

Updated since the Call for Evidence/Royal Haskoning studie

Use Category
Photolithography
Photolithography
Photolithography
Photolithography
Photolithography
Photolithography
Nanoimprint Lithography
Photoresist
Color Filter photoresist for imaging semiconductor components "photopatterning"
Plasma [Dry] Etch and Wafer Cleaning
Vapour deposition chamber
Wet surface modification chemistries (eg. Wafer)
Advanced Semiconductor Packaging

Development of necessary chemistries and their packaging to be used for manufacturing of process recipes (Photo Acids, Polymer with Fluorine Groups, Monomers/prepolymers, Surfactants, Dyes etc.)
The use of fluoropolymers in process chemistry manufacturing equipment (Filtration system e.g. PTFE filters, Pump, etc.), production infrastructure (Blending Kettles, Piping, Valves, etc.) and evaluation tools (coating, exposure and development tools, NMR, IR, ICP/MS, Titrator, etc.)
The use of Consumable Materials for process chemistry development and manufacturing (air and wet chemical filters, seals/o-rings, piping/tubing, embedded lubricants (oils, greases, solids), non-process chemicals, replacement parts, release film for mold process etc.)
Articles to store, handle, and deliver liquid process chemicals (Bottle Cap Seals, PTFE inner, PTFE tape, Dip tube, O-ring, Packing, Connector, Valve etc.)
MEMS wafer process
Semiconductor Manufacturing Equipment (photolithography coaters, scanners and developers, dry etch, ion implant, deposition, CMP, assembly test, metrology, pumps, point of use abatement equipment, spare parts, equipment repair, maintenance of articles and mixtures used etc.)

Semiconductor Manufacturing Equipment & Infrastructure - Enabling Uses of Fluoropolymer Articles (raw materials including precursors, fluoropolymer parts embedded within manufacturing equipment, spare parts, equipment repair, maintenance of articles and infrastructure, filters, piping, tubing, gaskets, cables etc.)

Plasma Etch and Wafer Cleaning

Plasma Etch and Wafer Cleaning

Wafer

Heat Transfer Fluids

Thermal Testing of Semiconductor Devices (in-line and end of line)

Vacuum pump

Plastics such as PC/ABS

Fluoroelastomers, polymers including polyimides, polyamides, polyesters, polycarbonate etc.

Adhesive, coating, lubricant

Lubricants

Semiconductor Manufacturing Equipment & Infrastructure - the design, manufacture and delivery of semiconductor manufacturing equipment

Reticle and pellicle manufacturing and all of its required chemicals, materials and tooling etc.

Consumable Materials in semiconductor manufacturing equipment (air and wet chemical filters, seals/o-rings, piping/tubing, embedded lubricants (oils, greases, solids), non-process chemicals, replacement parts etc.)

Development of semiconductor manufacturing equipment (fluoropolymers, PFAS in mixtures etc.)

The use of fluoropolymers and PFAS in mixtures in the production of semiconductor manufacturing

Semiconductor Manufacturing infrastructure (production and storage, high purity water manufacturing/delivery systems, high purity chemical & gas delivery systems, air filtration systems, bulk chemical delivery systems treatment and distribution, planar chemical delivery systems, liquid waste collection system, abatement systems, semiconductor wastewater treatment and HVAC including corrosive exhaust ducting and treatment, facilities systems controls, gaskets for pipelines, etc.)

Plasma Etch and Wafer Cleaning

Vapour deposition chamber

Consumable Materials in semiconductor manufacturing infrastructure (air and wet chemical filters, seals/o-rings, piping/tubing, embedded lubricants (oils, greases, solids), non-process chemicals, replacement parts etc.)

Development of semiconductor manufacturing infrastructure equipment (fluoropolymers, PFAS in mixtures etc.)

Support equipment for SM Processes

Semiconductor Manufacturing Support Equipment (Automated Material Handling Systems, lab equipment such as Die yield/Failure Analysis, Pathifinding/R&D, Chemical evaluation, associated abatement systems etc.)

Consumable Materials in semiconductor manufacturing support equipment (air and wet chemical filters, seals/o-rings, piping/tubing, embedded lubricants (oils, greases, solids), non-process chemicals, replacement parts etc)
Development of semiconductor manufacturing support equipment (fluoropolymers, PFAS in mixtures etc.)
Wafer processing and transportation semiconductor manufacturing support systems - cassettes from front end to back end
Advanced Semiconductor Packaging
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MEMS sensor packaging

MEMS sensor packaging

MEMS sensor packaging

MEMS sensor packaging

Sub-Use	Properties
Photoacid generators	- Strong electronegativity of F atom in the complex resist/chemical matrix allows for controlled generation of strong acid upon exposure to UV light
Antireflection coatings	- Low dielectric constant - Low refractive index - Good thermal stability - Good barrier properties
Topcoats and Embedded Immersion Barriers Layers	- Hydrophobicity
Surfactants	- Uniformity in coating with minimal effect on properties provided by other critical resist/chemical ingredients (i.e., without impact to refractive indexes)
Dielectric Polymers (PBO/PI)	- Hydrophobicity - Electrical non-conductivity - Thermal resistance
Filters	- Chemical resistance - Low extractables against solvents
	- Low surface adherence
Epoxy, case masking	- Resistance to fire, grease, stain, etc.
	- Anisotropic etching capabilities
Cleaning	Less shedding
Wet etch	- Wetting agents - Selective metal oxide removal
Flux	- High-temperature thermal stability (>160 C)

Semiconductor manufacturing - process chemistries	
Semiconductor manufacturing - process chemistries	
Semiconductor manufacturing	High temperature stability up to 180°C Low Young's modulus Low tensile strength (i.e. high stretchability with low tearing risk) Low adhesion strength Chemical inertness
Semiconductor manufacturing	
Vapor HF Sacrificial Etch: Tool Parts, Seals, Fittings etc.	Chemical resistance to HF vapor, low particle generation

Data, Power & Fluid Delivery and Interconnects, sealants/piping, waste removal used in semiconductor manufacturing	- Chemical resistance - Low volatility/high stability - Thermal resistance - Cleanliness - UV resistance - Flame resistance - Inertness - Purity - Low flammability - Temperature stability - Resistance to chemical permeation - Low coefficient of friction - Optical properties - Low dielectric constant - Low dissipation factor - low outgassing factor - Stable electrical performance over high temperature
Filters Ozone functionalized water	Chemical resistance Thermal durability High retention and high flow Low extractables
Thermal insulation for wet solution	Low thermal conductivity Chemical resistance Thermal durability Less shedding Less gas
Wet etch & clean filters	Chemical resistance Temperature resistance Low extractables

Equipment Chillers	- High precision temperature control imparted by thermal stability - Viscosity vs temperature characteristics - Specific heat - Electrical conductivity characteristics
Equipment Chillers	- High precision temperature control imparted by thermal stability - Viscosity vs temperature characteristics, - Specific heat and electrical non-conductivity characteristics - High boiling point - Low pour point - Non-flammability
Vacuum fluid	- Thermally stable - Non-flammable and insoluble in water, acids, bases and most organic solvents - Inertness - Low off-gassing and particle generation
	- Flame retardancy
	- Cross linking agent for fluoroelastomers, monomer, high temperature composites and electronic materials
	Solvability

	- Inertness - Low off-gassing and particle generation
Semiconductor manufacturing	- Chemical resistance - Low volatility/high stability - Thermal resistance - Cleanliness - UV resistance - Flame resistance - Inertness - Purity - Low flammability - Temperature stability - Resistance to chemical permeation - Low coefficient of friction - Optical properties
Semiconductor manufacturing - photolithography	
Semiconductor manufacturing	
Production of semiconductor manufacturing equipment	
Production of semiconductor manufacturing equipment	

Support of semiconductor manufacturing (Chemical transportation, waste removal, waste treatment, etc.)	- Inertness - Chemical resistance - Low volatility/high stability - Purity - Low flammability - Temperature stability - Resistance to chemical permeation
Thermal insulation for gas supply and exhaust in Plasma Etch	Low thermal conductivity Chemical resistance Thermal durability Less shedding Less gas
Thermal insulation for gas supply and exhaust in Plasma Etch	Low thermal conductivity Chemical resistance Thermal durability Less shedding Less gas
Semiconductor manufacturing	
Semiconductor manufacturing	
Protection Equipment for Maintenance/Firefighting	Special requirements when F-containing gases come into play
Support of semiconductor manufacturing	

Semiconductor manufacturing	
Semiconductor manufacturing	
FOUPs - Front Opening Unified Pod/ Front Opening Universal Pod	High airflow and low particle penetration Low outgassing Low particle emission Water spray washing resistance
Encapsulants (epoxy underfills, mold compounds etc.)	Temperature resistance Beneficial material flow Wetting, degassing and composite homogeneity Electrical non-conductivity
Thermal Interface Materials	High thermal conductivity/heat resistance Tear resistance High tensile strength Incorporation of various fillers into different resin systems - High-temperature thermal stability (>160 C) - Low surface tension
Adhesives	- Solubility in organic solvents, low dielectric constants, and high thermal and thermo-oxidative stability
Hydrophobic coating/hermetic seal packages	- Unique hydrophobicity

Substrates including buildup/dielectric material	- High-temperature thermal stability (>160 C) - Electrical non-conductivity/low dielectric constant - Surface roughness/adhesion - Low coefficient of thermal expansion
MEMS anti-stiction layer/coating	- Low coefficient of friction - Low surface energy - High thermal stability - chemical inertness - mechanical durability, - electrical insulation - low particle generation
Die for chiplets	
Release sheet for thermocompression bonding process of semiconductor chips	- Heat-resistant - Releasability - Flexibility - Tensile strength
Packaging (bump, test, sort & assembly)	
Passivation gels and coating materials	Unique property: simultaneous high chemical stability against polar, unpolar and oxidative agents and acids Low Young's modulus that is constant over very wide operational temperature range (-50..175°C) High thermal stability No significant aging over product lifetime (up to 15 years)

Chemically robust adhesives for chip and package component attach	Unique property: simultaneous high chemical stability against polar, unpolar and oxidative agents and acids Low Young's modulus that is constant over very wide operational temperature range (-50..175°C) High thermal stability No significant aging over product lifetime (up to 15 years)
Soft adhesives for chip attach	Intermediate Young's modulus that is constant over very wide operational temperature range (-50..175°C) High thermal stability No significant aging over product lifetime (up to 15 years)
Air-permeable membranes, protective meshes, and their hydrophobic and oleophobic coatings	Unique property: simultaneous high chemical stability against polar, unpolar and oxidative agents and acids Unique property: simultaneous hydrophobicity and oleophobicity High thermal stability up to reflow solder temperature (>260°C)

Examples of PFAS

Fluorinated salts

Acrylate and methacrylate-based copolymers

Fluoropolymers

Non-polymeric PFASs (non-ionic)

Water-insoluble C1 PFAS polymers

Fluoropolymers

Fluoropolymers

Fluorotelomer-related compounds

PFC, HFC and HFO gases

PFC, HFC and HFO gases

Fluorinated organic acids

Surfactants

Fluoropolymer
Fluoropolymer

Fluoropolymers (i.e., Teflon™, Viton™, PTFE, PFA, FEP, ETFE, PVDF, FFKM, etc)

Fluoropolymers

Fluoropolymers

Fluoropolymers

Hydrofluoroethers, perfluoropolyethers (including PFPMIE), and other fully fluorinated liquids (perfluorinated amines and perfluoroalkylmorpholines, PFPE, Butane, 1-ethoxy-1,1,2,2,3,3,4,4,4-nonafluoro-, 2,3,3,4,4-pentafluoro-5-methoxy-2,5-bis[1,2,2,2-tetrafluoro-1-(trifluoromethyl)ethyl]tetrahydrofuran, Perfluamine, 1,1,1,2,2,4,5,5,5-nonafluoro-4-(trifluoromethyl)-3-pentanone
PFCs
HFCs
HFOs

Hydrofluoroethers, perfluoropolyethers (including PFPMIE), and other fully fluorinated liquids (perfluorinated amines and perfluoroalkylmorpholines, Reaction mass of 1,1,2,2,3,3,4,4,4-nonafluoro-N,Nbis(nonafluorobutyl)butan-1-amine and 1,1,2,2,3,3,4,4,4-nonafluoro-N-[1,1,2,3,3-hexafluoro-2-(trifluoromethyl)propyl]-N-(1,1,2,2,3,3,4,4,4-nonafluorobutyl)butan-1-amine

Fluorocarbon ether polymers of polyhexafluoropropylene oxide,

Perfluoroalkane sulfonic acids (PFSA), their salts and esters

Bisphenol AF and its salts

Perfluoroalkylethers

PFPE Fluorosilicone PCTFE PTFE
Fluoropolymers (i.e., Teflon™, Viton™, PTFE, PFA, FEP, ETFE, PVDF, FFKM, etc)

Fluoropolymers (PVDF, PTFE, etc.)

Fluoropolymers

Fluoropolymers

Viton™ gloves, personal protective equipment for firefighters etc.

Fluoropolymers
Fluoropolymers
Fluoropolymers
Fluorinated Tetracarboxylic acid anhydride derivatives, aromatic diamines, acrylate and methacrylate-based copolymers
Fluoropolymers

Fluoropolymers
Fluoropolymers Fluoroalkyl Silanes
PTFE
Fluoropolymers

Fluoropolymers

Fluoropolymers

Fluoropolymers

Estimated Timeframe To Substitute with Non-PFAS Alternatives (Timeline commences after an invention is identified)	Element
25+ years	Process Chemistries
15-20+ years	Process Chemistries
25+ years	Process Chemistries
15-20+ years	Process Chemistries
15-20+ years	Process Chemistries Semiconductor device
15+ years	Process Chemistries
15-20+ years	Process Chemistries
15-20+ years	Process Chemistries Semiconductor device
15+ years	Process Chemistries
10+ years	Process Chemistries
3-15+ years	Process Chemistries
5 years	Process Chemistries

	Process Chemistries
	Process Chemistries
	Semiconductor Manufacturing Equipment Semiconductor Manufacturing Infrastructure Semiconductor Manufacturing Support Equipment Process Chemistries
	Process Chemistries
at least 20+ years	Process Chemistries Semiconductor Manufacturing Equipment
	Semiconductor Manufacturing Equipment

15+ years	Semiconductor Manufacturing Equipment Semiconductor Manufacturing Infrastructure
	Semiconductor Manufacturing Equipment
	Semiconductor Manufacturing Equipment
	Semiconductor Manufacturing Equipment

8-14+ years	Semiconductor Manufacturing Equipment Semiconductor Manufacturing Infrastructure
8-14+ years	Semiconductor Manufacturing Equipment
10+ years	Semiconductor Manufacturing Equipment
15+ years	Semiconductor Manufacturing Equipment
15-20+ years	
10+ years	

10+ years	Semiconductor Manufacturing Equipment Semiconductor Manufacturing Infrastructure
15+ years	Semiconductor Manufacturing Equipment Semiconductor Manufacturing Infrastructure
	Semiconductor Manufacturing Equipment
	Semiconductor Manufacturing Equipment Semiconductor Manufacturing Infrastructure
	Semiconductor Manufacturing Equipment Semiconductor Manufacturing Infrastructure
	Semiconductor Manufacturing Equipment

15+ years	Semiconductor Manufacturing Infrastructure
	Semiconductor manufacturing Infrastructure
	Semiconductor Manufacturing Infrastructure
	Semiconductor Manufacturing Infrastructure
	Semiconductor Manufacturing Infrastructure
Not known	Semiconductor Manufacturing Infrastructure
	Semiconductor support equipment

	Semiconductor support equipment
	Semiconductor support equipment
	Semiconductor support equipment
13 years	Semiconductor Device
20+ years	Semiconductor Device
20+ years	Semiconductor Device
10+ years	Semiconductor Device

10+ years	Semiconductor Device
15-20+ years	Semiconductor Device
10+ years	Semiconductor Device
	Semiconductor Device
10+ years	Semiconductor Device

10+ years	Semiconductor Device
7+ years	Semiconductor Device
at least 20+ years	Semiconductor Device