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June 3, 2024

Majority Chairman Greg Vitali
Minority Chairman Martin Causer
Environment, Resources & Energy Committee
Room G50
Capitol Building
Harrisburg, PA 17120

Re: HOUSE BILL 2238 AN ACT CONCERNING THE USE OF PFAS IN CERTAIN PRODUCTS

Chairman Vitali and Minority Chair Causer and members of the committee, I am Chris Correnti, President and General Counsel of AGC America. I want to thank you for the opportunity to testify this morning on HB 2238 and for meeting with me two weeks ago.

AGC is an international company with U.S. operations in chemicals, electronic materials, life sciences, automotive glass, and research and development. Of particular importance to the Commonwealth, our chemicals subsidiary AGC Chemicals Americas, Inc. (AGC America and AGC Chemicals Americas will be referred to herein as “AGC”), is headquartered in Exton, Pennsylvania, along with their manufacturing facility located in Thorndale, Pennsylvania, in State Representative Dan Williams and Senator Comitta’s districts.

AGC has been in Pennsylvania since 1999, and we recently made a $20 million expansion at our Thorndale facility. AGC employs over 150 people in Pennsylvania, including specialized technicians and hourly workers who are members of the United Steelworkers Union Local No.1165-06.

In the Thorndale facility we compound fluoropolymer resins which we sell to 35 Pennsylvania-based manufacturers located across the Commonwealth along with many other customers in the Americas. AGC’s materials are incorporated into a wide range of products essential to the daily lives of Pennsylvania residents and businesses. AGC products fall within the very broad definition of “PFAS” in HB 2238 and would be banned completely in 2033 under the bill as currently written.

Given the critical importance of our products to Pennsylvania businesses, its citizens, and the Commonwealth’s economy at large, we appreciate the opportunity to submit this testimony to share our concerns with HB 2238.

HB 2238 Will Have Broad Unintended Impacts

AGC appreciates the Committee's work to address the concerns in Pennsylvania over contamination from a small group of PFAS chemicals. But, HB 2238 as drafted would impact hundreds of thousands of manufactured products, including those critical to the transition to clean energy, such as electric vehicles, hydrogen fuel cells, wind turbines, and solar panels. Implementing the bill will cost the state millions of dollars and require the Department of Environmental Protection to undertake a costly and unnecessary regulatory exemption process.

Not All PFAS Are The Same

The legislation also incorrectly treats all 14,000 PFAS chemicals the same, despite their significant differences. For example, fluoropolymers, which AGC sells and compounds in Pennsylvania, meet internationally recognized criteria for being "Polymers of Low Concern" which are deemed to have negligible environmental and human health impacts. Unlike other PFAS chemicals, fluoropolymers do not dissolve in water, are inert, are not bioavailable, have excellent durability, are highly resistant to extreme temperatures and environments, and do not degrade.

Fluoropolymers Are Essential In Thousands Of Products

These properties make fluoropolymers the safest and most reliable materials for:

- Insulating wires in electric vehicles and airplanes
- Membranes in hydrogen fuel cells
- Protecting tubing in vehicles
- Protecting underground cabling
- Gaskets and o-rings in manufacturing or testing equipment

Additionally, fluoropolymers are used in many other applications, such as batteries, wind turbines, solar panels, printed circuit boards, heart stents, pacemakers, and similar critical technologies.

HB 2238 Should Exempt Fluoropolymers

As this bill is considered by this Committee, we urge you to amend it to exclude fluoropolymers and focus on substances like PFOA and PFOS, which have the greatest potential for environmental and health impacts. This approach would allow companies like AGC to continue providing products essential for the health, safety, and welfare of Pennsylvania. Otherwise, the regulatory uncertainty created by HB 2238 could force AGC to reconsider its presence in Pennsylvania, potentially resulting in the loss of significant local employment and economic contributions, including union jobs, that would not only impact our operations, but also the operations of many manufacturers across the Commonwealth.

Thank you for the opportunity to testify today on this important bill. We look forward to being a working partner with you as you consider this legislation.

Appendix

AGC manufactures and supplies a range of specialized industrial chemicals and materials, including resins, coatings, films and membranes, that are incorporated into a wide range of products essential to the daily lives of Pennsylvania residents and businesses. Many of these materials are comprised of fluoropolymers. Although fluoropolymers fall within the extremely broad definition of "PFAS" used in the bill, they are very much *unlike* the PFAS chemicals that have been found in drinking water, groundwater and biosolids, such as PFOA and PFOS. For example, unlike those PFAS chemicals of concern, fluoropolymers are not soluble in water, so they cannot enter drinking water or groundwater. Furthermore, fluoropolymers do not degrade into smaller, water-soluble molecules. Also, fluoropolymers are not bioavailable nor do they degrade to smaller, bioavailable molecules, so they do not present toxicity concerns associated with PFAS chemicals of concern. Indeed, peer-reviewed studies demonstrate that, because of these and other characteristics, fluoropolymers satisfy internationally-recognized criteria for being "Polymers of Low Concern" (PLC) -- i.e., polymers deemed to have insignificant environmental and human health impacts.[1]

Fluoropolymers also possess a unique combination of properties that make them critical to the performance of a wide range of products and technologies, such as semiconductors, fuel cells, wind turbines, printed circuit boards, coated wires, batteries, solar photovoltaics, avionics, aircraft components, motor vehicle engines, manufacturing equipment, scientific instruments, and laboratory and diagnostic equipment, among others. This unique, and irreplaceable, combination of properties includes the following:

- **Heat resistance**: fluoropolymers are able to maintain their physical properties at very high temperatures. This makes them particularly suitable for use in aerospace and electronic components.

- **Chemical resistance**: fluoropolymers are highly resistant to chemicals, acids, fuels, and solvents. This makes them a material of choice for use in chemical processing equipment, aerospace, automotive and pharmaceuticals.

- **Mechanical resilience**: mechanical properties include high tensile strength, flexibility, and impact resistance. This is particularly important in applications such as seals and gaskets as well as architectural films and coatings.

[1] See "A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers," Korzeniowski, Stephen H., et al., Integrated Environmental Assessment and Management 19, 2 (2023): 326–354. DOI: 10.1002/ieam; "A Critical Review of the Application of Polymer of Low Concern and Regulatory Criteria to Fluoropolymers," Integrated Environmental Assessment and Management, Henry, Barbara.J., et al.,14, 3 (2018): 316-334. DOI: 10.1002/ieam.4035.

- **Electrical properties**: fluoropolymers have low dielectric constant, high insulation durability, and are used as sheathing materials for wire and cable due to their excellent electrical properties.

- **Inertness**: fluoropolymers are inert, non-reactive and stable (they do not degrade or decompose over time). These properties make them critical to a wide range of industrial and commercial applications in situations where equipment is likely to be exposed to chemicals.

- **Cryogenic properties**: fluoropolymers present excellent cryogenic properties, which makes them particularly suitable for use in high-tech applications such as aerospace, electronics or chemical industries.

- **Separation / barrier properties**: fluoropolymers have excellent moisture barrier and superior gas separation properties. Fluoropolymer membranes are essential to the production of clean hydrogen.

- **Dielectric properties**: dielectric properties cover low dielectric constant (Dk) and dissipation factor (Df) and are unaffected by fluctuations in temperature and humidity. This makes fluoropolymers a critical material for use in electronics and telecommunication applications.

- **Weather resistance**: fluoropolymers are able to maintain their physical properties even when exposed to harsh weather conditions, e.g., environmental degradation, including exposure to ozone, ultraviolet radiation and extreme temperatures. This makes them an essential material for architectural coating and films.

- **Durability**: fluoropolymers can withstand harsh conditions while maintaining their physical properties. This makes them particularly important for use in seals, gaskets, and wires and cables insulation.

- **Non-stick properties**: fluoropolymers prevent sticking, making them a material of choice for applications for which friction and adhesion are concerns is a concern.

This unique *combination* of properties underlies the irreplaceability of fluoropolymers in a wide range of applications, including those noted above. Alternative materials may be able to achieve comparable performance to fluoropolymers for one or a few specific parameters or properties, but overall, due to deficiencies in other properties, they have lower performance and other disadvantages as compared to fluoropolymers. Thus, while alternatives might be considered to be comparable in one or two areas of performance, they often fail to offer the combination of properties that fluoropolymers deliver. It is also important to highlight that, because fluoropolymers are generally more expensive than potential alternatives, for applications where the superior performance of fluoropolymers is **not** necessary, the market has already switched to non-fluoropolymer alternatives.

The unmatched performance of fluoropolymers across multiple areas of performance means that, for most applications in which fluoropolymers are used, attempting to substitute other materials for fluoropolymers will result in a loss of reliability and durability that in many instances will have negative effects on health, safety and the environment as well as negative economic impacts. For example, if a seal or gasket fails in a piece of heavy equipment or a heavy-duty vehicle due to temperature, chemical and mechanical stresses, the failure of that seal could threaten worker safety and result in releases of chemicals into the environment, in addition to causing economic losses due to repair costs and equipment down time. These adverse impacts are averted by the use of fluoropolymers.

Similarly, if a household or commercial appliance fails because a printed circuit board in the appliance was not protected by a fluoropolymer coating and suffered an electrical short as a result, the repair costs and, perhaps collateral costs (e.g., from spoilage) will cause economic loss to the consumer, which will disproportionately impact members of disadvantaged communities. Alternatively, in such a circumstance, the affected appliance might be disposed of prematurely, creating unnecessary waste, unnecessarily occupying landfill space, and unnecessarily consuming virgin resources to manufacture a replacement machine.

Because of the favorable health and environmental safety profile of fluoropolymers, as well as their irreplaceability in a wide range of products and applications that are essential to the daily lives of Pennsylvania residents and the daily operations of Pennsylvania businesses, fluoropolymers should not be banned. Moreover, because fluoropolymers are critical components in such a wide range of essential products and applications, as illustrated by the examples described above, we believe it is impossible to compile a comprehensive list of essential products for which fluoropolymers are used – which is why fluoropolymers themselves should be designated as exempt from the bill. In this regard, we urge Pennsylvania to heed the admonitions of the US Department of Defense in their recent report surveying uses of PFAS compounds that are critical to the national security of the United States.[2] In that report, the Department concluded that:

> PFAS are critical to DoD mission success and readiness and to many national sectors of critical infrastructure, including information technology, critical manufacturing, health care, renewable energy, and transportation. . . . Most of the structurally defined PFAS are *critical to the national security of the United States*, not because they are used exclusively in military applications (although a few are) but because of the civil-military commonality and the potentially broad civilian impact. (emphasis in original)[3]

[2] US Department of Defense, Report on Critical Per- and Polyfluoroalkyl Substance Uses (August 2023), available at: https://www.acq.osd.mil/eie/eer/ecc/pfas/docs/reports/Report-on-Critical-PFAS-Substance-Uses.pdf ("DoD report").

[3] Id. at 15.

Importantly, many of the critical PFAS applications identified by DoD are fluoropolymer applications. These include:

- subcomponents in modern Li-ion batteries: electrolyte solutions, cathode binders, separator coatings, casing materials, and gaskets;
- semiconductor fabrication;
- microelectronics applications, including base laminate materials used in Radio Frequency (RF) and microwave circuits;
- printed circuit boards;
- mold release agents and films typically used in composite manufacturing processes;
- hoses, tubing, hydraulic system lines, O-rings, seals and gaskets, tapes, and cables and connectors widely used in civil and military aircraft, space systems, vehicles, weapon systems, utility systems, and other applications;
- resins for specialty high-temperature or weather-/UVresistant composites; and
- specialty filters and membranes (e.g., aviation filters).[4]

Finally, it is noteworthy that the Department of Defense spent nearly $100,000 and took more than one year to complete its report. Nevertheless, the Department highlighted that the information on critical uses contained in the report "represents a fraction of the mission critical PFAS uses" due to a lack of knowledge about the composition of products and components. Therefore, DoD noted, "a more complete understanding of PFAS essential uses would require an extensive and complex evaluation of the market, a gap analysis of current requirements for manufacturer-provided product information, and illumination of the value chain of products." In other words, identifying all uses of PFAS to be exempted is a herculean task, and the DoD's year-long effort to catalogue such uses touched only the tip of the iceberg.

For this reason and others articulated above, we urge the Committee to exempt fluoropolymers (and articles manufactured from fluoropolymers) from the bill, since it will be detrimental to society to ban all individual products and components which use fluoropolymers. In order to illustrate that, we have attempted in this submission to identify a range of specific applications where the use of fluoropolymers is essential, as well as representative products within those applications. This information is summarized in the table below, with more detailed information for each application provided as attachments to this letter.

[4] Id. at A1-A7.

Sector	Representative application(s)	Attachment
Transportation	• Cable and wire coatings and sheathing for civil and military aircraft, aerospace, motor vehicles, watercraft, and other transportation modes, including high temperature sensor cables (e.g., sensor cables for emissions reduction and improvement of engine efficiency) • Mold release film for composites used for aircraft and helicopter fuselage, wings, etc. • Coatings for aircraft exteriors and interiors and motor vehicle exteriors • Fuel cell components including: polymer electrolyte, catalyst ink binder for Proton Exchange Membrane Fuel Cell (PEMFC), as well as humidifier/drier in balance of system for fuel cell vehicle to control moisture of incoming hydrogen required for reliable and efficient operation of the fuel cell. • Hoses and tubes, including brakes hoses, hydraulic hoses and fuel hoses to reduce evaporative fuel emissions in combustion engine vehicles • Oil seal components, piston rings, shock absorbers, bearings and gasket • Lubricants where other lubricants are not suitable, such as bushings for car door hinges, and trunk lids • In ABS and braking systems because of safety needs • Coatings for engine parts, protection film	A
Electronics	***Semiconductors*** • Molding assist film for power semiconductors packaging • Coating for electronic semiconductor wires • Air and liquid filtration filters used in the semiconductor industry • Molded products for semiconductor equipment, tubes/release sheets used during semiconductor processing • Advanced Semiconductor Packaging • Pellicles for Semiconductor chip manufacturing	B

Sector	Representative application(s)	Attachment
	• Seals, gaskets, O-rings, packings, linings and coatings for pipes and joints for semiconductor manufacture • Encapsulating material for UVC LED chip • Surface coatings of fixing films ***Batteries*** • Solid-state lithium batteries for electric vehicles ***Printed Circuit Boards*** • Mold release film in compression lamination of printed circuit boards, in semiconductors, optoelectronics components, standard packaging to protect memory chips and sensor devices used for mobile devices, data centers, and LED lens production • Substrate for print circuit board • Sound transmission membranes in circuit boards, antennas for mobile phones, technical / industrial linings, electromagnetic flowmeters ***Cables & Wire, Other*** • Coating material for wires, coaxial cables and various other cables for chemical resistance conforming with international factory mutual standards (fire risk reduction) • Heat-resistant sheath wire in electronic equipment operating at high frequencies and high temperature • Optical fibers • Antifouling and mold-release coating agent for touch panel glasses, lenses and mirrors; functional anti-smudge coatings applied to various substrates (e.g. glass, metal, plastic), removing sebum and fingerprints on exterior parts (e.g. cover glass, housing, camera module in portable devices) especially smart phones and other touchscreen applications; coatings for automotive use (e.g. instrument panels with touchscreen interface); adhesion prevention for glass and parts for multifunctional printers	
Communications	• Plastic optical fiber (POF) in telecommunication	C

Sector	Representative application(s)	Attachment
	• Coating of special optical cables called “buffer tubes” • Coating of signal cables • Tubes and machine or injection molded parts, printed circuit boards material for use in high-speed communication technology	
Medical devices and life sciences	***Tubes, catheters, etc.*** • Catheters for intravenous and inside body interventions; small “non-kink” tubes; endoscopy; pancreatic and biliary stents; foreign body retrieval devices; balloon dilators; needles, brushes and specialty items; single use snares in colonoscopies; endoprostheses • Gaskets; diaphragms in medical ventilators/respirators and sterile syringe filters; membrane filters for sterile venting of gases, aggressive fluids, acids & non-aqueous solvents, gas filtration and aerosol sampling; humidifier/drier membranes used in CPAP (Continuous Positive Airway Pressure) machines; breath gas analyzers. • Artificial blood vessels • Dialysis-related devices • Surface coating for medical devices • Packaging of terminally sterilized medical devices • Coatings for biochip devices ***Equipment & Manufacture*** • Laminate rubber stoppers • Wire sheath material for medical equipment • Humidification or conditioning of various medical gasses • Tubes, seals, gaskets, O-rings, lining of vessels, pipes, valves, hoses, process control devices, pumps, gas scrubbers, dryers, evaporators, heat exchangers and connectors for pharmaceutical manufacturing equipment • Coating for image plate of medical printing film	D
Construction and Infrastructure	• Roofing and façade material for membrane structures such as train stations, sport stadia, shopping malls, airports, exhibition	E

Sector	Representative application(s)	Attachment
	centers, bridges, greenhouses for commercial-scale growth of fruits, vegetables, flowers, etc. • Sports facilities and sewage disposal facilities • Light weight and composite constructions (development / future application) • Heat-resistant flexible wire • Architectural coatings and paints • Sliding bearings • Anti-graffiti overlay for traffic signage / safety • Laminate films to provide antifouling and touch-proofing of metals, fire and heat resistance and oil resistance to kitchen hoods	
Food Contact and Processing	***Food industry*** • Seals, O-rings, gaskets, tubing and pipes, valves and fitments, tank linings, sensor covers, and non-adhesive coating for food equipment • Lining of food cans • Ion exchange membranes • Industrial-scale food and feed processing equipment, in seals, tubes, pipes, hoses, o-rings, gaskets, valves and fitments, conveyor belting, tank lining, filter membranes, sensor covers, lubricants and equipment specific to food and feed transport.	F
Energy	***Oil & Gas and Mining*** • Cables and cable outer "jackets", including sub-sea heating cables and self-regulating heating cables. • Structural or fluid handling components • Coating resin material for electrical wires for crude oil drilling • Wire insulation for downhole sensor cables, extract duct coating, trace heating for cold production areas, and self-regulating heating cables for cold areas • Dehumidification of sample gas for analysis	G

Sector	Representative application(s)	Attachment
	• Packers, blow out preventers, seals, gaskets and O-rings ***Nuclear*** • Cables and wires, including cables of control rooms, sensor cables, and general cables for the industry. ***Photovoltaics and Wind*** • Building integrated photovoltaic (BIPV) modules, solar panels, molding wind turbine composites • Next-generation solar cells for BIPV and megasolar projects • Coatings for PV modules • Coatings for wind turbine blades and towers ***Hydrogen*** • Proton Exchange Membrane Electrolyzer (PEMEL): water electrolysis, electromechanical hydrogen compressors and purification and electrolysis plant for renewable hydrogen production ***Other*** • Separator for REDOX flow batteries • Exchange Membrane Electrolyzer for anion exchange membrane water electrolysis (AEM) • Binders for electrode materials in batteries • Release films used for photovoltaic cells, proton exchange membrane of fuel cells, Li-ion batteries • Key polymer electrolyte, also used as a key ingredient of catalyst ink's binder for Proton Exchange Membrane Fuel Cell (PEMFC)) • Coating of tidal power cables • Humidification or conditioning of various gases	
Manufacture/Processing	***Chemical Industry*** • Coating material for industrial wires, coaxial cables and various other cables • Hoses, tubes, gaskets and other seals	H

Sector	Representative application(s)	Attachment
	• Distillation column packings • Rotolining or electrostatic coating, e.g., vessels, tanks, pipes, tubes, elbows, complex manifolds, pump casings and filter housings • Electrodialysis processes for wastewater treatment (desalination and salt concentration) and separation of organic components and inorganic salts (cosmetics, medicals, food, medicine, and purification of intermediates in inorganic synthesis) • Expansion joints, compensators and bellows • Bearings, ball joints, hinges, calipers, valves • Ion exchange membranes for production of caustic soda, potash, chlorine for use in end products such as: paper, aluminum, wind turbines, hydrazine used in fuel cells, rocket fuels, pharmaceuticals, antiseptics, nylon, EDTA, soaps, cleaning agents, household bleaches and germicides, and many organic and inorganic chemicals ***Metal Plating*** • Acid recovery (acid and metal salt separation process by electrodialysis/diffusion dialysis) ***Water treatment*** • Industrial water treatment; electrodialysis ***Lubricants*** • Solid lubricants where other lubricants are not suitable; thread seal pastes • Coatings for improved rub and scuff resistance, reduction of friction, chemical inertness and temperature resistance and to impart release characteristics (e.g., mold release agents) ***Misc. Equipment*** • Manufacturing equipment such as belts, rollers, heat-sealers in dying, laminating, drying processes • Dryers used to remove moisture from gas samples prior to analysis to improve signal resolution	

Sector	Representative application(s)	Attachment
	• Dehumidification or humidification pretreatment in pneumatics or compressed gas • Manufacturing equipment, including seals, hoses, gaskets, o-rings, valves, linings in vessels, pipes, reactors, process control devices, pumps, gas scrubbers, 3D printers	

Attachment A -- Transportation Applications

Safe, reliable and accessible transportation is the lifeblood of our economy and is an essential feature of modern life. Fluoropolymers perform critical and irreplaceable functions for all modes of transportation.

Fluoropolymers are used for sheathing for cable and wire used in motor vehicles (on- and off-road), civil and military aircraft, spacecraft, watercraft, and other modes of transportation. Fluoropolymers are essential for this application because they provide flexibility plus durable and reliable protection against extreme temperatures, aggressive fluids such as hydraulic fluids and fuels, humidity, vibration and compression. For example, aircraft wires must comply with the international standard SAE AS22759, which requires temperature resistance of -65 ~ 200 °C, and similar high performance is required for electric vehicle (EV) cables. Potential alternative materials, such as polyvinyl chloride, polyethylene, alkane-imide and polyamide are not suitable for these applications due to one or more of the following deficiencies: inadequate heat resistance, poor arc resistance, poor moisture resistance, or cracking. Similarly, fluoropolymers are essential to satisfying international standard for automotive cables, ISO 6722-2, which cannot be satisfied by these potential alternatives. Only SIR (silicone rubber), polyether ether ketone (PEEK), mica, and ceramic can provide similar heat resistance as compared to fluoropolymers, however they fail to ensure similar mechanical strength and chemical resistance. Thus, the use of potential alternatives would lead to premature deterioration of the wire sheath material (insulation degradation or insulation breakdown), which could lead to electrical leakage, resulting in equipment failure, electrical shock and fire hazards. Furthermore, fluoropolymers have superior electrical properties (low dielectric constant and low dielectric loss tangent) compared to potential alternatives (dielectric constant below 2,1 kHz and dielectric loss tangent below 0.0002 kHz). This becomes increasingly important as larger volumes of data are transmitted and the wavelengths used shift toward higher frequencies, which are more susceptible to attenuation during transmission. Fluoropolymers are the material with the least loss during this transmission and are the most suitable insulating material for high frequencies.[5]

Fluoropolymers also provide critical functionality for hoses, fuel lines and gaskets and seals (such as crankshaft seals, transmission seals, pinion seals, and shock absorber seals) which require the following combination of properties: durability, heat resistance, oil and fuel resistance, flexibility and sealing. These properties are essential to assure that vehicle fluids do not leak, resulting in potential safety concerns, human and environmental exposures, decreased reliability and increased repair costs. For consumers (and personal vehicles), increased repair costs would disproportionately impact disadvantaged communities. Only fluoropolymers can provide the required properties to satisfy the relevant standards for Rubber Products in Automotive Applications (ASTM D2000). According to the standard, in operating environments surpassing 250 °C, type H or higher (required heat resistance) and class K (required oil

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[5] Notably, only fluoropolymers can meet the following international standards for automotive cables: ISO 6722-1; ISO 6722-2; LV 112-1; LV 112-2; LV 112-3; LV 112-4; LV 122; LV 212; LV 213-1; LV 213-2; LV 216-1 and LV 216-2.

resistance) should be used, meaning that only fluoroelastomer-based rubber can meet the performance level. Non-fluorinated materials, such as silicone, do not provide the same level of performance, and do not fulfil industry standards. At the current time, there is no prospect of technically or economically feasible substitution.

In fuel lines, the use of fluoropolymers ensures the necessary flexibility without the need for a corrugated structure, which reduces the loss of efficiency due to air contamination and eliminates the need for replacement as there is no deterioration. The primary alternative, PA6 (polyamide 6), has poorer barrier performance therefore increasing the likelihood of fuel vapor leaking into the environment. This is essential as environmental requirements for motor vehicles, in terms of fuel emissions reductions, become increasingly stringent.

Fluoropolymer membranes are also essential for fuel cells used in transportation, providing essential release properties, chemical durability to solvents of catalyst ink, and non-contaminating to platinum supported carbon and ionomer binders for suitable catalyst layer formation of fuel cells. The operating conditions inside fuel cells are harsh, with OH radicals being constantly generated at operating temperatures of 60 to 100 °C. Non-fluorinated polymer materials can only be used for short periods of time, as the polymer decomposes, rendering operation impossible. For example, the Fenton test (test method for fuel cells) shows that hydrocarbon-based materials degrade five times more than fluorinated materials. If non-fluorinated materials such as PEEK-(Polyetheretherketone) based hydrocarbon electrolyte polymers are used in fuel cell vehicles, the critical components of the fuel cell (stack parts) will need to be replaced more frequently, which means that the operating time of the fuel cell vehicle would not be assured and the amount of waste generated considerably higher. Fluoropolymer membranes are the only materials that can withstand operation for tens of thousands of hours in the presence of radicals. They are also the only materials that allow the cell to operate at high power density.

The US Department of Energy (DOE)[6] standard for fuel cell vehicles include high performance and continuous service life, and fuel cells using fluoropolymer ionomer membranes can be used continuously for more than 25,000 hours. In addition, vehicles need to be able to generate electricity instantaneously, which solid oxide fuel cells are not able to do, making them unsuitable for automotive applications. Hydrocarbon-based electrolytes are not durable for the required length of operation time in stationary applications such as back-up power for datacenter. Although other types of stationary power generation exist, such as SOFCs (solid oxide fuel cell) made of inorganic materials, they are not suitable for generating instantaneous power. Fluoropolymer humidifier/drier membranes are also essential in fuel cell electric vehicles to control moisture of the incoming hydrogen, which is necessary to ensure reliable operating conditions of the fuel cell.

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[6] Fuel Cell Technologies Overview, US Department of Energy, Arlington V.A., 2023. Fuel Cell Technologies Subprogram Overview (energy.gov)
https://www.hydrogen.energy.gov/pdfs/review23/fc000 papageorgopoulos 2023 o.pdf

Fluoropolymers are also essential to EV batteries, which need higher voltages and, in turn, require greater heat resistance and superior insulation properties for sealing materials.

Fluoropolymers provide sufficient heat resistance and insulation to withstand high voltages associated with EV batteries. They are also essential for use as binders in EV batteries, due to their ability to function in strong oxidization environments. None of the potential alternatives to fluoropolymers simultaneously meet the required chemical, heat, and voltage resistance, as well as adhesion to the substrate. If used as binders, these alternatives will be oxidized and tattered. Fluoropolymers used as a binder in Li-ion batteries provide extended lifetime and performance over a broad range of conditions. Those batteries are the central component of EV and their use is expected to increase significantly until 2030 and beyond.

In addition, fluoropolymers are required to bring ORFBs (Organic Redox Flow Batteries) to the market, to provide superior performance to rechargeable batteries and reduce greenhouse gas emissions. The use of fluoropolymer anion exchange membranes will also offer high durability and stability in the ORFB application. These applications - highly dependent on the use of fluoropolymers - will be the cornerstone of the decarbonization of US transportation. Also, for power semiconductors used in fuel cell vehicles and battery electric vehicles, fluoropolymer film is essential to provide the required properties of non-adhesion, high melting point (200-280°C) and mechanical properties at molding temperatures (100-200°C). Those properties are needed to prevent contamination of semiconductors and protect molding equipment and therefore ensure high performance and energy efficiency of fuel cell vehicles and battery electric vehicles.

Fluoropolymers are also essential for aircraft exterior coatings, to protect the aircraft from harsh environmental conditions during flights at high speed of about 800 to 900 km/h (e.g., temperature spikes and drops, atmospheric pressure, friction, strong ultraviolet rays, dust, rain, hail, etc.). They also prevent oxygen seepage, reducing the likelihood of corrosion of the fuselage. Fluoropolymer coatings also provide improved fuel efficiency due to reduced icing (wings and fuselage) and high resistance to physical friction (e.g., wind at the wing sections). Use of fluoropolymer exterior coatings also allows for reduced volatile organic compounds (VOC) and CO2 emissions by lengthening the period of re-coating, and reducing the energy demand required for repainting. Fluoropolymers are difficult to replace for this application due to the exacting industry standards required to be met.[7],[8],[9],[10] Fluoropolymer coatings are also

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[7] Aerospace Industry Standards, NQA, What Standards Apply to the Aerospace Industry? https://www.nqa.com/en-us/certification/sectors/aerospacehttps://www.nqa.com/en-us/certification/sectors/aerospacehttps://www.sae.org/standards/aerospacehttps://enhancequality.com/standards/aerospace -quality-standards/https://www.iso.org/ics/25.220/x/

[8] Aerospace Quality Standards, QSE. Quality Systems Enhancement | Aerospace Quality Standards (enhancequality.com)

[9] ISO-25.220, Surface treatment and coating including processes and equipment for surface treatment and coating. ISO - 25.220 - Surface treatment and coating

[10] ISO-25.220.60, Organic coatings. ISO - 25.220.60 - Organic coatings

important for aircraft interiors, to provide excellent stain resistance as well as color and gloss retention, while satisfying applicable smoke and fire prevention criteria.

There are no suitable fluorine-free alternatives available that would provide the same level of protection as fluoropolymer coatings. Only two-component polyurethane paints, that were used before the introduction of fluoropolymer coatings, have been identified as readily available and potential alternatives. However, using non-fluoropolymer materials that are less weather resistant than fluoropolymers will increase the maintenance frequency significantly. A comparison of high weather resistance, chemical resistance, and room temperature baking and manufacturing show that non-fluoropolymer material has a product lifecycle of approximately 5 years, compared to 10 years for fluoropolymer coatings.[11],[12]

Similarly, fluoropolymer-coated automotive films provide weather, heat and corrosion resistance that performs 3-5 times better than available alternative materials, ensuring the longest lifetime of vehicles, the least efforts and costs for removing and re-applying the film to protect the car's appearance in the long term. Non-fluorinated alternatives do not provide the same level of performance. For example, polyurethane film causes reduced performance (e.g., deteriorated dirt removal when insects adhere to the film), resulting in increased frequency of film replacement and manual cleaning. Acrylic films do not provide the same level of acid resistance that is required to protect the roof of a car. Finally, polyester films provide inferior protection of gloss in continuous accelerated weathering tests and natural exposure tests, and is inferior to fluoropolymers in terms of weather, heat and corrosion resistance, stain protection, and self-healing.

[11] Wind Hullo Topcoat. windhullo.pdf (nttoryo.co.jp)

[12] Wind Hullo Topcoat. windhullo.pdf (nttoryo.co.jp)

Attachment B – Electronics Applications

Safe, reliable, affordable and durable electronics and electrical components are essential to virtually all facets of modern life, and fluoropolymers are essential to enabling those technologies. This is exemplified by the CHIPS Act, which is intended to ensure US leadership in "the technology that forms the foundation of everything from automobiles to household appliances to defense systems."[13]

Semiconductors

Fluoropolymers are essential in the manufacturing of semiconductors, in wet cleaning and wet etch processing equipment, where high purity, high chemical and temperature resistance and low flammability are required. Fluoropolymer resins with an adhesive function provide the ability to bond to metals including copper and other polymers (e.g., polyimides and polyamides). Adhesive fluoropolymers provide critical benefits as coatings for chemical resistance. They are essential because of their ability to not react with other chemicals, not to leach contaminants that could potentially negatively impact yield and to be stable under process conditions including elevated temperature. Fluoropolymer tubing additionally presents the advantage of being highly flexible, which allows for easier design and implementation in wet etch processing equipment and fluoropolymer coating on metal parts provides corrosion protection, allowing for increased efficiency as no primer or adhesive interlayer is needed.

Fluoropolymers are essential as pellicle films used in the photolithography process for the protection of photomasks from particle contamination in semiconductor lithography processing. They provide practical light resistance for the excimer laser in an environment that is irradiated with exposure wavelength ArF (193nm) and KrF (248nm), and achieve superior light transmittance through extremely high transparency (>95%). Additional essential performance requirements for pellicle film provided by fluoropolymers are uniformity of film thickness which helps avoid the tearing of the film, and low refractive index, and extinction coefficient which ensures that the light maintains a straight path without losing power. Fluoropolymer film coatings to a thickness of a few sub-microns, are essential for semiconductor innovation and associated node size reductions.

Fluoropolymers are critical as a UVC transparent window material or encapsulant for UVC LEDs to extract higher levels of light (i.e., to optimize the use of energy/electricity) from the UVC LED chip. Fluoropolymers are the only material that can simultaneously achieve the performance required for transparent encapsulants and for UVC LEDs, namely UVC durability, electrical insulation and water vapor barrier properties, which also ensure the proper functioning of the UVC LED. Synthetic quartz is not a suitable alternative for UVC-LEDs as it requires adhesives

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[13] The White House, FACT SHEET: CHIPS and Science Act Will Lower Costs, Create Jobs, Strengthen Supply Chains, and Counter China (Aug 9, 2022) available at https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/09/fact-sheet-chips-and-science-act-will-lower-costs-create-jobs-strengthen-supply-chains-and-counter-china/

to be used as the encapsulation materials, which easily deteriorates with strong UVC light. Other potential alternatives such as acrylic resin, generally absorb the UVC light and cannot be used for this application.

Top Anti-reflective coatings (TARC) are widely used in the semiconductor industry, particularly in the manufacturing of semiconductors, integrated circuits, printed circuit boards, and other related components. TARC helps to reduce unwanted reflection of light from the surface of these materials, thereby improving optical performance and increasing efficiency. This coating is crucial for enhancing the functionality and quality of various electronic devices, ensuring better performance, and reducing the losses caused by reflections. The performance requirements of TARC material and its raw polymer are to simultaneously meet low refractive index, low surface energy, and solubility in water and developer. TARC material made of fluoropolymers has a unique performance superiority, such as low refractive index, low surface energy, and

simultaneous solubility in water and developer. These performance requirements are directly related to the yield of commercial semiconductor manufacturing and process suitability. To our knowledge, there is no suitable alternative to fluoropolymer TARC material on the market. Similarly, BARC (Bottom Anti Reflective Coating) is an inadequate alternative to TARC, since BARC is only used for the production of certain semiconductors that have narrow patterning made by ArF immersion or EUV, as it requires a completely different manufacturing process and setting from those utilizing TARC made of fluoropolymers. Therefore, BARC is not considered a realistic and viable option for most semiconductor manufacturers to replace TARC.

Furthermore, BARC is generally an inorganic layer stuck to the wafer and needs dry etching process to be removed from the wafer surface. On the other hand, TARC is easily removed together with photoresist at once due to performance requirements.

Thermal processes such as rapid thermal processing, Low Pressure Chemical Vapor Deposition, oxidation, diffusion and lamp annealing in semiconductor manufacturing processes require significant chemical and heat resistance. The ultra-high temperature (up to 260°C), plasma resistance (exposure to O2 plasma, F2 plasma or a mixture of both) and insulation properties (high breakdown voltage) of fluoropolymers make them invaluable for semiconductor fabrication processes (and other industrial extreme high-temperature areas) requiring elastomer seals. Also of critical importance, fluoropolymers do not form particle contaminants because they have high chemical bonding energy, making them resistant to plasma cleavage. This ensures that no particles adhere to the wafer, causing malfunctions. To our knowledge, there are no potential substitute materials that satisfy these requirements.

Fluoropolymers are also essential for the packaging of semiconductors, as they are the only material that can provide the necessary properties of high-temperature durability, anti-static, easy release, and mechanical properties (e.g. tensile elongation of 600% or above, elastic modulus of 70MPa or below) to package semiconductors without deforming or damaging chips, particularly at high temperatures ranging 150 – 220 °C. Other films, such as polyethylene, polybutylene telephthalate (PBT), and polyvinyl chloride (PVC) have inferior mechanical properties and less flexibility at high temperatures compared to fluoropolymer film and can cause damage/deformation of chips and decrease in productivity due to oligomer contamination.

Fluoropolymers also exhibit superior electrical properties (low dielectric constant and low dielectric loss tangent) compared to other potential alternatives (dielectric constant around 2,1 and dielectric loss tangent below 0.0002). Those properties maintain signal integrity and reduce transmission loss, and they also have a low thermal expansion coefficient as heat is generated. As increasing volumes of data are transmitted, the wavelengths used are shifting toward higher frequencies, with higher frequencies being more susceptible to attenuation during transmission. Modified polyimide and liquid crystal polymers have been evaluated as alternative materials, but none of these materials has achieved electrical properties comparable to those of fluoropolymers. The dielectric loss tangent of both “alternative” materials is more than 0.001. High-speed data communication requires higher frequencies, so there is a possibility that communication speeds may reach a ceiling if fluoropolymers are not used. To our understanding, no alternative has been found to be able to meet one or more essential functional quality characteristics of fluoropolymers such as adhesion, dielectric constant and ability to process, and there is no prospect of technically or economically viable alternatives at present.

In addition to the critical functions described above, fluoropolymers also play an essential role in assuring the “clean room” environment necessary for semiconductor manufacture. Specifically, fluoropolymer membranes are used to meet the high-performance filter standard EN 1822 (ULPA,

HEPA) which is essential for semiconductor and LCD related plants and equipment. These fluoropolymer membrane filters combine high air permeability and collection efficiency, and can reduce power costs compared to non-woven filters and glass filters made of other materials. In addition to their superior performance, fluoropolymer filters do not have the potential to leach boron (B), which is present with glass filter media, and can adversely affect the performance of semiconductors. Similarly, filters with both high chemical resistance and filtration performance are required for filtration of chemicals used in semiconductors. Fluoropolymer membranes are among the few materials that can satisfy these requirements. Ceramic, a potential alternative, has high chemical resistance but is very expensive and therefore difficult to replace for economic reasons.

For more information on the importance of fluorine materials used in the semiconductor manufacturing process, please refer to the technical documents available on SIA (Semiconductor Industry Association) website.

Batteries

Fluoropolymers are essential components of high-performance lithium-ion rechargeable and lithium metal rechargeable batteries. High power and energy dense batteries require very thin high-performance gaskets. For gaskets to function optimally, proper thermal functionality is essential, for which a stable and compressive polymer providing a high degree of insulation to withstand very high currents of up to 280 amps is needed. Chemical resistance is also a requirement. The high compressive and moisture properties of fluoropolymers are required to enable adequate, reliable gasket performance. Other potential methods and materials such as multilayer construction do not provide long-term and leak-proof lining systems and would lead to frequent maintenance intervals. In addition, materials such as high-alloy steels (e.g., hastelloy, inconel, titanium, zirconium) are not sufficiently chemical-resistant.

For nickel-metal hydride batteries, the binder is required to have strong alkali resistance and the polymers need to be dispersed. This essential functionality is provided by fluoropolymers, which also may be used in the electrodes of lithium-ion batteries, where chemical resistance and low flammability are key requirements. Furthermore, to meet increasing performance demands, next generation batteries with higher functionality will need binder materials that can meet more exacting requirements in terms of alkaline solution concentration and voltage (oxidation potential of the cathode). Fluoropolymers are essential for providing these functionalities.

Studies assessing alternatives to fluoropolymer binders have been conducted without finding promising non-fluorinated alternatives.[14] None of the potential alternatives simultaneously meet the required chemical, heat, and voltage resistance, as well as the adhesion to the substrate at a level comparable to fluoropolymer materials. Within battery applications, fluoropolymers are mainly used as binder because of their ability to function in strong oxidization environments. For lithium-ion batteries at positive electrodes, more than 4V is occurring, which causes oxidization. When applying non-fluorinated polymers as binder, these polymers will be oxidized and tattered. As holes are generated these polymers lose their function as a binder.

Printed Circuit Boards

Fluoropolymers are essential components of copper-clad laminates (CCL), the key material in printed circuit boards, because they combine the critical performance characteristics required for this application: heat resistance (solder reflow endurance temperature 300 °C), solder resistance, water resistance, good adhesion to copper foil, and low dielectric constant. We are not aware of suitable alternatives that provide equivalent performance and reliability. Fluoropolymers are also used to coat printed circuit boards to provide protection against moisture or other contamination that might lead to short circuit and device failure.

Wire & Cable

Insulating fluoropolymer coatings are essential components of wire and cable, to assure the safety of the structures within which wire and cable are used, and to comply with factory mutual standards including FM 4922 – the Global Specification for ventilation/duct extract systems.

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[14] Application for Derogation from PFAS Restrictions For Specific Uses in BATTERIES, Battery association of Japan, available at: https://www.baj.or.jp/about/ades5k0000001vxx-att/ades5k0000001wa9.pdf

Fluoropolymer sheathing is essential for this because of their superior chemical and heat resistance and their non-flammability.

Fluoropolymer coated wire is rated to at least 260 °C, which provides the necessary protection for use in automotive, aerospace and industrial high temperature applications. These include thermocouples, self-regulating heater cables and any location where a temperature of above 200 °C is needed for extended periods of time. In addition, fluoropolymer coated wire is used in high voltage, high frequency heating cables, needed in many subsea applications that require high temperature resistance, low dielectric losses and the ability to withstand electrical and chemical breakdown over a long service life. Fluoropolymers are critical for achieving these performance requirements. Similarly, self-regulating heater cables are used for freeze protection and process maintenance. In high temperature and high chemical resistance heating, fluoropolymers are necessary to both conduct electricity in the inner layer of the cable, as well as provide insulation in the outer layers.

Because of their low dielectric constant, fluoropolymers used in wires and cables confer a low dielectric loss up to 250 °C. Potential alternatives such as polyolefin-based materials do not offer a viable substitution potential, as their applications are limited to temperatures below 80-100 °C. Polyimide (PI) and liquid crystal polymers (LCP) are also potential alternatives to fluoropolymers for wire and cable and electronics coatings more broadly. However, both PI and LCP are unsuitable for many applications, due to their high dielectric constant.

Finally, as a technology enabling future innovations, fluoropolymer coated wire and cable is ideally suited for use in electric engines in aerospace applications. These require high temperature, high voltage and high frequency low loss performance. Partial discharge issues affect these cables at high altitude so semi conductive fluoropolymers are a promising solution. As such, fluoropolymers will be a critical material in the long-term decarbonization of air-travel.

Other

Electronic equipment with touchscreen interfaces, such as smart phones and tablets, require a smudge-resistant, easy-to-clean surface to maintain optimal performance. Fluoropolymer-based functional coatings are both hydrophobic and oleophobic and provide excellent water-and oil-repellency to such surfaces by forming an extremely thin monomolecular layer on the surface. Moreover, fluoropolymer-based functional coatings impart these benefits with no change in optical properties and they provide high resistance to abrasion (e.g., steel wool), UV exposure (e.g., outdoor sun light), and chemicals (e.g., acid, base, and a set of solvents).

Conventional anti-fouling and mold-release coatings exhibit low abrasion resistance, which causes them to wear-off quickly from friction as they are used. This makes it necessary to apply overly thick coatings or reapply frequently to keep the desired effects. Additionally, some coating agents have no oil repellency, a drawback that makes them prone to build up fingerprints, sebum, and other oily smudges. Other possible alternatives include washing with mild soap or wiping with alcohol; however, these are liquid-based and moisture, or excessive wiping might cause damage to the equipment.

Attachment C – Communications Applications

Fast, reliable data and voice communication is an essential feature of modern society, and a major contributor to health and safety. Fluoropolymers are irreplaceable in enabling this technology.

In the telecommunications sector, fiber optics is a critical technology allowing the fast transmission of large amounts of data. Amorphous fluoropolymers are used in plastic optical fiber cables due to their excellent light transmission. As data transmission speeds increase (>10Gbps), optical data transmission will become more efficient and low attenuation of light rays in the 650-1300nm laser wavelength range for data communication is required. Fluoropolymers provide this functionality. In addition, when wiring indoors or in automobiles or aircraft, data must be transmitted correctly and reliably even when the cable is bent because it passes through narrow spaces. Plastic optical fibers made of fluoropolymers enable the necessary flexibility and durability, whereas potential alternatives cannot provide that required functionality. For example, acrylic resin and quartz glass are considered as alternative candidates for optical fibers. However, acrylic resin is not suitable for high-speed data transmission due to its high transmission loss in the 650-1300 nm range. Meanwhile quartz glass is not suitable for installation in confined spaces, e.g., indoors, in automobiles and airplanes, because of safety risks stemming from reduced amounts of information being transmitted (i.e. information exchange in airplanes and cars is lost) and its intrinsic risk of fiber break due to bending.

Fluoropolymer "buffer tubes" are also used to hold and carry fiber optic cables to protect them from the potentially harsh adjacent environment and thereby enhance the reliability and integrity of data being transmitted. Similarly, fluoropolymer insulation is critically important for tidal power/signal cables, to provide temperature and chemical resistance necessary for protracted exposure to sea water. More generally, fluoropolymer sheathing also provides excellent dielectric properties and therefore improved performance for high-volume data transmission and connectivity.

Fluoropolymer coatings on circuit boards also ensure low signal loss, which is essential to the future of 5G or higher transmission speeds. By comparison, potential alternatives are

inadequate. For example, Polyimide (PI) has a high dielectric constant of 3.0 due to the presence of polar groups in its structure and cannot be used for high-speed communications after 5G, while Liquid Crystal Polymer (LCP) has a high dielectric constant of 2.9 and also cannot be used. Fluorine has low dielectric loss due to its low polarity and is essential in the 28 GHz band used for high-speed communications after 5G. In high-speed wireless communication signal transmission, the characteristic impedance of printed circuit boards must be matched to 50 Ω. For this purpose, it is important to have a low dielectric constant, as provided by fluoropolymers.

Attachment D – Medical and Life Sciences Applications

Medical devices and the equipment and devices needed for medical and life sciences research are, per se, essential to health. Many of these technologies would not be possible without fluoropolymers.

Fluoropolymers are essential components of endoscopes, catheters, laparoscopic devices, stents, balloon dilators, needles, brushes, pacemakers, artificial blood vessels, dialysis-related devices, stent surface coating and other items inserted or implanted into the body for diagnostic or therapeutic purposes. Fluoropolymers are necessary for these applications because of the combination of properties they possess. Specifically, they are biocompatible, resistant to contamination and easy to clean, resistant to bodily fluids as well as chemicals (such as chemical sterilizers) and irradiation, do not degrade in heat (and are therefore autoclavable), corrosion resistant, and have a low dielectric constant and therefore superior electrical insulating capabilities. Similarly, fluoropolymers do not stick to surfaces and are anti-kinking. These properties are of utmost importance for devices requiring high lubricity and flexibility in navigating human physiology. Potential alternatives cannot provide the same functionality as fluoropolymers in these critical applications. For example, the low mechanical strength and tearability of silicone-based materials agents can lead to higher risks of contamination.

Fluoropolymers are also used as wire coating materials for medical equipment. Medical equipment has many hinge parts that bend and stretch, requiring high mechanical strength in addition to insulation and flame resistance. Silicone materials are known as alternatives, but they are not used due to their low mechanical strength and tear resistance.

Biochip or analysis chips (microfluidic devices) for medical and DNA diagnostic applications use fluoropolymers to impart water and oil repellence and electrical insulation. By forming a fluoropolymer coating on a glass surface, it is possible to produce fine hydrophilic / hydrophobic patterns that serves as a dielectric, hydrophobic surface in electrowetting. The fine patterns ensure that a fluorescence observation can be carried out. Fluoropolymers also provide low autofluorescence and a refractive index which is close to that of water (1.34), which ensures that it can easily be read with a microscope. Furthermore, due to its wettability control,

fluoropolymers enable a change of wetness under an electric voltage, which allows for the manipulation of microscopic droplets. Potential alternatives studied to date demonstrate inferior or inadequate performance. For example, Parylene and PDMS lack the required water and oil repellency, anti-biofouling property, and chemical resistance for electrowetting on dielectric (EWOD) devices, and glass substrates lack the required high water and oil repellency, only reaching contact angle of 44 degree for water and 21 degree for oil (n-hexadecane).

Fluoropolymer membranes are also essential in gas analysis and applications requiring humidification and/or dehumidification. In the medical sector, breath gas analyzers are needed to monitor the effects of drugs on patients, metabolism and other diagnostic purposes.

Humidifier / drier membranes have a key role in controlling the level of moisture in oxygen or other gasses administered to patients and can be used in moisture-wicking sampling lines for intubated and non-intubated patients in low-and high-humidity applications. There are no adequate substitutes for these applications. For example, hollow fiber humidification modules present risks of oxygen leakage. In addition, potential alternatives provide lower detection accuracy and response performance of capnography and asthma analyzers, leading to impaired patient monitoring. Fluoropolymers are needed for high water vapor selective permeability, high separation ratio with other component gases, and a non-porous membrane to prevent the permeation of bacteria.

Fluoropolymer coatings also play an important role in diagnostic imaging, by preventing contamination or soiling of the image plate. Without the protection of a fluoropolymer coating, if contamination occurs at the time of imaging, the patient may have to undergo additional imaging or, even worse, the distortion in an image may lead to misdiagnosis. To our knowledge there are no suitable alternatives for diagnostic imaging plates that provide the comparable protection against surface contamination.

Attachment E – Infrastructure and Construction Applications

Reliable construction and infrastructure form the backbone of modern society and are essential to its continued functioning and existence. Fluoropolymers play an essential role in preserving and protecting infrastructure and enabling the reliable, effective and sustainable construction practices that are essential to the continuation of modern society.

Fluoropolymer-based coatings (FBCs) offer superior performance, service life, sustainability, appearance and value for applications on a wide variety of metal substrates used in commercial and monumental building projects. These fluoropolymer-based systems include film-forming binder resins used in settings where extreme durability and lifespan of several decades or more are needed to provide substrate protection. FBCs extend the lifespan of the underlying materials and are a critical specification for certain products and end markets. FBCs can be applied to a variety of components used in projects ranging from pre-engineered metal buildings to

municipal arenas and skyscrapers. Important properties that FBCs enable for construction include, but are not limited to the following:

- Adhesion, flexibility, formability, abrasion resistance, hardness and impact resistance;
- Resistance to chemicals, flame spread/surface burning; and
- Durability as demonstrated by UV-resistance, film integrity, low film erosion rate, humidity resistance and corrosion resistance.

FBCs have been shown not to be susceptible to attack by UV light, which results in a coating that is highly resistant to degradation upon exposure to sunlight, unlike virtually all other polymers. This property provides a very high resistance to fading and chalking as well as very good long-term maintenance of gloss and color. Apart from being highly resistant to UV light, the FBCs are also highly resistant to many chemicals and can have excellent stain resistance. Due to these superior qualities, FBCs also tend to carry a premium price compared to most other coating systems. Because of their solar reflectance, FBCs used on roofing also offer the additional benefits of lower energy usage from higher solar reflectivity and lower roof temperatures and a lower carbon footprint, as well as lower maintenance costs and increased efficiency and longer lifespan of HVAC equipment.[15]

We are aware of no other coating technology that enables the performance parameters of durability and product longevity that are the defining characteristic of FBCs. Indeed, outdoor exposure testing demonstrates that FBCs have an erosion rate approaching 50 percent less than other coating technology options used in Infrastructure & Construction settings. This difference explains why FBCs have a life expectancy of 50 years or more in many settings

[15] White Paper on Fluoropolymers in Infrasturcture and Construction (December 2023), available at https://fluoropolymerpartnership.com/wp-content/uploads/2023/12/PFP-White-Paper-on-Fluoropolymers-in-Infrastructure-and-Construction.pdf

compared to 20 years or less for some alternate technologies. This reinforces why FBCs are so unique and useful in the development of durable and essential building products.[16] In addition, the FBCs long lifespan means less recoating is necessary and less VOC's are emitted (as a result of the recoating process) as compared to other alternatives.

Bridge structures clearly need durable coating performance to protect the painted metal substrate below and maintain the bridge's structural integrity. Any coating system must last a long time given how difficult, disruptive and expensive the recoat process is. Bridges are subject to highly adverse environmental conditions including high intensity sunlight, fog, rain, saltwater (coastal areas) spray and constant automobile exhaust among other stressor factors. The superior anti-weathering performance of fluoropolymers allows the paint system to prolong the bridge's service life and decrease the number of re-painting cycles, contributing to lower life cycle costs for municipalities (and residents) and reduced VOC emissions and lower CO2 generation. The same is true for water tanks and other large pieces of infrastructure. Available data conclusively establish that FBC's substantially outperform potential alternatives with respect to weather and corrosion resistance. For example, compared to commonly used urethane resin paints, the service life of this product can be expected to be three times longer, while reducing CO2 emissions by approximately 38% over 100 years and VOCs by about 50% in 100 years.[17]

Fluoropolymer films are used as essential structural elements, such as roofing, wall panels and canopies in a variety of buildings and structures, including large public structures such as sports stadiums, airports and other transportation hubs. The use of fluoropolymer films in this application has several essential benefits, including, crucially, a substantial reduction in the volume of material, typically concrete, steel and/or glass, that would otherwise be required for a structure. The reduced use of concrete, steel and glass, in turn, results in lower CO2 emissions as well as less waste being generated and sent to landfill upon demolition of the structure. In addition, fluoropolymer films have excellent light harvesting properties for light with wavelengths from 300 to 2100 nm and at all angles of incidence. Several properties of fluoropolymer films, together, cause them to be uniquely suited to this application and therefore essential. These include:

- Excellent resistance to temperature extremes, weather, chemicals, stains and fouling ("self-cleaning");
- Superior durability -- retains at least 90% of its initial tensile strength and elongation after 30 years of exposure to rain and ultraviolet rays;
- Lightweight but strong, requiring minimal structural support, highly resistant to tear propagation, no breaking or splintering;

[16] Id.

[17] Id.

- Self-extinguishing, UL V-0 certified for combustion resistance, ASTM E 108 for Fire Test of Roof Coverings, designated as a non-combustible material (Japan), and European Combustion Test EU EN13501-1; non-flammable material certified B1 in DIN4202 part 1;

- Superior sound absorption.

Fluoropolymer film made of ETFE resin is also used in greenhouses, to improve the growth efficiency of fruits, vegetables and plants. This film has a higher light and UV transmission rate than glass, polyethylene or polycarbonate, allowing the full spectrum of sunlight to pass through the growing area. The result is increased production, earlier blooms, more colorful petals, sweeter fruit and higher quality vegetables.

Overall, potential alternatives to fluoropolymers (e.g., glass, PVC, fiberglass-impregnated membranes without a fluoropolymer layer for protection) are unsuitable. They present safety concerns in terms of increased flammability and degradation of components due to low flame resistance and low weatherability. They are also less weather resistant and require early replacement, which shortens the structure’s lifespan by 15-20 years. For example, with glass and PVC, the product life is 10-50% of fluoropolymer film and the frequency of replacement is 2¬10 times higher. They also contribute to greater CO2 emissions.

Attachment F – Food Contact and Processing Applications

It is self-evident that food is essential to health. In modern society, it is also essential to be able to process, store, transport and prepare food in a manner that is sanitary and preserves the purity and cleanliness of our food. Fluoropolymers are an essential technology for achieving these requirements.

Fluoropolymers play an essential role in food production and processing, including in the applications listed below. Importantly, for all of these applications, the U.S. Food and Drug Administration (FDA) has extensively reviewed the safety and efficacy of the fluoropolymers in use, and has authorized their continued use.

- In food and feed production equipment, fluoropolymers are used as base film in ion exchange membranes for water treatment and separation of organic components and inorganic salts in the electrodialysis process.

- In linings of food cans, fluoropolymer film is laminated with steel plates and, due to their chemical and temperature resistance, function to prevent corrosion of the can.

- In tubes and hoses, fluoropolymers provide superior heat and water resistance and durability. This combination of properties is critical because sterile cleaning with high temperature steam is standard for food applications, and it is common to clean under high pressure steam conditions at 121 °C for 15 minutes (see, e.g., ISO 17665, JIS T 0816-1).

- In tubes, hoses, gaskets and other food processing and handling equipment, fluoropolymers provide excellent heat resistance, oil and chemical resistance, helping to assure the purity of foods being processed and prevent cross-contamination.

- In food contact surfaces including processing, storage and packaging, fluoropolymers provide non-stick efficacy, heat and chemical resistance, cleanability, wear (abrasion) resistance and superior friction coefficient. They are also highly effective mold release agents for plastic packaging, helping to assure the purity and physical integrity of the packaging.

Fluoropolymers are essential in these applications because of their unique combination of properties. For example, silicone materials have been tested but are not suitable due to their low mechanical strength and tearability. Ceramic coatings provide sufficient heat resistance, but their release properties are inferior and insufficient. They are also more difficult to coat than fluoropolymers, making it difficult to coat complex and fine shapes evenly, and they are more expensive than fluoropolymers to coat. To our knowledge, no non-fluorinated material has so far been found with mold release and processability comparable to fluoropolymers coupled with heat resistance above 200 °C. Silicones and ceramics have been widely accepted and used for such applications in the past, but fluoropolymers have been used in applications where these materials are inadequate in terms of performance. Therefore, if the use of fluoropolymers is prohibited, the risk of process purity degradation, leakage and foreign material contamination due to accelerated component degradation will increase and have a significant impact on manufacturing control and maintenance systems.

Attachment G – Energy Applications

Modern society runs on energy. While we as a society seek to transition entirely to clean energy solutions such as solar, wind and clean hydrogen, until we complete that transition we rely on an “all of the above” approach to meeting our energy needs. Thus, the development, generation, capture, storage, transmission and distribution of all sources of energy are essential functions in our society, and fluoropolymers are essential to all of those activities.

Solar Panels

Fluoropolymers are critical components of solar panels. Lightweight, durable, transparent fluoropolymer films used on top of flexible or rigid solar modules have higher light transmittance than glass while providing long-term weather protection as well as a “self-cleaning” anti-fouling functionality. Moreover, because of their weather resistance, these fluoropolymer films retain their superior performance characteristics for more than 25 years. These functionalities combine to increase the electrical output of the solar panel by as much as 30%. In addition, because of their light weight in comparison to glass, fluoropolymer films open up more roof spaces to photovoltaic modules made with fluoropolymers, facilitating the expansion of solar panel deployment.

Because of their unique combination of properties, fluoropolymers are also uniquely well suited for use as back sheets (films) in photovoltaic solar panel construction. Back sheets are used on solar panels to help protect the solar cell from weather, humidity, and impact damage. They can also help provide electrical isolation for safety purposes. Thus, the proper choice of the back sheet can increase the panel life and reduce the cost of electricity generated from the panel over the solar panel cell’s life. Materials used in this end-use should have significant UV resistance and stability, corrosion resistance and flexibility. Fluoropolymers satisfy all of these criteria. They are light in weight and have extended durability in full exposure to a variety of environmental conditions, including intense sunlight and heat.

Finally, fluoropolymers are essential components of mold release films and transport materials used in the production of solar cells. For example, in the production of solar cells, cell modules and surface materials such as glass are laminated with EVA (ethylene vinyl acetate resin) at 150 °C under vacuum. Because EVA is extremely adhesive under high temperatures, the materials used for lamination and transport must have excellent non-adhesiveness and heat resistance. Furthermore, they must be organic materials that will not damage surface materials such as glass. At present, the only technically and economically feasible materials that provide these functionalities are fluoropolymers. For example, a material with excellent non-stick properties (low surface tension) is high-density polyethylene, but it does not have a heat resistance of 150°C and therefore is not a feasible alternative. The use of multilayer film, where several types of film are laminated together, has also been proposed as an alternative, but the technology to separate and recover each layer has not been established, making recycling difficult and reducing the recyclability after use.

Wind Turbines

Fluoropolymer coatings perform an essential function for wind turbines (both the blades and the turbine tower) by imparting weather resistance and durability as well as "self-cleaning"

functionality. These properties are especially important for offshore windmills, to provide resistance to the corrosive effects of seawater. They are also especially important for the wind-cut parts of the blades in snowy locations, where snow would otherwise adhere to the blade and clump, forcing the turbine to stop operation due to the risk of falling snow.

Potential alternatives to fluoropolymer coatings are polyurethane and polysiloxane coatings. However, fluoropolymer coating systems are several times more durable than polyurethane resin coating system, meaning that polyurethane coatings would require several more re-coatings during the 20-year design life of the wind turbine, as compared to fluoropolymer coatings. For wind turbines, which are often installed at high altitudes and in harsh environments, durability is an essential factor in their usefulness and efficiency.

Finally, fluoropolymers are essential components of mold release films and transport materials used in the production of wind turbine blades.

Clean Hydrogen

Fluoropolymers are an essential enabling material for several hydrogen technologies, including electrolysis membranes, electrodes, as well as sealing and lining equipment for hydrogen storage and transport equipment. Hydrogen is a highly flammable gas; therefore containing any potential leaks is essential for the safety of personnel and equipment. For this reasons, seals and linings in hydrogen transport and storage demand the superior chemical, heat and electrical resistance and overall durability of fluoropolymers. The electrolyte membrane used in the PEM (Proton Exchange Membrane) water electrolyser that produces hydrogen from water is made of fluoropolymer, which is essential for the realization of a hydrogen society because the PEM water electrolyser can operate at high current density, has high responsiveness to voltage fluctuations and is compact. Alternatives to hydrocarbon-based membranes have been proposed but they lack practical durability due to low thermal and chemical stability, difficulty in achieving high proton conductivity, low mechanical strength, etc. Without fluoropolymers, development and adoption of hydrogen generation, storage and transport technologies in the US will be severely constrained.

Batteries and Fuel Cells

As discussed more fully in Attachments A and B above, fluoropolymers are essential for use as binders, separator coatings, gaskets and seals, and electrolyte additives for batteries, due to their combination of chemical and heat resistance, dielectric properties, durability and adhesion to the substrate. None of the potential alternatives to fluoropolymers simultaneously meet these required performance characteristics.

In flow batteries, fluoropolymers provide the unique combined performance requirements for ORFB (organic redox flow batteries) systems, including (i) low voltage allowing for high energy efficiency; (ii) long lifespan, resulting in lower cost and environmental impact; and (iii) low activation crossover, allowing for higher efficiency and lower power consumption. Overall, fluoropolymers enable high retention of redox molecules, high chemical stability and good battery performance. ORFBs are set to replace vanadium-based RFBs (redox flow battery) on the market, with the following advantages:

- They do not use rare metals such as vanadium or rare materials
- The active materials can be synthesized organically, enabling significant cost reductions
- Higher voltage (up to twice)
- Higher durability, i.e. less waste generated
- Cost savings

Several non-fluorocarbon hydrocarbon anionic membranes have been tested for use in flow batteries. However, they cannot achieve the performance of fluoropolymers with respect to key parameters including voltage reduction, battery life and crossover reduction. Thus, there are no suitable alternatives for fluoropolymers in this application.

Nuclear

In nuclear generating facilities, fluoropolymers are essential for use in seals and wire jacketing, due to their heat resistance, chemical resistance, resistance to radiation, mechanical strength and insulation properties. This combination of properties is essential in the harsh environment of a nuclear reactor to mitigate against leakages and failure, and to assure safe and reliable operations. Potential alternatives are not suitable. For example, PE becomes brittle and breaks after irradiation, rendering it unusable. By comparison, fluoropolymers tested according to ASTM D2587 show that physical durability and integrity are maintained after 10^8 rads of irradiation.

Oil, Gas and Mining

Fluoropolymers are essential in a broad range of applications in the oil and gas extraction sector, as well as downstream, in transport and refining of petroleum products.

The “down hole” applications in which fluoropolymers are essential include packers, blow out preventers, seals, gaskets and O-rings, where heat resistance coupled with chemical resistance are required. Resistance to hydrogen sulfide is particularly important since it is a natural, poisonous by-product in many gas/oil wells and is highly corrosive. Fluoropolymers provide superior resistance to this chemical at high temperatures. In addition, high temperature steam is sometimes used to enhance the efficiency of oil well extraction particularly in older wells or where oil viscosity is high. Also in down hole applications, seals must be able to cope with a rapid gas decompression without losing seal integrity. In the worst case this could lead to an environmental incident or other safety-related issues. Explosive Decompression (ED) resistance or rapid gas decompression resistance is also a key property of fluoropolymers in these very harsh conditions. Fluoropolymers are unique in their ability to resist for prolonged periods the combination of stresses – chemical, thermal, and pressure – that are present in “down hole” applications. In many cases oil needs to be pumped up to the surface and “electrical

submersible bags” are used in the drilling systems to house the pump mechanism.

Fluoropolymers are used in the construction of this “electrical submersible bag”, which needs to withstand the crude and other high temperature chemicals on the outside of the bag but also resist the “lubricating oil” from the pump on the inside. Fluoropolymers provide this dual resistance at high temperatures.

The internationally recognized industry standard for sealing materials used for oilfield equipment, i.e., NORSOK M-710, developed by the Norwegian Petroleum Industry, sets the qualification requirements of non-metallic sealing materials and manufacturers, referencing ISO 23936. Fluoropolymers are the only polymers that can resist rapid expansion due to compressed gas absorption, which can cause seal failure, while maintaining necessary chemical resistance performance in environments where heat resistance is required above 200°C. Fluoropolymers are also used for wire sheathing in equipment used in these harsh operating environments where high heat and chemical resistance is required. Sometimes alternative materials such as polypropylene are mentioned, but they are poor at corrosion resistance and cannot be used in such environments, and no alternatives to fluoropolymers have been identified. Similarly, in the mining sector, fluoropolymers are essential to ensure the safe operation of equipment which needs to work continuously under extremely harsh and dangerous conditions with practically no margin for errors. Potential alternatives cannot meet the very high performance requirements for temperature (as high as 270°C), chemical and mechanical resistance.

Attachment H – Manufacturing & Processing Applications

Fluoropolymers are used in critical applications throughout the manufacturing sector, including the chemical industry, where they are essential because of their unique combination of performance characteristics. This section describes a representative cross section of the manufacturing and processing applications in which fluoropolymers play a critical role.

Fluoropolymers are essential for use in valve seals, pipe packing, gaskets and other seals in industrial processes that entail the use of hot, hazardous or corrosive liquids and gasses. Potential alternatives such as polyethylene or polyamide cannot provide the same degree of temperature and chemical resistance and mechanical strength as fluoropolymers, and their use in high stress industrial processes would result in an increased risk for leaks or catastrophic failures that could result in threats to human health and the environment. Compared to potential alternatives, fluoropolymers provide superior corrosion prevention, leak prevention, chemical emission reduction, lower maintenance costs and downtime, increased component life span, cleaner flue gas emissions and lower CO2 emissions, higher efficiency and production yield, improved quality and purity of products, and waste reduction.

In chemical, petroleum and pharmaceutical plants in particular, many systems need seals, linings, hoses, reactor vessels and other equipment that provide corrosion resistance, heat resistance, chemical resistance, mechanical strength and non-flammability. These critical functionalities are uniquely provided by fluoropolymers, which have a heat resistance of more than 250 °C, are chemically stable over a wide pH range of 1-13 and have virtually no leaching of impurities. In addition, fluoropolymers are particularly well suited to line complex shapes and parts in tanks, since they can be rotolined and spray coated. Fluoropolymers are similarly essential in for use as packing material in distillation processes, especially for very aggressive chemicals at high temperatures.

Potential alternative materials are not suitable, particularly for highly aggressive chemicals. In terms of heat resistance, ceramic and refractory fibers are sometimes used, but these materials create impurities and cannot be used in clean applications. Polyimide is inferior in terms of chemical resistance; silicones are inferior in terms of heat resistance; and PEEK which costs several times more than fluoropolymers, is difficult to process due to its high stiffness (flexural modulus 3,8 GPa) and high linear expansion coefficient (linear expansion coefficient 10.8).

Fluoropolymer ion-exchange membranes are essential for chlor-alkali electrolysis due to their low electric resistance and low susceptibility to impurities. These properties help achieve substantial energy savings, stable performance, and maintain 97-98% electrical current efficiency in the functioning of electrolyzers. Products made from chlorine and caustic alkaline are used in a variety of sectors, which include construction (PVC, aluminum, polyurethane thermal insulation), energy (e.g. wind turbines, hybrid car batteries purification, fuel cells), fertilizers and herbicides, health & personal care (water disinfection, soap manufacture, PVC blood bags, nylon surgical sutures), home care (dry cleaning, PVC windows, aluminum) pharmaceuticals (production e.g. aspirin, antibiotics, medicine packaging), safety (heat resistant and protective clothing police and fire services, Zinc chloride in forensic finger printing, sport (aluminum baseball bats, spandex, Aramid motor racing suits), technology (circuit boards, fiber-optics, semiconductors, smartphones), transportation (car parts, brake fluid, anti-freeze). This illustrates the importance and wide impacts of chlor-alkali electrolysis. The only potential alternatives to fluoropolymer ion-exchange membranes in this application require the use of either mercury or asbestos – both of which are highly restricted substances that present substantial risks to human health and the environment. Moreover, the mercury and asbestos technologies provide inferior performance (e.g., higher energy consumption, lower purity) than fluoropolymer ion-exchange membranes.

As discussed in Attachment G, above, fluoropolymer-based electrolysis membranes are also essential to the production of clean hydrogen, since membranes from alternative materials have lower chemical resistance and a much lower life span as well as significantly higher energy consumption (up to 50% higher) than those made from fluoropolymers. In addition, potential alternative hydrocarbon-based ion exchange membranes have low mechanical strength and are easily damaged during assembly, while fluoropolymer-based membranes have high mechanical strength which resists damage during assembly and maintenance (i.e. disassembly, cleaning, and inspection) and, thus, result in the creation of much less waste compared to non-fluorinated membranes. This is true for applications in all downstream sectors. Fluoropolymer membranes are also critical in wastewater treatment applications, for desalination of wastewater (where they can concentrate salinity to high concentrations while requiring low energy consumption, compared to potential alternatives) and metal plating (where due to their durability under oxidizing acid conditions and their chemical resistance more generally).

Fluoropolymers are also essential for various components used in a wide array of industrial applications, including:

- **Plate heat exchangers**, where fluoropolymers are typically used as gaskets or seals. Plate heat exchangers are used in many industrial applications to transfer heat between two fluids. Typical applications include: heating, ventilation and air conditioning (HVAC); refrigeration; engine or other mechanical cooling; food processing; oil production; boilers; aerospace, cryogenics; and pharmaceutical manufacturing. In many applications – particularly those involving corrosive chemicals and high temperatures – there are no suitable alternatives to fluoropolymers – which, among other benefits, allow complex plate heat exchanger systems to run for much longer times at higher temperatures – extending plant/production operation, reducing maintenance downtime and generating far less waste (spent gaskets) over the life of the production plant.

- **Stator/Mono pumps**, ranging from laboratory- to industrial-sized, particularly for operations involving corrosive chemicals, high temperatures or steam, where the chemical and temperature resistance of fluoropolymers is essential.

- **Compressed gas storage and transportation equipment** which relies on the exceptional properties of fluoropolymers at cryogenic temperatures -- essential for equipment used in transporting, handling and storing liquefied gas (e.g., liquefied natural gas or liquefied hydrogen). At cryogenic temperatures (- 161 °C for liquid methane gas, -253 °C for liquid hydrogen) no other elastomeric materials are adequate.

- **Hoses, tubes, gaskets and seals** used in all types of industries for applications and processes that require: durability, flexibility, heat resistance (greater than 200 °C) and chemical resistance.

- **Rubber rollers** utilized in material handling, assembly, and manufacturing operations, especially those involving the use of acidic or alkaline chemicals and high temperatures, such as processes used in the manufacture of steel and aluminum.

- **Wire and cable** used in aggressive industrial environments. As discussed in Attachment A, above, fluoropolymers are essential in these applications because their unique combination of properties including durable and reliable protection against extreme temperatures, harsh chemicals, humidity, vibration and compression, as well as their flexibility and strength.

- **Lubricants** used in bearings, ball joints, hinges, calipers, valves and other components utilized in a wide range of industries including automotive, aerospace, chemical processing, packaging, medical and mining, among many others. Fluoropolymer lubricants impart superior surface lubricity and reduced wear over a wide temperature range; they are virtually immune from chemical attack, do not absorb water, have a wide temperature range (-190 °C to +260 °C), and have excellent weathering and aging characteristics.

- **Conveyor belts, coaters, and thermal processing devices** used in various manufacturing and processing applications where chemical and temperature resistance are necessary – for example, in textile, upholstery, and carpet manufacture.

- **Humidifier / dryer membranes** used for compressed gasses, metals manufacturing and refrigeration units. Fluoropolymer membranes have high selective permeability to water vapor and high separation ratio with other component gases.