

Solvolysis of Photopolymer Networks: Solvent Selection, Mass Transfer, Separation and Recovered-Feedstock Quality

Engineering solvolysis as a coupled transport-reaction-separation process rather than a solvent-soak demonstration

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Abstract

Solvolysis can convert crosslinked polymer networks into soluble fragments or recoverable molecular products, but the solvent is simultaneously a transport medium, swelling agent, reactant and separation burden. Qualification therefore requires more than showing that a printed specimen disappears. This review defines a solvolysis framework for photopolymer networks centred on solvent selection, network accessibility, diffusion-reaction coupling, product separation, solvent recovery and the quality of the recovered feedstock. It distinguishes laboratory degradation rate from an industrially credible recovery route.

Keywords: solvolysis; thermoset recycling; photopolymer; solvent; diffusion; swelling; chemical recycling; separation; recovered feedstock

1. Significance and scope

Hydrolysis and solvolysis are established routes for end-of-life thermosets because a liquid phase can penetrate the network and support bond cleavage under milder conditions than many thermochemical processes [1].

This review owns solvent-centred processing of cured photopolymer networks. ER-452 owns the broader chemistry of selective bond cleavage and reuse; here the engineering object is the coupled solvent, transport, reaction and recovery train.

2. Solvent selection sets both chemistry and process burden

Solvent choice controls polarity, swelling, reagent solubility, catalyst activity, boiling point, safety and downstream separation. A solvent that gives fast coupon degradation may still be impractical if it is difficult to recover or contaminates the products.

Reviews of epoxy solvolysis emphasise that solvents can act as media, reactants, catalysts or activation partners rather than passive carriers [2]. Photopolymer networks require the same explicit role assignment.

Solvent compatibility should be tested against reactor seals, filters and recovery hardware as well as the polymer. Corrosion, extractables or elastomer swelling can introduce contaminants that later appear to be products of the network itself.

Swelling and solvent uptake should be separated from true network cleavage. Early mass gain or softening can accelerate transport without producing recoverable molecules, while apparent mass loss can include extraction of unreacted species rather than backbone or crosslink scission.

3. Mass transfer and bond cleavage are coupled

The degradation front advances only after solvent reaches reactive sites. Network density, glass transition, filler loading and specimen thickness therefore couple diffusion to reaction.

Recent in-situ work on thermoset recycling resolves mobility, diffusion and bond cleavage as interacting processes, supporting the view that apparent kinetics cannot be reduced to a single reaction constant [3].

4. Geometry and swelling control apparent kinetics

Swelling is useful because it opens transport pathways, but excessive swelling can fragment the part before chemistry is complete and complicate recovery of fillers or inserts. Report dimensional change separately from chemical conversion.

Geometry should be part of the test matrix. Thin films, thick walls and lattices can show different apparent rates even with identical chemistry because characteristic diffusion lengths differ.

Agitation, solvent renewal and temperature alter boundary layers and concentration gradients. These process variables must be stated if degradation times are compared across studies.

Concentration changes during recycling should be tracked because dissolved products progressively alter solvent activity, viscosity and mass transfer. A fresh-solvent coupon test can overstate performance of a closed-loop bath.

Separation after solvolysis should be designed together with the reaction. Dissolved products, insoluble filler, catalyst, solvent and unreacted fragments may require filtration, phase separation or distillation, and each operation can alter the composition of the recovered fraction.

5. Separation determines recovered-feedstock quality

Separation starts as soon as products enter the liquid phase. Precipitation, filtration, extraction, distillation or membrane operations may be required to isolate useful products and recover solvent.

A recovered feedstock should therefore be specified after separation, not at the point where the solid has vanished. Residual solvent, catalyst, oligomers and coloured degradation products can all affect later photopolymerisation.

Solvent recovery should be included in process mass and energy balances. A route that consumes a large solvent inventory per unit polymer may shift rather than solve the circularity problem.

Axis	Measurement	Failure mode
Solvent	identity, purity, role, recovery	fast degradation treated as optimum solvent
Transport	swelling, geometry, agitation	coupon time treated as intrinsic kinetics
Reaction	cleavage target and conversion	fragmentation treated as chemistry complete
Separation	product and solvent recovery	dissolved stream treated as feedstock
Reuse	residual solvent/catalyst and cure response	recovered mass treated as reusable mass

Table 1. Domain-specific qualification matrix for solvolysis of photopolymer networks.

6. Device-level verification of the complete route

Device-level verification should use representative printed geometry and, where relevant, composite or filled formulations. Measure time to defined conversion, recovered fractions, solvent condition and downstream feedstock quality.

If recovered material is reused, test its cure response and final-part performance under the same controls used for virgin material. The solvolysis step is not independently qualified from the reuse step.

Failure modes include incomplete penetration, surface-only cleavage, precipitation inside the network, catalyst deactivation, excessive solvent retention and separation losses that erase nominal recovery yield.

Device-level verification should challenge representative part thicknesses and geometries because diffusion length changes reaction time and product distribution. Thin coupons are useful for kinetics but should not be treated as sufficient evidence for bulk printed components.

7. Minimum qualification framework

Report network chemistry, specimen geometry, solvent identity and purity, solvent-to-solid ratio, temperature, agitation, catalyst/reagent, swelling, conversion metric and time.

Report product fractions, analytical identity, solvent-recovery method and yield, residual solvent or catalyst, and the acceptance criteria for any recovered feedstock.

8. Engineering conclusions

Solvolysis should be qualified as a coupled transport-reaction-separation process. The credible endpoint is a controlled recovered stream and recoverable solvent, not simply the disappearance of a printed thermoset.

References

- [1] M. Shen, H. Cao, M. L. Robertson, "Hydrolysis and Solvolysis as Benign Routes for the End-of-Life Management of Thermoset Polymer Waste," *Annual Review of Chemical and Biomolecular Engineering* 11 (2020) 183-201. <https://doi.org/10.1146/annurev-chembioeng-120919-012253>
- [2] X. Sun, Y. Zhang, Y. Wang, M. Niu, Z. Liu, J. Liu, X. Liu, "Solvolysis for chemical recycling of traditional epoxy/anhydride thermosets: A review," *European Polymer Journal* 250 (2026) 114713. <https://doi.org/10.1016/j.eurpolymj.2026.114713>
- [3] Z. Wu, Q. Zhu, Y. Zhang, J. Zhao, Q. Zhou, Z. Zhang, C. Gao, G. Wang, Q. Zhang, "Resolving mobility-diffusion-reaction coupling in thermoset chemical recycling through in-situ dielectric spectroscopy with DRT analysis," *Polymer Degradation and Stability* 253 (2026) 112343. <https://doi.org/10.1016/j.polymdegradstab.2026.112343>

Competing interest

Juan Segurola is founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L., which develops and commercialises photopolymer materials and related additive-manufacturing technologies. This review is an engineering analysis and does not constitute a product-performance claim or a device qualification.