

Fluorinated and Fluoropolymer-Derived Photopolymers for Vat Photopolymerisation: Chemical Identity, Surface Energy, Optical-Cure Trade-Offs, Chemical Resistance, PFAS Boundaries and Qualification

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Statement of Significance

Fluorinated photopolymer, fluoropolymer, PTFE-filled composite, fluorinated surface and PFAS are not interchangeable descriptions. They can refer respectively to a network containing fluorinated groups, a polymer class, a dispersed phase, a post-print surface treatment or a broad structure-based universe. Collapsing them transfers low surface energy, chemical resistance, dielectric behaviour, persistence or regulatory meaning without evidence. This review establishes an identity gate, maps the main light-based fabrication routes and defines the optical, surface, chemical, mechanical, ageing and end-of-life evidence required before a fluorinated vat-printed material is qualified.

Keywords: vat photopolymerisation; fluorinated photopolymer; fluoropolymer; perfluoropolyether; PFPE; polytetrafluoroethylene; PTFE; surface energy; contact angle; chemical resistance; PFAS; end-of-life qualification.

Abstract

Fluorinated materials offer combinations of low surface energy, solvent resistance, optical transparency, dielectric response and low friction that are attractive for microfluidics, electronics and demanding interfaces. Their established bulk-processing routes are often incompatible with vat photopolymerisation, so light-based fabrication has followed several chemically distinct strategies: direct curing of perfluoropolyether methacrylates, two-photon structuring of PFPE photoresists, dispersion and subsequent sintering of PTFE particles, vat printing of elastic fluorinated networks, post-print fluoroalkyl surface modification, photoreactive modification of existing fluoropolymers and recyclable thiol–ene fluorinated photoresists. Primary studies demonstrate viable structures and devices, but no route transfers the complete property set of PTFE or another reference fluoropolymer automatically. Optical clarity at one wavelength range does not establish cure-depth stability; a high water-contact angle does not establish surface durability or solvent resistance; immersion survival does not establish environmental-stress-crack resistance; and fluorine content does not define PFAS regulatory treatment by itself. Under the OECD 2021 structural terminology, many fluorinated monomers and polymers can fall within the broad PFAS universe, yet that classification alone does not communicate hazard, exposure, use-specific regulation or product composition. Qualification must therefore identify the fluorinated moiety and its location in the load-bearing network, control the printed state, separate surface and bulk measurements, use exact liquid and stress conditions, assess extractables and degradation products, and document fluorine mass flow at end of life. This paper supplies that framework without granting regulatory compliance, intended-use approval or chemical equivalence to a conventional fluoropolymer.

1. Scope and boundaries

ER-104 owns the chemical-identity and claim-transfer problem for fluorinated and fluoropolymer-derived materials processed by vat or closely related light-based additive manufacturing. It covers PFPE and other fluorinated photoresists, particle-derived PTFE structures, bulk fluorinated networks, surface-only fluorination, optical-cure trade-offs, wetting and adhesion, liquid resistance, environmental-stress cracking, persistence, PFAS terminology and end-of-life evidence.

Adjacent Engineering Reviews retain their established scopes. ER-01 owns cross-study optical reporting; ER-12 owns organ-on-chip sorption, gas transport and extractables; ER-20 owns generic high-temperature qualification; ER-41 owns chemical resistance and solvent uptake; ER-53 owns general wetting and build-platform adhesion; ER-54 owns gas barrier and permeability; ER-64 owns thiol–ene photopolymerisation; ER-72 owns the general environmental-ageing framework; ER-75 owns tomographic volumetric operating windows; ER-92 owns residual-reactant and manufacturing-conversion hazard; and ER-102 owns silicone and silicone-like identity [C1–C11]. ER-104 narrows those domains to fluorinated chemical identity and its transfer limits.

The review does not treat every carbon–fluorine bond as proof of a fluoropolymer, assign a legal status to a product, certify that a material is free of a named PFAS, equate in vitro cytocompatibility with biomedical safety, or establish chemical resistance from one short immersion. Regulatory requirements and working definitions remain jurisdiction-, date-, substance- and use-specific.

2. Nomenclature and identity gate

Organofluorine is the broadest chemical description used here. Fluorinated monomer or oligomer identifies a precursor carrying covalently bound fluorine. A fluorinated photopolymer identifies a cured network containing such units but still requires the fluorinated fraction and network role to be reported. Fluoropolymer should be reserved for a polymer in which fluorinated repeat units form a meaningful polymer backbone or network component. A PTFE-filled photopolymer is a composite until removal of the binder and sintering produce the identified PTFE structure. A fluorinated surface may consist only of a thin modified layer on a non-fluorinated bulk.

PFAS is a separate structure-based classification problem. The OECD 2021 report defines PFAS broadly as fluorinated substances containing at least one fully fluorinated methyl or methylene carbon atom, with stated exceptions, and stresses that the general term communicates a structural trait rather than hazard [R1]. A user-specific regulatory or reporting scope can be narrower or otherwise conditioned. ER-104 therefore records the exact structure or controlled identity first and does not convert the OECD definition into a legal conclusion.

Description	Minimum evidence	What remains unproven
Fluorinated photoresist/network	Fluorinated constituent, fraction and network role are identified	Fluoropolymer equivalence, low extractables or class-wide resistance
PFPE-based network	Perfluoropolyether segment and cure linkage are established	PTFE properties, universal solvent resistance or lifetime
PTFE-filled photopolymer	PTFE particle phase and temporary binder are distinguished	Continuous PTFE before debinding/sintering
Sintered PTFE structure	Binder removal, sintering state and retained PTFE identity are shown	Bulk-grade density, defect population or service life
Surface-fluorinated object	Surface chemistry and modification depth/durability are measured	Fluorinated bulk, barrier performance or permanent low adhesion
PFAS classification	Applied definition, exact structure and assessment date are stated	Hazard, exposure, restriction, exemption or regulatory compliance

Table 1. Identity gate. Chemical class, phase location, surface treatment and regulatory terminology remain separate.

3. Property origin and transfer limits

Fluorinated segments can reduce cohesive interactions and surface energy, change refractive index and dielectric response, alter solubility and increase resistance to particular chemical environments. These trends depend on fluorine content, segment length, architecture, crystallinity, free volume, crosslink density, surface segregation, fillers and defects. The strength of a carbon–fluorine bond does not mean that every fluorinated network is inert as a whole. Ester, urethane, ether, thioether, acrylate-derived and interfacial bonds may control failure first.

Surface enrichment creates an additional scale problem. A small fluorinated fraction may migrate or orient toward an interface and change contact angle while contributing little to bulk chemical resistance. Conversely, a highly fluorinated bulk can still present processing residues or a damaged surface that dominates wetting and bonding. Surface composition, bulk composition and network continuity must therefore be measured independently.

Observed result	Permitted interpretation	Prohibited transfer without evidence
High water-contact angle	Low water wettability for the measured surface, liquid and time	Oleophobicity, solvent resistance, self-cleaning or durable release
Low surface-energy estimate	Model-dependent interfacial descriptor from declared probe liquids	Universal adhesion failure or friction coefficient
Optical transparency	Transmission through the stated thickness and wavelength range	Matched photoinitiator absorption, low cure gradients or optical-device quality
Short solvent immersion survives	No selected failure exceeded the criterion during that exposure	Long-term chemical compatibility, ESC resistance or low sorption
Fluorine detected by surface analysis	Fluorinated species exist within the method's sampling depth	Bulk fluoropolymer identity or covalent durability
Low dielectric constant	Electrical response at stated frequency, temperature and specimen state	Low loss, breakdown strength or stability over duty

Table 2. Claim-transfer controls for common fluorinated-material observations.

4. Light-based fabrication routes

4.1 Direct PFPE photoresists

De Marco et al. designed a polyfunctional PFPE-based photoresist and used two-photon polymerisation to fabricate hydrophobic, chemically resistant submicrometre three-dimensional structures [1]. Kotz et al. developed highly fluorinated PFPE methacrylate formulations printable in commercial benchtop stereolithography systems [2]. Their study reported minimal cross-sectional dimensions of 600 μm for embedded channels and 200 μm for open structures, optical transmittance above 70% from 520 to 900 nm and resistance to the organic solvents tested. These values belong to those formulations, geometries and protocols.

4.2 Particle-derived PTFE

Zhang et al. dispersed PTFE nanoparticles in a photocurable PEGDA solution, formed microstructures by layerwise digital UV projection and then removed the temporary organic phase during sintering to leave PTFE structures [3]. This route differs fundamentally from direct polymerisation of a fluorinated liquid resin. Particle dispersion, scattering, green-body strength, debinding atmosphere, shrinkage, sintering and porosity become controlling state variables. The green composite must not be called a continuous PTFE part before conversion is demonstrated.

4.3 Elastic bulk fluorinated networks

Song et al. reported a custom fluorinated photocurable resin structured in vat printers with 523% linear deformation capability in their tensile state and retained stretchability after 24 h in tetrahydrofuran [4]. Multi-material printing combined bonded hard and soft fluorinated segments for valves, pumps and other microfluidic components. The evidence establishes a formulation-specific combination of elasticity and liquid resistance. It does not transfer to every fluorinated elastomer or to other solvents, stresses or exposure durations.

4.4 Surface-only fluorination

Catterton et al. treated printed (meth)acrylate resins with a fluoroalkyl trichlorosilane [5]. In the investigated system, deposition in fluorinated oil produced higher contact angles than ethanol or gas-phase routes; optimized surfaces exceeded 110°, and the authors reported resistance to mechanical damage and methanol hydrolysis with long-term storage stability. This demonstrates post-print surface modification, not a fluorinated bulk network. Resin chemistry, pretreatment, solvent, humidity, mask and hydrolysis state remain part of the treatment specification.

4.5 Volumetric printing and fluorine recovery

Thijssen et al. used an alkene-functionalised fluorinated diol and multifunctional thiol in a 405 nm tomographic volumetric process [6]. The study reported reproducible features down to about 56 μm at specified locations and recovered $97.4 \pm 2.1\%$ of the fluorinated diol after alkaline cleavage under the selected 2.5 M NaOH, 85 °C, 3 h condition. Refunctionalisation and reprinting retained the measured print fidelity, thermal and mechanical properties. Only the fluorinated content was closed in the demonstrated loop; non-fluorinated crosslinker and initiator were replenished. Recovery yield, chemical burden, byproducts and cumulative loss remain essential.

4.6 Adjacent photoreactive fluoropolymer routes

Kallitsis et al. grafted photo-crosslinkable functionality onto commercial P(VDF-co-TrFE) and used the modified ferroelectric copolymer as a negative photoresist in photolithography [7]. The work establishes that an existing fluoropolymer can be made photoreactive. It is adjacent evidence rather than a demonstrated VPP route, so ER-104 does not convert it into a vat-printability claim.

5. Optical-cure and resin-state trade-offs

Optical printability depends on absorption, scattering, refractive-index contrast, initiator spectrum and part geometry. A transparent cured plaque may still have unsuitable pre-gel attenuation at the printing wavelength. PTFE particles scatter and may sediment; a homogeneous fluorinated monomer can alter initiator solubility or oxygen response; PFPE-rich phases can segregate from non-fluorinated crosslinkers or modifiers. Working curves and cure thresholds must be measured on the complete formulation at the process temperature.

Volumetric printing adds a three-dimensional dose-contrast requirement. In the Thijssen system, absorption was aligned to the printer's compensation window, viscosity was raised to suppress gravitational movement and an inhibition period preceded gelation [6]. These are formulation and platform controls, not universal properties of thiol-ene or fluorinated resins. ER-75 owns the general volumetric operating-window framework, while ER-64 owns generic thiol-ene chemistry [C7,C9].

State variable	Fluorinated-system risk	Minimum report
Fluorinated species and phase	Surface segregation, incompatibility or discontinuous property path	Identity, fraction, functionality and phase role

State variable	Fluorinated-system risk	Minimum report
Optical spectrum	Different absorption/scattering at cure and use wavelengths	Resin transmission/absorbance, thickness, wavelength and temperature
Particle state	PTFE agglomeration, sedimentation and cure shadowing	Size distribution, loading, mixing, stability and print delay
Resin rheology	Low interactions or modifiers alter recoating and volumetric stability	Viscosity versus shear and temperature; dwell history
Wash and extraction	Fluorinated/non-fluorinated residuals can dominate surface and exposure	Solvent, time, dry state, mass change and extractables
Thermal conversion	Debinding/sintering changes chemistry, dimensions and porosity	Programme, atmosphere, mass loss, shrinkage and final density

Table 3. Minimum state description for transferable fluorinated-material evidence.

6. Surface energy, wetting, friction and adhesion

Contact angle is not an intrinsic scalar property of the polymer alone. Probe liquid, drop volume, dwell, advancing or receding state, roughness, contamination, humidity and surface age matter. Wenzel and Cassie-type topographic effects can amplify apparent hydrophobicity without changing chemistry. Static water angle should therefore be complemented by advancing/receding angles, hysteresis, roll-off where relevant, surface composition and roughness. ISO 19403-2:2024 anchors surface-free-energy determination by contact angle, ISO 19403-6:2024 addresses dynamic angles and ISO 8296:2003 anchors wetting tension for films and sheets [S1–S3]. Applicability and deviations must be stated for printed solids.

Low surface energy can impede bonding to the build platform, supports, coatings or another printed material. A bond demonstrated immediately after printing may change after wash, migration or ageing. Friction is also a separate system property controlled by counterface, load, velocity, roughness, wear debris and environment. No coefficient of friction or release performance follows directly from fluorine content or contact angle.

7. Chemical resistance, sorption and environmental stress

Chemical resistance must name the exact liquid, concentration, temperature, time, stress state, dimensions and failure criterion. Fluorinated segments may reduce affinity for particular solvents while non-fluorinated crosslinks, diluents, interfaces or residuals remain vulnerable. Uptake can plasticise, swell or extract the network without immediate visible damage. Conversely, small mass change can coexist with cracking under load. ISO 175:2010 anchors immersion effects and ISO 22088-1:2006 provides general environmental-stress-cracking guidance; a new edition of ISO 22088-1 is under development, so the 2006 edition and its 2020 confirmation must be stated explicitly [S4,S5].

A robust study reports wet mass and dimensions, reconditioned state, full mechanical retention and chemical or microscopic evidence where mechanism matters. Permeability and molecular sorption are not inferred from immersion resistance; ER-12 and ER-54 own those measurement frameworks [C2,C6]. Microfluidic qualification should additionally examine bonding, channel dimensions, pressure, leakage, valve cycling, analyte loss and extractables.

8. Mechanical, thermal and ageing qualification

The mechanical envelope depends on whether the object is a crosslinked PFPE network, an elastic fluorinated network, a surface-treated conventional resin, a green PTFE composite or sintered PTFE. Tensile testing should report full curves, orientation, strain method and conditioning under ISO 527-1:2019 and a justified specimen part such as ISO 527-2:2025 [S6,S7]. Surface-only modification may leave bulk tensile response unchanged while changing crack initiation, bonding or friction.

DSC and TGA answer different questions. Glass transitions, melting and cure events do not equal mass-loss onset, and neither defines long-term service temperature. ISO 11357-2:2020 and ISO 11358-1:2022 provide separate anchors [S8,S9]. UV and weathering can change a non-fluorinated crosslinker, surface treatment or interface before the fluorinated segment itself fails. ISO 4892-1:2024 provides general exposure guidance, but laboratory hours do not convert directly into outdoor life [S10]. ER-20 and ER-72 retain the generic thermal and ageing frameworks [C3,C8].

9. Persistence, PFAS and end-of-life boundary

A broad PFAS structural classification should trigger precise inventory and mass-flow questions, not a generic declaration of safety or hazard. Record the fluorinated precursor, fluorinated processing aids where known, unreacted fraction, volatile or extractable species, degradation products and waste route. Product formulation, workplace exposure, emissions, use, recycling and disposal are distinct assessment stages. ER-92 owns residual-reactant hazard; ER-104 owns the fluorinated-identity and end-of-life mapping needed to feed that assessment [C10].

The 2026 volumetric study is instructive because it distinguishes recovery of fluorinated content from recovery of the entire network [6]. A high isolated-monomer yield does not alone supply energy demand, solvent burden, impurity tolerance, repeated-cycle mass balance or industrial collection feasibility. Likewise, destructive removal of a non-fluorinated binder to produce PTFE is not recycling. Every circularity claim should state system boundary, recovered mass fraction, purity, replenished material and retained function across cycles.

This review is not regulatory advice. The OECD terminology is a transparent structural reference, not a substitute for current requirements from the competent authority in the relevant jurisdiction and intended use [R1]. Any release decision must be rechecked against the rules and supply-chain information current on the date of manufacture or placing on the market.

10. Qualification architecture

Qualification block	Minimum evidence	Release question
Chemical identity	Exact fluorinated moiety, fraction, phase/network role and final conversion	Is the selected material name structurally defensible?
Optical and print state	Absorption/scattering, cure threshold, rheology, layer or volumetric dose and orientation	Is the printed state reproducible without hidden gradients?
Surface state	Chemistry, depth, roughness, advancing/receding angle, hysteresis and ageing	Is the surface function real and durable?
Liquid and stress state	Exact liquids, duration, temperature, stress, uptake and retained properties	Does compatibility survive combined chemical and mechanical duty?
Thermal and environmental state	DSC, TGA, functional retention after heat/light/humidity and interfaces	What fails before decomposition?
Exposure and end of life	Residuals, extractables, fluorine mass flow, byproducts, recovery yield and replenishment	Are hazard, persistence and circularity claims properly bounded?
Component validation	Representative geometry, bonds, pressure or electrical duty and failure criterion	Do coupon claims survive the application?

Table 4. Qualification stack for fluorinated and fluoropolymer-derived light-printed materials.

11. Failure-mode interpretation

- Contact angle rises but bonding fails inconsistently: check treatment depth, contamination, roughness, surface migration and advancing/receding hysteresis.
- A resin is transparent after cure but printing broadens: measure uncured spectral attenuation, conversion-dependent refractive index and cure-depth response at the actual wavelength.
- A PTFE-filled green part prints but distorts after sintering: quantify solids distribution, debinding mass loss, anisotropic shrinkage, density and pore/crack formation.
- Short immersion passes but loaded parts crack: add environmental-stress-cracking tests and inspect defects, interfaces and residual stress.
- Bulk solvent resistance is good but microfluidic response drifts: test extractables, analyte sorption, channel dimensions, bonding and pressure cycling.
- A surface treatment initially exceeds 110° but loses function: repeat after abrasion, wash, heat, storage and exact process-fluid exposure.
- High TGA onset coexists with early loss of force or dielectric response: qualify the functional endpoint instead of using decomposition as the service limit.
- A recycling cycle reports high monomer yield but fluorine balance declines: include purification losses, side streams, replenished reagents and cumulative retained mass.

12. Minimum workflow

- Name the exact fluorinated structure, phase and network role; distinguish bulk, filler and surface-only routes.
- State the PFAS definition or working scope used, the assessment date and the competent jurisdiction; do not infer hazard or compliance from the acronym.
- Freeze formulation, particle state, resin temperature, optical spectrum, printer settings, orientation, wash, drying, post-cure and specimen age.
- Verify conversion, gel/extractable state and, for particle-derived routes, debinding, shrinkage, density and final phase continuity.
- Measure optical attenuation and feature transfer at the process wavelength before using visible transparency as evidence.
- Characterise surface chemistry, roughness and dynamic wetting before claiming low surface energy, release or anti-fouling function.

- Test exact liquids in unstressed and application-relevant stressed states; report wet and reconditioned mass, dimensions and retained function.
- Separate DSC, TGA and long-term functional retention; add light, humidity and interface ageing where relevant.
- Measure residual fluorinated species, extractables and degradation products according to exposure and end-of-life questions.
- Close with component validation and a stated property, environment, duration and failure criterion; exclude all untested transfer claims.

13. Research and standardisation priorities

- A reporting taxonomy separating fluorinated monomer networks, backbone fluoropolymers, particle-derived PTFE and surface-fluorinated conventional resins.
- Matched optical, conversion and mechanical datasets across fluorine content and printing wavelength.
- Round-robin advancing/receding contact-angle and surface-composition measurements on printed, washed and aged surfaces.
- Environmental-stress-cracking and long-duration microfluidic data under exact solvents, pressure, temperature and bond geometries.
- Mass-balanced studies of residual fluorinated monomers, processing aids, wash streams and degradation products.
- Repeated-cycle recycling studies reporting fluorine recovery, purity, reagent burden, cumulative loss and retained performance.
- Transfer studies from coupons to channels, valves, dielectric elements, seals and low-friction interfaces.
- Versioned PFAS inventory and reporting templates that preserve exact chemical identity while allowing jurisdiction-specific working scopes.

14. Conclusions

Light-based additive manufacturing can produce fluorinated structures through several fundamentally different routes. Direct PFPE photoresists, particle-derived and sintered PTFE, elastic fluorinated networks, surface fluorination, photoreactive fluoropolymers and recyclable thiol–ene systems demonstrate real capability. None should be described by the same chemical or property shorthand.

The controlling rule is to identify where fluorine resides and what forms the load-bearing structure. Surface wetting, bulk resistance, optical printability, mechanical response, permeability, persistence and end-of-life behaviour then require separate evidence. A static water angle is not chemical resistance; one solvent is not a compatibility table; mass-loss onset is not service temperature; and a broad PFAS classification is not a hazard or compliance verdict.

ER-104 therefore closes with a state-resolved qualification chain: identity, optical and process state, surface characterisation, liquid plus stress exposure, mechanical and thermal retention, residuals, fluorine mass flow and component function. The chain supports disciplined selection and comparison while withholding product equivalence, intended-use approval and regulatory conclusions not established by the evidence.

Limitations

This paper is a qualitative engineering review, not a systematic meta-analysis or legal opinion. The cited studies use different fluorinated chemistries, printers, wavelengths, cure routes, surfaces, solvents, specimens and endpoints, so numerical values are not pooled or ranked. Regulatory definitions and obligations can change after the assessment date. No proprietary composition, independent commercial-product assay, universal PFAS status, service-life model, intended-use qualification or regulatory approval is provided.

Author contributions

Juan Seguro: conceptualisation, evidence synthesis, boundary definition, engineering interpretation, manuscript preparation and final author verification.

Competing interests

The author is founder and CEO of 3Dresyns by Resyner Technologies S.L. No comparative product recommendation is made.

Data availability

No new experimental dataset was generated for this review. Scientific statements derive from the cited primary literature, standards and official terminology source. The review package includes QA and source-boundary records for independent review.

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References - independent scientific evidence

- [1] De Marco, C., Gaidukevičiūtė, A., Kiyan, R., Eaton, S.M., Levi, M., Osellame, R., Chichkov, B.N. and Turri, S. A New Perfluoropolyether-Based Hydrophobic and Chemically Resistant Photoresist Structured by Two-Photon Polymerization. *Langmuir* 29(1) (2013) 426–431. DOI: 10.1021/la303799u. <https://doi.org/10.1021/la303799u>
- [2] Kotz, F., Risch, P., Helmer, D. and Rapp, B.E. Highly Fluorinated Methacrylates for Optical 3D Printing of Microfluidic Devices. *Micromachines* 9(3) (2018) 115. DOI: 10.3390/mi9030115. <https://doi.org/10.3390/mi9030115>
- [3] Zhang, Y., Yin, M.-J., Ouyang, X., Zhang, A.P. and Tam, H.-Y. 3D μ -printing of polytetrafluoroethylene microstructures: A route to superhydrophobic surfaces and devices. *Applied Materials Today* 19 (2020) 100580. DOI: 10.1016/j.apmt.2020.100580. <https://doi.org/10.1016/j.apmt.2020.100580>
- [4] Song, Q., Hamza, A., Li, C., Sedeky, A.S., Chen, Y., Zhu, M., Goralczyk, A., Mayoussi, F., Zhu, P., Hou, P., Piesold, C., Helmer, D., Rapp, B.E. and Kotz-Helmer, F. 3D printed elastic fluoropolymer with high stretchability and enhanced chemical resistance for microfluidic applications. *Additive Manufacturing* 81 (2024) 103991. DOI: 10.1016/j.addma.2024.103991. <https://doi.org/10.1016/j.addma.2024.103991>
- [5] Catterton, M.A., Montalbino, A.N. and Pompano, R.R. Selective Fluorination of the Surface of Polymeric Materials after Stereolithography 3D Printing. *Langmuir* 37(24) (2021) 7341–7348. DOI: 10.1021/acs.langmuir.1c00625. <https://doi.org/10.1021/acs.langmuir.1c00625>
- [6] Thijssen, Q., Jaen-Ortega, A., Pien, N. and Van Vlierberghe, S. Volumetric 3D printing of a fluoropolymer and closed-loop chemical recycling of its fluorinated content. *Nature Communications* 17 (2026) 4153. DOI: 10.1038/s41467-026-70897-z. <https://doi.org/10.1038/s41467-026-70897-z>
- [7] Kallitsis, K., Alvarez-Fernandez, A., Cloutet, E., Brochon, C. and Hadzioannou, G. Introducing Photo-Cross-Linkable Functionalities on P(VDF-co-TrFE) Ferroelectric Copolymer. *ChemPlusChem* 89(8) (2024) e202400113. DOI: 10.1002/cplu.202400113. <https://doi.org/10.1002/cplu.202400113>

Standards and measurement references

- [S1] ISO 19403-2:2024. Paints and varnishes — Wettability — Part 2: Determination of the surface free energy of solid surfaces by measuring the contact angle. Edition 2. <https://www.iso.org/standard/87262.html>
- [S2] ISO 19403-6:2024. Paints and varnishes — Wettability — Part 6: Measurement of dynamic advancing and receding angle by changing the volume of a drop. Edition 2. <https://www.iso.org/standard/87266.html>
- [S3] ISO 8296:2003. Plastics — Film and sheeting — Determination of wetting tension. Edition 2; confirmed current in 2023. <https://www.iso.org/standard/38451.html>
- [S4] ISO 175:2010. Plastics — Methods of test for the determination of the effects of immersion in liquid chemicals. Edition 3; confirmed current in 2026. <https://www.iso.org/standard/55483.html>
- [S5] ISO 22088-1:2006. Plastics — Determination of resistance to environmental stress cracking (ESC) — Part 1: General guidance. Edition 1; confirmed current in 2020; replacement work item under development in 2026. <https://www.iso.org/standard/34861.html>
- [S6] ISO 527-1:2019. Plastics — Determination of tensile properties — Part 1: General principles. Edition 3; confirmed in 2025; stage 90.92, with ISO/AWI 527-1 (4th edition) registered in November 2025. <https://www.iso.org/standard/75824.html>
- [S7] ISO 527-2:2025. Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics. Edition 3. <https://www.iso.org/standard/85822.html>
- [S8] ISO 11357-2:2020. Plastics — Differential scanning calorimetry (DSC) — Part 2: Determination of glass transition temperature and step height. Edition 3; confirmed current in 2025. <https://www.iso.org/standard/77310.html>
- [S9] ISO 11358-1:2022. Plastics — Thermogravimetry (TG) of polymers — Part 1: General principles. Edition 2. <https://www.iso.org/standard/79999.html>
- [S10] ISO 4892-1:2024. Plastics — Methods of exposure to laboratory light sources — Part 1: General guidance and requirements. Edition 4. <https://www.iso.org/standard/83801.html>

Official terminology source

- [R1] OECD. Reconciling Terminology of the Universe of Per- and Polyfluoroalkyl Substances: Recommendations and Practical Guidance. Series on Risk Management No. 61, ENV/CBC/MONO(2021)25. Paris, 2021. Accessed 29 August 2026. [https://one.oecd.org/document/ENV/CBC/MONO\(2021\)25/En/pdf](https://one.oecd.org/document/ENV/CBC/MONO(2021)25/En/pdf)

Related Engineering Review boundaries

- [C1] Seguro, J. Optical photopolymers for additive manufacturing: reporting practices and cross-study comparability. ER-01. Zenodo (2026).
- [C2] Seguro, J. Engineering Qualification of Vat-Printed Organ-on-Chip Materials: Optical Background, Molecular Sorption, Gas Transport, Extractables and Microfluidic Fidelity. ER-12. Zenodo (2026).
- [C3] Seguro, J. Thermal Performance in Vat-Photopolymerised Polymers: HDT, Tg, Post-Cure and High-Temperature Qualification. ER-20. Zenodo (2026).
- [C4] Seguro, J. Chemical Resistance and Solvent Uptake of Vat-Printed Photopolymers: Qualification Boundaries and Recovery. ER-41. Zenodo (2026).
- [C5] Seguro, J. Substrate and Build-Platform Adhesion in Vat Photopolymerisation: Wetting, Surface Treatment, Cure-State Coupling and Qualification. ER-53. Zenodo (2026).

- [C6] Segurola, J. Gas Barrier and Molecular Permeability in Vat-Printed Photopolymers: Diffusion, Sorption, Network State, Defects and Qualification. ER-54. Zenodo (2026).
- [C7] Segurola, J. Thiol–Ene and Thiol–Yne Photopolymerisation in VPP: Stoichiometry, Oxygen Response and Network Architecture. ER-64. Zenodo (2026).
- [C8] Segurola, J. Environmental Ageing and Property Retention in Vat Photopolymerisation: Resin Storage, Photooxidation, Hydrothermal Conditioning and State-Resolved Qualification. ER-72. Zenodo (2026).
- [C9] Segurola, J. Material Operating Windows in Tomographic Volumetric Additive Manufacturing: Gelation Criteria, Inhibition Reserve, Optical Transport and Exposure Drift. ER-75. Zenodo (2026).
- [C10] Segurola, J. Residual Reactants, Impurities and Manufacturing Conversion as Hidden Drivers of Photopolymer Hazard. ER-92. Zenodo (2026).
- [C11] Segurola, J. Silicone and Silicone-Like Elastomers in Vat Photopolymerisation: Polysiloxane Chemistry, Silicone-Free Functional Analogues, Thermal-Service Limits and Qualification. ER-102 review-corrected release (2026).

Version note

v0.2 closes the ER-104 v0.1 review findings without changing the identity gate, PFAS terminology, numerical evidence or frozen architecture. The ISO 4892-1 title, ISO 527-1 revision stage, ISO 527-2 locator and Kotz measurement wording are corrected; the Kallitsis bibliographic fields are confirmed by the institutional record. Independent review returned APPROVE on 30 August 2026.