

Vat Photopolymerisation of High-Molecular-Weight Polymer Latexes: Colloidal Printability, Scaffold Formation, Coalescence and Pseudothermoplastic Reprocessing

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Statement of Significance

High-molecular-weight polymers are usually excluded from conventional VPP by solution and melt viscosity. Latex feedstocks separate those variables by confining entangled chains inside colloidal particles while a photocurable continuous phase fixes the printed geometry. This review defines the resulting sequence from colloidal feedstock to green body, carrier removal, particle coalescence and final or reprocessed material, and establishes the measurements needed to distinguish printable viscosity from colloidal stability, green strength, coalescence, dimensional consolidation and genuine reprocessability.

Keywords: vat photopolymerisation; polymer latex; high molecular weight; colloidal resin; green body; coalescence; semi-interpenetrating network; interpenetrating network; pseudothermoplastic; elastomer; reprocessing

Abstract

Vat photopolymerisation generally relies on low-molecular-weight monomers and oligomers because processable feedstocks must flow, refill and level within the printer. High-molecular-weight polymers provide entanglement, toughness and thermoplastic or elastomeric behaviour, but their solutions and melts commonly become too viscous for conventional VPP. Polymer latexes provide a different materials architecture: the high-molecular-weight chains are confined inside pre-existing colloidal particles, while the continuous liquid phase remains comparatively low in viscosity. In the demonstrated latex route, water-soluble monomers, oligomers or crosslinkers in the continuous phase form a temporary or permanent photocured scaffold around the particles. This scaffold fixes the printed geometry and creates a particle-embedded green body. Drying and thermal post-processing then remove the aqueous carrier and promote particle contact, deformation, interdiffusion or coagulation through the scaffold. The final material may become a semi-interpenetrating network, a true interpenetrating network or a thermoplastic-dominant hybrid whose behaviour depends on latex chemistry, scaffold fraction, particle functionality and post-processing history. Published systems now include styrene-butadiene rubber, synthetic and natural polyisoprene, waterborne polyurethane, poly(styrene-*b*-isoprene-*b*-styrene), sulfonated EPDM and high-T_g methacrylic latexes. These studies demonstrate that latex VPP can expand the accessible molecular-weight and polymer-family space, but they also expose coupled risks: scattering by the particles, colloidal instability, green-body weakness, drying gradients, large isotropic shrinkage, incomplete coalescence and persistent influence of the photocured scaffold on final properties. This review develops a state-resolved engineering framework for latex VPP. It separates the liquid colloidal feedstock, photocured green body, dried/coalesced material and any reprocessed state. It defines boundaries against polymerisation-induced phase separation, dual cure, covalent adaptable networks and generic filled-resin rheology. It also proposes minimum reporting requirements for particle state, scaffold fraction, carrier removal, directional shrinkage, coalescence, final network morphology and property retention after reprocessing.

1. Introduction

Vat photopolymerisation combines high geometric resolution with a stringent feedstock constraint. The formulation must remain sufficiently mobile for vat filling, recoating or free-surface levelling, while also forming a mechanically coherent network rapidly under patterned light. In many practical VPP systems, this favours low-molecular-weight reactive species and densely crosslinked final networks.

High-molecular-weight polymers create a different property basis. Chain entanglement can support extensibility, toughness, melt processability and thermoplastic or elastomeric response. The same molecular weight that produces those properties also raises solution and melt viscosity, creating a printability-performance conflict.

Scott and co-workers addressed this conflict by using polymeric latexes as VPP feedstocks. The high-molecular-weight polymer was compartmentalised inside discrete particles, effectively decoupling molecular weight from the bulk viscosity of the aqueous formulation. A continuous-phase photocurable scaffold fixed the object during printing, and thermal post-processing coalesced the latex particles through that scaffold to form a semi-interpenetrating network [1].

The central engineering question of ER-66 is therefore:

How can a pre-existing colloidal polymer phase be printed as a low-viscosity liquid, immobilised as a green body and converted into a continuous high-molecular-weight material without allowing the photocured scaffold, carrier-removal history or particle interfaces to dominate the final performance?

2. The latex VPP architecture

A latex-based VPP formulation should be interpreted as a sequence of material states rather than as a conventional one-step resin cure.

Table 1. State sequence in latex-based vat photopolymerisation

State	Principal material structure	Dominant engineering requirement	What must not be inferred
Initial feedstock	High-molecular-weight polymer particles dispersed in a continuous liquid phase containing photocurable species	Colloidal stability, printable rheology, optical response	Final polymer continuity or final mechanics
Photocured green body	Particles embedded in a light-formed continuous scaffold	Geometry fixation, green strength, wash and handling resistance	Complete particle coalescence
Drying/coalescence intermediate	Carrier removal brings particles into contact while the scaffold constrains the object	Controlled mass transport, shrinkage and crack avoidance	Uniform coalescence from surface observation alone
Final latex-derived material	Coalesced polymer phase plus persistent or transformed scaffold	Target network morphology and final properties	Equivalence to the neat bulk polymer
Reprocessed state, where demonstrated	Mechanically or thermally reformed material containing the thermoplastic-dominant phase and any persistent scaffold	Property retention, dimensional control and repeated-cycle evidence	Closed-loop recycling from one successful remoulding operation

The chemical reaction that occurs during printing may involve only the continuous phase. The principal high-molecular-weight polymer can remain chemically unchanged during exposure and become mechanically continuous later through drying and coalescence [1,3-7].

This architecture makes the printed green body a manufacturing intermediate. Its network must be strong enough to retain geometry, but it need not be the dominant source of final mechanical behaviour.

3. Why colloids decouple molecular weight from viscosity

A dissolved high-molecular-weight chain occupies a hydrodynamic volume that grows with molecular size and concentration. Above the overlap and entanglement regimes, viscosity rises strongly because chains interact and constrain one another.

A latex confines many chains inside a particle. The suspension rheology is then governed primarily by particle size, particle volume fraction, interparticle forces, continuous-phase viscosity and shear history rather than by unrestricted chain entanglement across the entire liquid. Scott et al. used this principle to print a high-molecular-weight styrene-butadiene rubber latex that would not be accessible as an ordinary low-viscosity molecular solution [1].

The same principle has since been demonstrated with synthetic isoprene rubber particles around 900 nm [4], waterborne polyurethanes [5], SIS triblock-copolymer latexes [6], sulfonated EPDM particles around 125 nm [7] and ammonia-free natural-rubber latex [9].

The conclusion must nevertheless remain conditional:

Latex compartmentalisation can reduce the viscosity consequence of molecular weight, but it does not guarantee printable rheology at every solids content, particle interaction state or temperature.

Bean and co-workers, in a perspective on rheology-guided design of aqueous colloidal composites for vat photopolymerisation, restate the general VPP printability constraint of viscosity below approximately 10 Pa s and provide the design vocabulary and stability criteria adopted across the Long-group latex series [3].

4. Colloidal stability is part of the material identity

A latex is not simply polymer dissolved in water. It is a metastable dispersion whose properties depend on particle-surface chemistry and the balance of attractive and repulsive interactions.

Potential changes during storage and printing include:

- flocculation or aggregation;
- coagulation;
- creaming or sedimentation;
- surfactant redistribution;
- particle swelling by reactive diluents;
- pH or ionic-strength drift;
- evaporation-driven concentration change;
- microbial or chemical degradation where relevant.

These changes can modify viscosity, scattering, cure depth and final morphology before any intentional photopolymerisation occurs.

The ammonia-free natural-rubber study illustrates how preservation chemistry, surfactant state, pH and concentrated-suspension rheology can become part of the printability problem rather than secondary handling details [9]. The sulfonated EPDM route similarly relied on chemical modification and ionic neutralisation to create a stable water-dispersible elastomeric latex [7].

A latex VPP study should therefore report the initial particle-size distribution, solids content, continuous-phase composition, temperature, storage time, mixing history and a time-dependent stability measurement appropriate to the system.

5. The photocurable scaffold

The continuous-phase scaffold performs at least four functions:

1. it responds to the printing wavelength;
2. it creates green strength;
3. it fixes the particle distribution during layerwise manufacture;
4. it constrains the part during carrier removal and coalescence.

The earliest latex VPP demonstration used water-soluble reactive species to create a hydrogel-like scaffold around SBR particles [1]. The same general route was subsequently applied to SIR, WPU, SIS and EPDM latexes [4-7].

The scaffold is not mechanically neutral. Its composition and fraction affect:

- gelation and green-body modulus;
- optical penetration;
- swelling and washing;
- drying shrinkage;
- final crosslink density;
- particle coalescence;
- Tg and phase morphology;
- extensibility and toughness;

- reprocessability.

Kasprzak and co-workers demonstrated a degradable acetal-containing scaffold for styrene-butadiene latex printing. Reactive extraction cleaved the crosslinks and changed the contribution of the glassy scaffold to the final material, demonstrating that scaffold chemistry can be designed as a removable or transformable manufacturing element [2].

Nettles et al. later showed directly that changing the covalent scaffold composition in SIS latex IPNs altered photorheology, thermal transitions, morphology and tensile response [10]. Therefore, the term latex resin is incomplete unless the persistent scaffold chemistry and dry-state fraction are also identified.

6. Green-body formation and photorheology

The primary exposure must generate enough connectivity for repeated layer formation, part removal and controlled drying.

A working curve provides geometric cure information but does not establish the mechanical state of the particle-embedded green body. Photorheology can identify the time-dependent development of storage and loss moduli and can be used to determine whether the scaffold reaches a plateau compatible with handling under the defined process conditions.

The degradable-scaffold SBR study reported sub-second G'/G'' crossover under the investigated formulation and exposure state, while the 2026 SIS study showed a ten-fold change in plateau storage modulus when the scaffold chemistry was changed from an NVP-containing system to an HEA-containing system [2,10]. These values are formulation-specific. Their broader significance is that green-body mechanics must be measured rather than inferred from cured depth.

For rheological reporting, ISO 3219-1:2021 provides vocabulary and symbols and ISO 3219-2:2021 provides general principles for rotational and oscillatory rheometry [S1,S2]. Neither standard defines a latex-VPP acceptance window. Geometry, gap, temperature, preshear, rest time, irradiation geometry, irradiance and acquisition rate must therefore accompany the result.

7. Optical scattering and exposure calibration

Latex particles create refractive-index heterogeneity before curing. Their size, concentration, aggregation state and optical contrast with the continuous phase can increase scattering and reduce the predictability of a conventional homogeneous-resin working curve.

Scott et al. combined scaffold photopolymerisation with in-situ computer-vision parameter optimisation to compensate for light scattering in the latex system [1]. This is an important precedent: particle compartmentalisation solves one viscosity problem while creating an optical-transport problem.

A printable latex formulation should be characterised using the complete wet feedstock, not an isolated continuous phase. At minimum, report:

- spectral transmittance or attenuation over a relevant path length;
- particle-size and aggregation state;
- cure depth and critical exposure under the chosen printer;
- lateral feature response;
- optical change during concentration, drying or ageing;
- temperature and vat residence time.

A formulation that prints immediately after mixing should not be assumed to retain the same optical calibration after prolonged open-vat use.

8. Drying, coagulation and particle coalescence

After printing, the carrier must be removed in a way that brings polymer particles into contact without destroying the object.

The process may involve:

- evaporation;
- thermal drying;
- coagulation;
- reactive extraction;
- particle deformation;
- chain interdiffusion;
- ionic or covalent secondary-network formation.

The temperature required for coalescence depends on polymer T_g, particle morphology, plasticisation, surfactant state and confinement by the scaffold.

WPU latexes formed a semi-interpenetrating or interpenetrating network depending on polyurethane end-group functionality [5]. SIS latexes retained their block-copolymer microphase morphology after coalescence, while the 2024 study reported approximately 25% isotropic shrinkage through the complete process [6]. EPDM latex printing generated an ionically crosslinked second network in addition to the photochemical scaffold [7].

Drying rate is therefore a manufacturing variable. The pseudothermoplastic latex study explicitly warned that excessively rapid water removal could generate internal fractures and used a staged drying sequence to preserve integrity [8]. Surface dryness is not evidence that the interior has completed carrier removal or particle coalescence.

9. sIPN, IPN and pseudothermoplastic states

The final network classification depends on whether the latex-derived phase and scaffold are independently continuous and whether they are covalently connected.

A semi-interpenetrating polymer network generally contains one crosslinked network interpenetrated by a linear or branched polymer phase. An interpenetrating network contains two networks that are independently crosslinked or physically networked but interlaced at the molecular or microstructural scale.

Latex VPP studies have reported both sIPN and IPN outcomes [1,4-7,10]. The classification should not be assigned solely from the ingredients. It should be supported by extraction, swelling, morphology, thermal analysis or another method that distinguishes the network states.

Ayestarán and co-workers introduced the term pseudothermoplastic for a specific thermoplastic-dominant sIPN architecture containing at least 90% thermoplastic material and no more than 10% thermoset scaffold in their definition [8]. The term is useful but should not be generalised to all latex VPP materials.

In ER-66, pseudothermoplastic is reserved for systems that meet the authors' stated compositional architecture and demonstrate practical thermomechanical reprocessing. A latex-derived thermoset-dominant sIPN is not automatically pseudothermoplastic.

10. Evidence across polymer families

10.1 Styrene-butadiene rubber

The foundational SBR study established the core sequence of low-viscosity latex printing, scaffold fixation and thermal coalescence, yielding precise printed elastomers with tensile extensibility above 500% in the reported system [1]. The later degradable-scaffold study demonstrated that scaffold removal or transformation could reduce water uptake and improve thermal and mechanical performance, with ultimate strain above 650% and ultimate stress of 8.5 MPa under its specific conditions [2].

10.2 Synthetic and natural polyisoprene

Synthetic isoprene rubber latexes formed sIPNs after thermal coalescence, and changing scaffold concentration produced reported elongations from 94% to 682% [4]. The ammonia-free natural-rubber formulation

demonstrated a different preservation and network route, with a two-step crosslinking/coagulation process and reported tensile strengths of 5-7.8 MPa and breaking strains of 750-900% [9].

These numerical values are not universal targets for latex elastomers. They show that colloidal high-molecular-weight feedstocks can produce a broad property range when particle, scaffold and post-processing states are jointly controlled.

10.3 Waterborne polyurethane

High- and low-molecular-weight WPU latexes provided a direct comparison between resolution and polymer molecular architecture. Low-molecular-weight WPUs printed with higher resolution in the reported work, while high-molecular-weight WPUs enabled elongations approaching 300%. End-group functionality influenced whether the dried material was described as an sIPN or IPN [5].

10.4 SIS and EPDM thermoplastic elastomers

SIS latex VPP combined a 15 wt% aqueous scaffold with thermal particle coalescence. The reported material retained a characteristic microphase-separated length scale of approximately 30 nm and exhibited tensile extensibility above 800%, but also approximately 25% isotropic shrinkage [6].

Sulfonated EPDM latexes produced a second ionic network during post-processing. The reported materials showed tunable ultimate strain and stress and controllable isotropic shrinkage using a commercial VPP printer [7].

10.5 Methacrylic pseudothermoplastics

The 2025 methacrylic-latex study reduced the permanent scaffold fraction so the thermoplastic phase dominated the final object. It demonstrated reprocessing by hot pressing, injection moulding and extrusion-based printing, as well as two-photon processing of an optimised latex formulation [8].

This work represents a distinct end-of-life route from covalent adaptable networks. Reprocessing arose from the high thermoplastic fraction rather than dynamic covalent exchange.

11. Scaffold fraction is a central design variable

Increasing scaffold concentration generally improves green-body stability and can widen the print window. The same increase can:

- raise permanent crosslink density;
- suppress particle coalescence;
- reduce final elongation;
- increase water affinity;
- increase shrinkage stress;
- reduce thermoplastic flow and reprocessability.

Reducing scaffold concentration can preserve more of the latex polymer's original behaviour but may produce weak green parts, poor layer integrity or drying collapse.

The correct optimisation target is therefore not minimum or maximum scaffold content. It is the lowest persistent or transformable scaffold fraction that provides the required print-state stability and final-state performance.

The 2026 SIS study confirms that composition matters independently of total scaffold loading: replacing or supplementing the network-forming monomer changed plateau modulus, phase definition and tensile response [10]. Scaffold chemistry and scaffold quantity must both be reported.

12. Shrinkage and dimensional evolution

Latex VPP contains at least two major dimensional events:

1. photochemical network formation in the continuous phase;
2. carrier removal and particle consolidation.

The second event can be much larger than ordinary photopolymerisation shrinkage. It may remain approximately isotropic for a particular formulation and geometry, but isotropy should be demonstrated rather than assumed.

Dimensions should be measured at defined states:

- CAD target;
- wet green body;
- washed green body;
- partially dried intermediate;
- fully dried/coalesced material;
- post-cured or annealed material;
- reprocessed state where applicable.

Global scale compensation can correct a reproducible mean shrinkage. It cannot correct local gradients caused by thickness, surface area, constrained drying, support attachment or non-uniform coalescence.

13. Reprocessability and circularity boundaries

A latex-derived material should not be described as recyclable solely because its principal polymer was originally thermoplastic.

A persistent crosslinked scaffold can prevent melt flow or alter the recovered material after every cycle. Surfactants, residual initiator, water-soluble fractions and oxidative or thermal history can also affect reprocessing.

The pseudothermoplastic study demonstrated up to two reprocessing cycles by hot pressing and injection moulding with comparatively small property changes in the reported system, and also investigated recovery of the thermoplastic fraction by extraction [8]. These results support reprocessability for that architecture. They do not establish closed-loop recycling for all latex VPP systems.

A defensible circularity claim requires:

- a defined recovery route;
- mass balance;
- identity of the recovered fraction;
- retained or changed molecular weight;
- property retention over repeated cycles;
- accounting for the scaffold and any unrecovered phase;
- energy, solvent and waste boundaries where environmental benefit is claimed.

14. Proposed engineering descriptors

The following descriptors are proposed reporting aids. They are not standardised quantities.

14.1 Persistent scaffold mass fraction

$$f_s = m_{\text{scaffold,final}} / m_{\text{total,dry}}$$

This is the dry mass fraction of the permanently retained photocured scaffold in the final material. A transformable or extracted scaffold should be reported separately before and after the transformation.

14.2 Carrier-removal ratio

$$R_c(t) = [m_{\text{green}} - m(t)] / [m_{\text{green}} - m_{\text{final}}]$$

This records progress toward the final conditioned mass. The final state, temperature, humidity and acceptance criterion must be declared. The ratio does not prove coalescence.

14.3 Directional consolidation strain

$$\varepsilon_i = [L_{i,\text{final}} - L_{i,\text{green}}] / L_{i,\text{green}}$$

Report separately for x, y and z or the applicable principal directions. A negative value indicates contraction. Registration and measurement timing must be stated.

14.4 Reprocessing property-retention ratio

$$R_{P,n} = P_n / P_0$$

P₀ is a declared property of the original conditioned material and P_n is the same property after reprocessing cycle n. A tensile-strength ratio cannot be compared with an elongation or fracture-energy ratio.

15. Minimum qualification framework

Table 2. Minimum reporting architecture for latex-based VPP

Domain	Minimum measurement or record	Required interpretation
Latex identity	Polymer chemistry, molecular-weight information where available, particle-size distribution, solids content	Defines the dispersed polymer phase
Colloidal state	pH, ionic/surfactant state where relevant, storage age, mixing history, stability observation	Distinguishes controlled latex from evolving instability
Rheology	Flow curve and relevant oscillatory measurements using declared ISO 3219 terminology/principles [S1,S2]	Establishes feedstock and green-body rheological state
Optical state	Spectrum or attenuation, working curve, lateral-feature test	Links particle scattering to exposure calibration
Scaffold	Monomer/crosslinker functionality, dry persistent fraction, photoinitiator and wavelength	Defines the geometry-fixing network
Green body	Gel or modulus criterion, wet dimensions, handling state	Establishes print-state integrity
Carrier removal	Mass versus time, temperature, humidity and geometry	Quantifies drying without assuming coalescence
Coalescence/morphology	Microscopy, scattering, thermal or extraction evidence as appropriate	Establishes continuity and network class
Dimensional response	Wet and final x/y/z dimensions with registration	Separates photocure from consolidation shrinkage
Final mechanics	Tensile method and conditioning under an applicable method such as ISO 527-1:2019 [S3]	Links properties to the final state
Thermal state	Tg or relevant transition with method definition, for example ISO 11357-2:2020 where applicable [S4]	Distinguishes latex polymer and scaffold transitions
Reprocessing	Route, temperature, pressure, cycle number, mass yield and R _{P,n}	Supports bounded reprocessability claims

16. Failure modes and interpretation errors

Table 3. Latex-VPP-specific failure modes

Observation	Possible origin	Required control
Printable viscosity but poor feature fidelity	Scattering or aggregation	Particle-state and optical calibration
Good cured depth but weak green body	Scaffold gels without adequate plateau modulus	Photorheology and handling test
Cracking during drying	Carrier-removal gradient or constrained shrinkage	Geometry-specific drying map
Surface appears dry but centre remains weak	Incomplete internal carrier removal	Mass endpoint and sectioned inspection
High final elongation varies by thickness	Non-uniform coalescence or scaffold fraction	Through-thickness morphology and mechanics

Observation	Possible origin	Required control
Final material is brittle despite elastomeric latex	Excessive rigid scaffold fraction	Dry composition and phase analysis
Large dimensional error	Consolidation shrinkage treated as ordinary cure shrinkage	Wet-to-dry dimensional sequence
Reprocessing fails	Persistent scaffold prevents flow	Melt rheology and scaffold accounting
Apparent recycling with declining properties	Thermal degradation or composition drift	Cycle-resolved molecular and property analysis
Phase-separated morphology attributed to PIPS	Latex particles existed before exposure	Document the initial colloidal state

17. Scope boundaries within the Engineering Review series

ER-36 addresses rheology, recoating and dispersion control of filled VPP suspensions. ER-66 is restricted to polymeric latexes in which the high-molecular-weight polymer is already contained in colloidal particles and later coalesces into a principal final phase.

ER-59 addresses independently activated dual-cure reactions. A latex process can include more than one transformation, but ER-66 focuses on scaffold formation, carrier removal and particle coalescence rather than classifying dual-cure chemistry.

ER-60 addresses polymerisation-induced phase separation and microphase separation. In latex VPP, the particles exist before exposure. Their later coalescence or retained morphology must not be described as PIPS unless polymerisation independently creates a new demixing event.

ER-61 addresses gelation, vitrification and mobility arrest during photocure. ER-66 uses gelation and mobility only to qualify formation of the temporary scaffold and the post-print consolidation window; it does not replace network-state metrology.

ER-62 addresses RAFT and other reactivatable networks that retain chemically addressable dormant groups after printing. Latex-enabled VPP does not require retained chain-end reactivity; its defining sequence is a pre-existing colloidal polymer phase, photocured green-body scaffold and post-print drying, coagulation or coalescence.

ER-63 addresses covalent adaptable networks and vitrimers. Pseudothermoplastic latexes can be reprocessed without dynamic covalent exchange because the thermoplastic fraction dominates the material [8].

ER-67 addresses hierarchical and double-network hydrogels as final hydrated materials. The hydrogel-like scaffold in many latex systems is primarily a temporary green-body architecture and the final material is usually dried.

ER-74 addresses cleavable and depolymerisable networks. A degradable scaffold can support a latex route [2], but ER-66 includes it only as a means of controlling the final latex-derived material.

18. 3Dresyns implementation boundary

No current standard 3Dresyns product is identified in this review as an independently validated high-molecular-weight latex VPP platform, pseudothermoplastic latex resin or polymer-colloid printing system.

The paper supports a future custom-development route, but the following expressions should not be used without formulation-specific evidence:

- printable thermoplastic latex;
- recyclable VPP latex;
- equivalent to the neat polymer;
- zero-shrinkage latex printing;
- complete particle coalescence;
- universal water-washable thermoplastic resin.

A future 3Dresyns latex platform would require, at minimum:

1. controlled latex identity and stability;
2. wavelength- and printer-specific optical calibration;

3. green-body and drying-window qualification;
4. dry scaffold-fraction accounting;
5. final morphology and network classification;
6. wet-to-dry dimensional compensation;
7. final property and ageing data;
8. cycle-resolved reprocessing evidence for any circularity claim.

19. Design rules

- Treat the liquid latex, green body and final coalesced material as different material states.
- Measure colloidal stability over the actual vat-residence window.
- Calibrate exposure using the complete particle-containing formulation.
- Design the scaffold for sufficient green strength, not maximum permanent crosslink density.
- Report scaffold chemistry and final dry scaffold fraction.
- Control carrier removal by geometry, temperature and humidity.
- Measure directional wet-to-dry shrinkage.
- Prove coalescence or network classification directly.
- Use pseudothermoplastic only for an explicitly defined thermoplastic-dominant architecture with demonstrated reprocessing.
- Separate reprocessability from closed-loop recycling and environmental benefit.

20. Research priorities

First, latex-VPP studies need stronger in-situ methods that connect particle packing, scaffold gelation, optical scattering and local carrier removal.

Second, lower-scaffold or transformable-scaffold routes should be compared systematically against green-body strength and dimensional stability.

Third, drying models should incorporate geometry, surface-area-to-volume ratio, local permeability and scaffold constraint rather than applying one bulk scale factor.

Fourth, high-Tg thermoplastic latexes expand the accessible polymer space but require improved crack-free drying and particle-coalescence strategies [8].

Fifth, repeated reprocessing must be evaluated beyond two cycles and should include molecular-weight, morphology, volatile and property changes.

Sixth, the 2026 SIS study indicates that scaffold monomer identity can be used to tune final morphology and mechanics independently of the latex polymer [10]. This creates a broader design space in which the same commercial latex may generate materially different printed networks.

21. Conclusions

Polymer latexes provide a route for introducing high-molecular-weight polymers into VPP without dissolving those chains as one continuous molecular phase.

The process works through a sequence:

colloidal feedstock -> photocured particle-embedded green body -> carrier removal -> particle coalescence or secondary network formation -> final material

This sequence creates opportunities that conventional homogeneous resins do not provide. Entangled elastomers, thermoplastic elastomers, waterborne polyurethanes and thermoplastic-dominant methacrylic materials have all been printed through latex-derived routes.

It also creates new qualification requirements. Printable viscosity does not prove colloidal stability. Green-body cure does not prove particle coalescence. A thermoplastic latex does not guarantee a thermoplastic final part. Reprocessing does not prove closed-loop recycling.

The central engineering principle is:

In latex vat photopolymerisation, light fixes the geometry, but colloidal consolidation and scaffold architecture determine what material the geometry becomes.

Limitations

The evidence base is concentrated in a small number of research groups and is dominated by aqueous elastomeric latexes. The reported particle sizes, scaffold fractions, shrinkage values, cure times and mechanical properties are formulation-specific and must not be pooled as universal operating limits.

The word coalescence can encompass particle contact, deformation and chain interdiffusion to different degrees. Not every cited study measures all of these processes independently.

Pseudothermoplastic is a recently coined, study-defined term requiring at least 90% thermoplastic material and no more than 10% thermoset scaffold in the cited study; it is not a standard materials class. This review preserves that source-specific definition and does not extend it to every thermoplastic-containing photopolymer.

No international standard specifically defines qualification of a polymer-latex feedstock for vat photopolymerisation. The standards cited here apply only to their stated rheological, tensile or thermal measurements.

Author contributions

Juan Seguro: conceptualisation, literature synthesis, engineering framework, writing and critical review.

Competing interests

The author is founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L. No current commercial 3Dresyns product is presented as an independently validated latex-based VPP platform, pseudothermoplastic resin or thermoplastic-latex printing system.

Data availability

No new experimental dataset was generated for this review.

Company information

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Standards and near-scope methods

- S1. International Organization for Standardization. ISO 3219-1:2021, Rheology - Part 1: Vocabulary and Symbols for Rotational and Oscillatory Rheometry.
- S2. International Organization for Standardization. ISO 3219-2:2021, Rheology - Part 2: General Principles of Rotational and Oscillatory Rheometry.
- S3. International Organization for Standardization. ISO 527-1:2019, Plastics - Determination of Tensile Properties - Part 1: General Principles.
- S4. International Organization for Standardization. ISO 11357-2:2020, Plastics - Differential Scanning Calorimetry (DSC) - Part 2: Determination of Glass Transition Temperature and Step Height.

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