automatic compression and isostatic molding, such as sleeves

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

Wear Resistance	1000x Increase
Deformation Resistance	15x Increase
Tensile Properties	2x Increase
Thermal Conductivity	10x Increase
Thermal Expansion	5x Decrease
Chemical Resistance	Generally Decrease
Dielectric Strength	Generally Decrease
Friction	2x Increase

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

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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…

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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

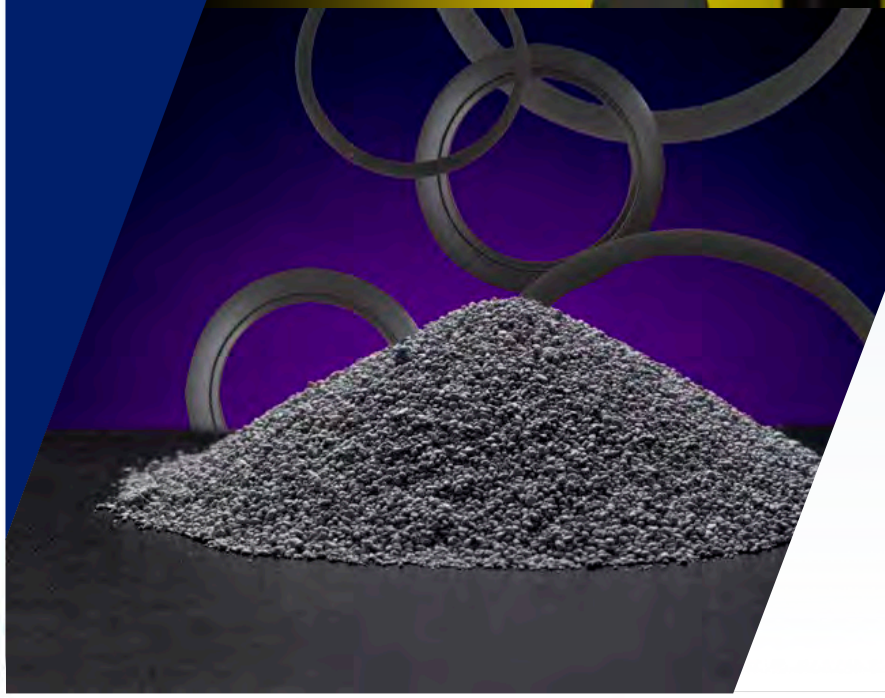
Moly

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

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…

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

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Mineral-Filled Compound Applications

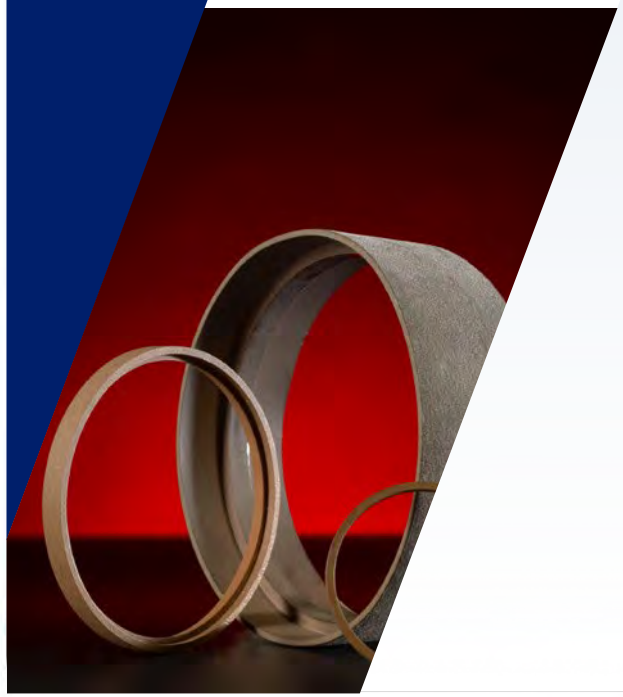
Mineral

- 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

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PPS-Filled PTFE Compounds

- Polyphenylene sulfide
- Excellent dimensional stability
- Excellent thermal stability
- Improve wear and abrasion properties
- Excellent deformation and extrusion resistance

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PPS-Filled Compound Applications

PPS

- 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…

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

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Polymide-Filled Compound Applications

Linear Aromatic Polyester

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

Introduction to Melt Processable Compounds

Fluon™ MPC
Melt Processable Compounds

Fluon™ ADHESIVE
Chemical Bonding Polymers

Fluon™ mPLASTICS
Fluoropolymer Modification Science

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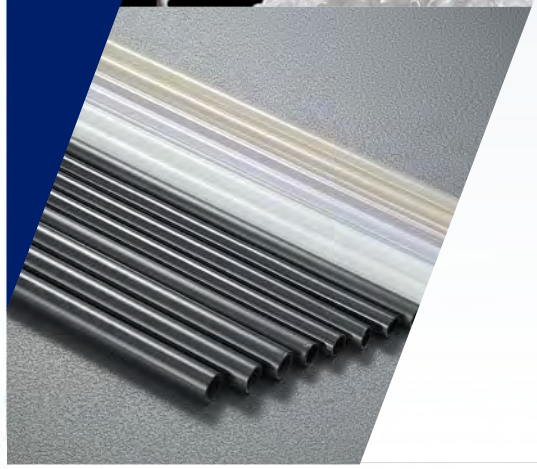
Introduction to Melt Processable Compounds

- 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

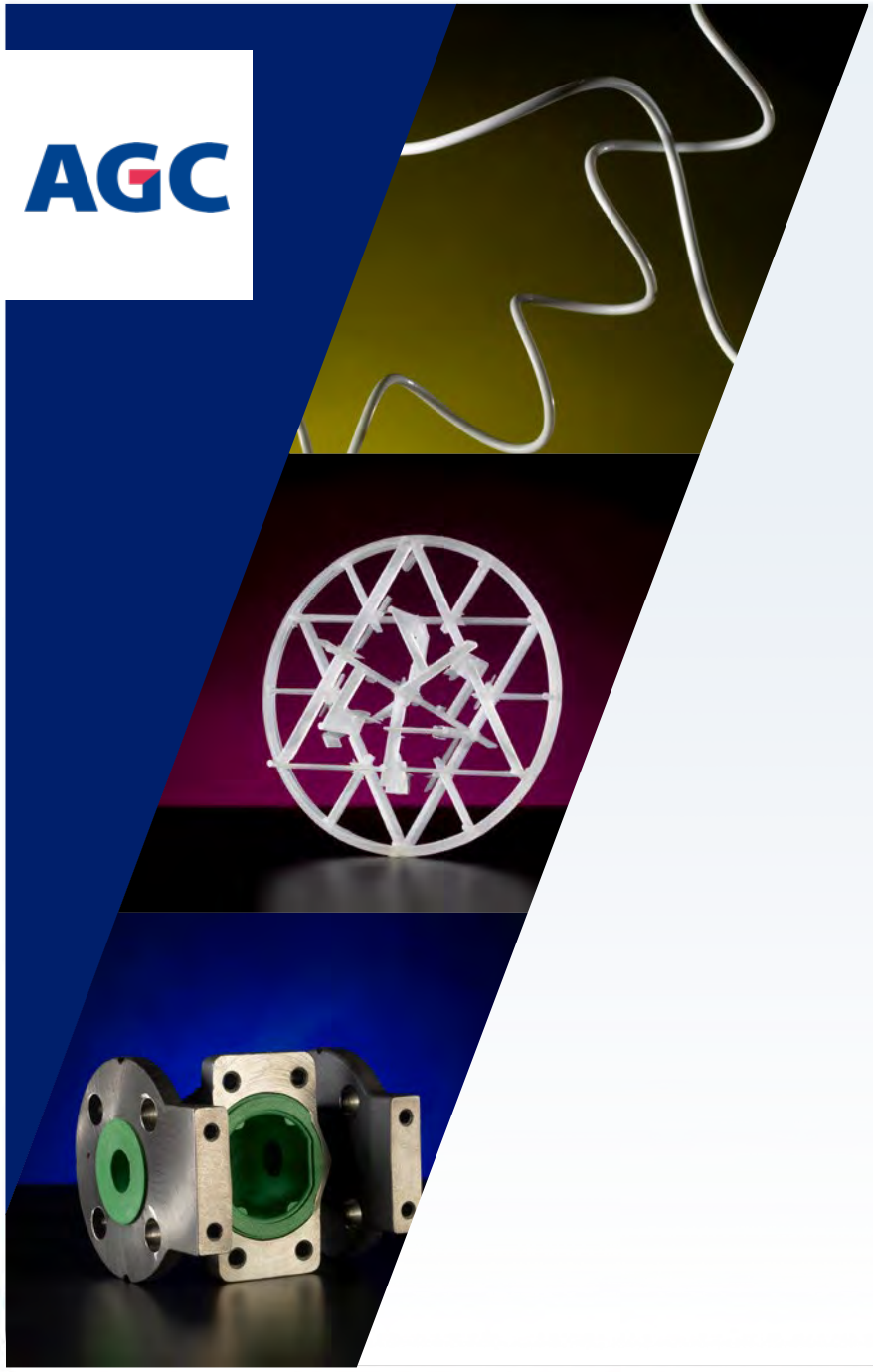
Reinforced & Cross-linkable Compounds

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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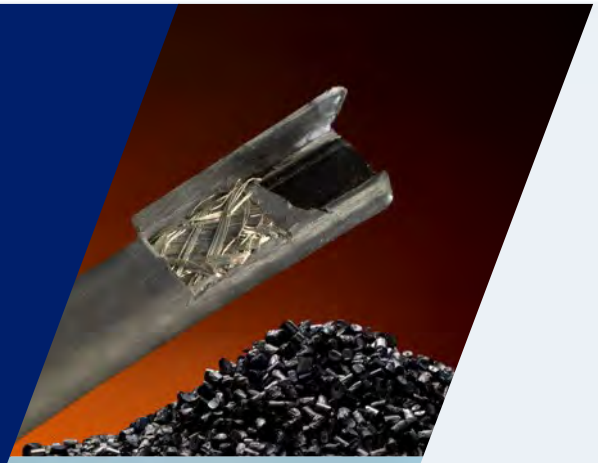
Conductive & Lubricated Compounds

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

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

Fluon+ ADHESIVE
Chemical Bonding Polymers

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

Fluon™ ADHESIVE
Chemical Bonding Polymers

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

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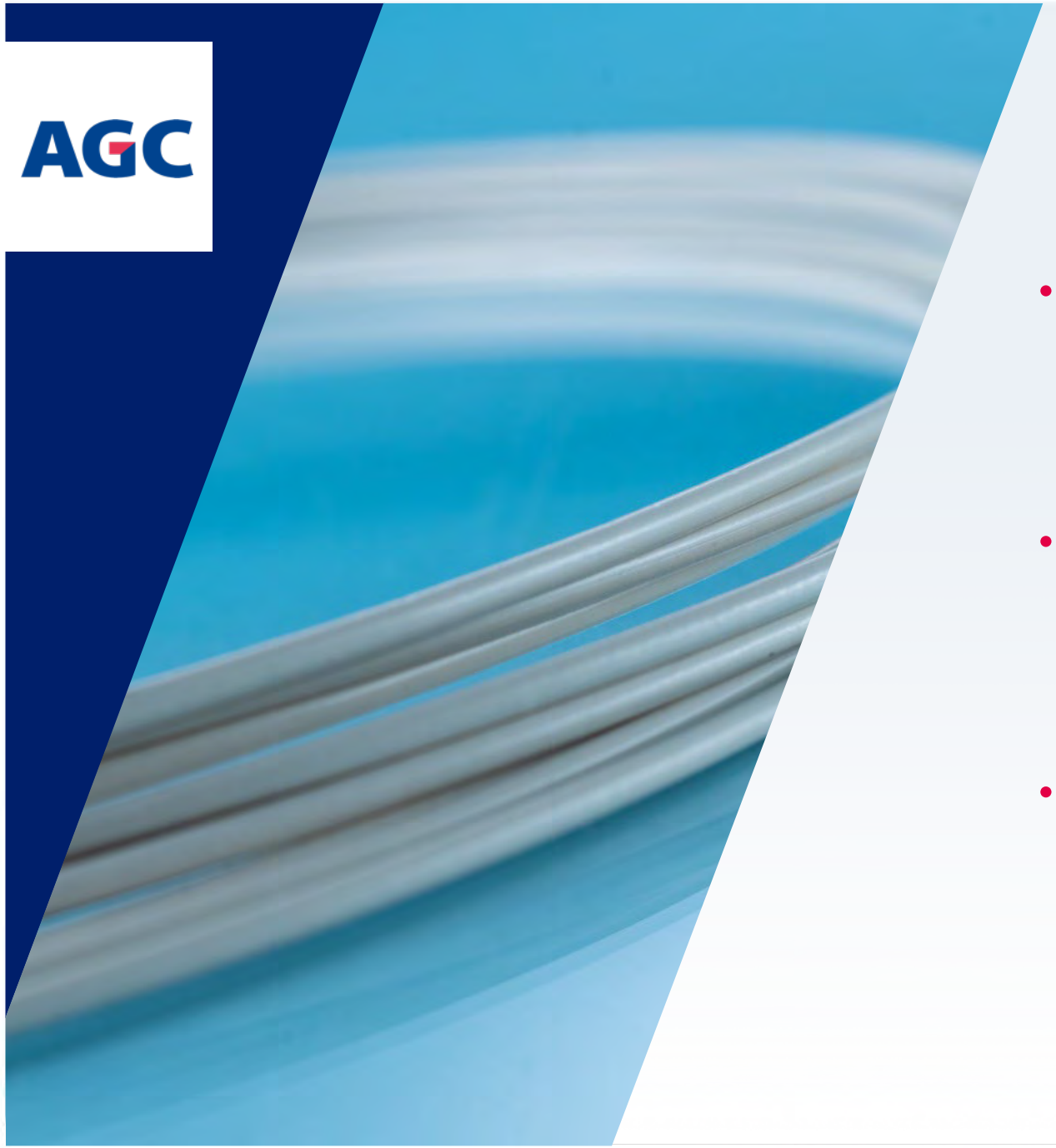
Fluoropolymer Modification Science



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

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