

Digital Photopolymer Printing Plates and Stamps: Material Requirements, Relief Fidelity and Durability in Vat Photopolymerisation

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ER-025 · Engineering Review · Version 1.5 · 2026

Statement of Significance

Digital manufacture of a relief tool is not equivalent to qualification of a printing plate or stamp. The manufactured surface must reproduce the intended topography, contact the substrate under a controlled mechanical state, accept and release an ink or functional material, resist the chemistry used during printing and cleaning, and preserve those functions over repeated cycles. This review therefore treats photopolymer printing plates and stamps as engineered transfer interfaces rather than as generic 3D-printed elastomeric parts. The central proposition is that plate performance must be qualified through a chain linking relief geometry, mechanical compliance, surface chemistry, ink-transfer behaviour and durability. A plate can be dimensionally accurate yet print poorly, while a compliant stamp can transfer material successfully even when its unloaded geometry changes under contact. The framework developed here separates manufacturing fidelity from transfer fidelity and defines the evidence required before a vat-photopolymerised tool can be described as suitable for flexographic, relief, pad or microcontact printing.

Keywords: vat photopolymerisation; flexography; printing plate; relief printing; stamp; microcontact printing; soft lithography; ink transfer; surface free energy; Shore hardness; solvent resistance; dimensional fidelity; DLP; SLA

Abstract

Photopolymer printing plates convert a digital image or pattern into a mechanically loaded transfer surface. This function creates requirements that are not captured by nominal printer resolution, Shore hardness or tensile properties alone. In flexography, a raised relief receives a metered ink film from an anilox roll and transfers it to a substrate under controlled impression; in pad and contact printing, conformity and release govern transfer to flat, curved or microstructured targets; in microcontact printing, stamp deformation, interfacial adhesion and ink mobility can determine the final pattern at micrometre and sub-micrometre scales. Additive manufacturing offers rapid digital fabrication of such tools, and published studies have demonstrated stereolithographic and material-jetting routes for flexographic plates as well as emerging directly printed microstructured stamps. However, the evidence also shows strong coupling among geometry, modulus, surface energy, ink rheology, substrate, printing pressure, chemical exposure and ageing. This review organises the field around five qualification domains: realised relief geometry, mechanical contact behaviour, surface and ink interaction, chemical durability, and repeated transfer performance. Particular attention is given to the distinction between plate geometry and printed-image fidelity, the role of compliance and surface microtexture, solvent-induced swelling, and stamp-deformation modes such as roof collapse, buckling and lateral sticking. A minimum reporting framework is proposed that links manufacturing state to print conditions and output metrology. The resulting architecture provides a defensible basis for evaluating digitally manufactured photopolymer plates without assuming that a successful 3D print is automatically a qualified printing tool.

1. Introduction

Flexographic and contact-printing tools occupy an unusual position in additive manufacturing. They are not final parts in the conventional structural sense. Their purpose is to interact repeatedly with another fluid and another surface while preserving a patterned contact geometry. The relevant engineering output is therefore not the printed plate alone, but the material transferred by that plate under defined pressure, speed, wetting and separation conditions. This distinction is fundamental when evaluating vat photopolymerisation (VPP) as a route to relief tooling.

Early studies specifically investigated stereolithographic routes for flexographic platemaking and showed that digital additive fabrication can produce relief geometries capable of ink transfer [1,2]. More recently, Izdebska-Podsiadły and Lasecki demonstrated flexible PolyJet plates and compared their chemical resistance and printed output with conventional photopolymer plates [3]. Although PolyJet is a material-jetting process rather than VPP, the study is important because it exposes the correct qualification question: the additive route must be evaluated through both plate properties and actual print behaviour. The successful manufacture of a flexible relief does not by itself establish raster reproduction, chemical durability or process equivalence.

Conventional flexographic research provides a second body of evidence that is directly relevant to additively manufactured plates. Surface modification changes ink deposition [4]; common solvents can swell photopolymer plates and alter hardness, surface free energy and print dimensions [5]; substrate properties alter line and text reproduction even when the same plate is used [6]; ink rheology influences uniformity during plate-substrate separation [7]; and micro-patterning of the plate surface can materially change solid ink laydown [8]. These results imply that a VPP plate cannot be qualified in isolation from the printing system in which it will operate.

A third evidence base comes from microcontact printing. There, the stamp is explicitly treated as a deformable contact-mechanics element. Classical experiments and models show that roof collapse, buckling, lateral sticking, adhesion and applied load can change the transferred pattern [11,12]. More recent studies have modified stamp chemistry, stiffness or geometry to control transfer on rough surfaces and to extend the process to new inks [13-18]. This literature is not directly interchangeable with flexography, but it makes the same system-level point at a smaller scale: realised transfer is an interaction among topography, mechanics, surface chemistry and process conditions.

The present review therefore focuses narrowly on digital photopolymer printing plates and stamps as transfer interfaces. Existing 3Dresyns WP-45 addresses printing applications more broadly. This review instead develops the material and qualification architecture needed to

evaluate relief fidelity and durability. It does not provide a formulation recipe or universal limits for resolution, screen frequency, workflow time, cost, PDMS substitution or food-contact suitability; each requires application-specific evidence.

2. The printing plate as a coupled transfer interface

2.1 Geometry is only the first state variable

A relief tool begins with digital geometry, but its functional state evolves through fabrication, post-processing, mounting, inking, compression and separation. The printed relief can deviate from CAD because of optical broadening, voxel or pixel sampling, cure depth, support strategy, shrinkage and post-cure. Once mounted, the same relief can change again under compression. During transfer, the ink redistributes according to viscosity, elasticity, surface tension and wetting. Finally, the substrate controls absorption, spreading and edge formation. The printed image is therefore several transformations removed from the CAD relief.

This chain explains why the dimensional capability of the printer and the graphical capability of the printing process must be reported separately. A plate may reproduce the intended line width accurately in the unloaded state but broaden the printed line under excessive impression. Conversely, a feature may be intentionally pre-compensated in the CAD model so that its transferred image approaches nominal dimensions. In both cases, only reporting the final print without the realised plate geometry prevents identification of the source of error.

2.2 Flexography, relief printing, pad transfer and microcontact printing

The phrase printing plate covers mechanically different applications. Flexography normally uses a compliant raised relief mounted on a cylinder and supplied by a metered anilox roll. Letterpress and other relief modes can use harder tools and different pressure histories. Pad printing introduces an intermediate deformable pad that decouples cliché geometry from substrate conformity. Microcontact printing uses the stamp itself as the compliant patterned transfer element and often operates with monomolecular, biochemical or functional inks rather than conventional graphic inks. A single material property cannot therefore rank suitability across all four classes.

Application class	Dominant tool function	Critical material variables	Failure modes to qualify
Flexographic plate	Metered relief transfer under repeated rolling contact.	Relief fidelity, hardness/compliance, elastic recovery, surface energy, ink/solvent resistance.	Dot/line deformation, nonuniform solids, swelling, wear, permanent set.
Letterpress / relief	Direct transfer from raised features under impression.	Relief height, compressive stiffness, surface finish, wear resistance.	Edge rounding, local crushing, incomplete contact, abrasion.
Pad-printing cliché / tool	Defined recess or relief feeding an intermediate compliant pad.	Surface energy, chemical resistance, dimensional stability, release.	Poor pickup/release, solvent attack, loss of edge definition.
Microcontact stamp	Conformal patterned contact at micro- or nanoscale.	Elastic modulus, feature aspect ratio, adhesion, surface chemistry, ink mobility.	Roof collapse, buckling, lateral sticking, smearing, incomplete transfer.
Functional-printing plate	Transfer of conductive, biological or other functional inks.	Geometric fidelity, surface chemistry, ink rheology compatibility, registration.	Open circuits, variable film thickness, contamination, functional loss.

Table 1. Application-specific functions of photopolymer printing plates and stamps.

3. Relief fidelity: from CAD topography to realised transfer surface

3.1 Positive relief, negative recesses and feature polarity

Relief plates contain both positive and negative geometry. Raised lines and dots must survive fabrication and mechanical contact, while recesses must remain sufficiently open to prevent unintended ink pickup. VPP does not reproduce these polarities symmetrically. Excess exposure can broaden positive features and partially close negative spaces; insufficient cure can weaken isolated raised elements. This polarity dependence is already well established in VPP microfeature studies and should be expected in relief-tool manufacturing as well [19,20].

For printing qualification, minimum printable feature size should not be used as a substitute for relief fidelity. The useful metric is the relation between designed feature, measured plate feature and transferred feature under a specified impression. That relation should be assessed across representative solids, isolated lines, reverse lines, text, halftone or micro-pattern features as appropriate to the application.

3.2 Relief height, top profile and surface microtexture

The upper surface of a printing element is itself functional. In flexography, flat-top versus rounded dot profiles, edge geometry and intentional micro-patterning can change the local pressure and ink volume delivered to the substrate. Kesan and Sahinbaskan showed that micro-pattern structures on flexographic plates can alter solid ink laydown and graininess [8]. This is an important warning for additive manufacturing: layer texture, pixel imprint or deliberate surface structures should not automatically be treated as cosmetic roughness. They can change the effective ink reservoir and contact mechanics.

Surface texture can therefore have three roles. It can be an unintended manufacturing artefact, an engineered microtexture intended to modify ink transfer, or a metrological confounder that changes how the plate surface is measured. A defensible study should distinguish these roles and quantify the final post-processed surface rather than report only nominal layer thickness or projected pixel size.

3.3 Thickness, flatness and mounting state

A plate operates after mounting, not as a free coupon. Thickness variation, global warpage and backing compliance can change local impression even if the relief itself is accurate. For cylindrical flexography, the adhesive mounting tape and cylinder geometry become part of the mechanical stack. For flat stamping, the support substrate and fixture determine how load distributes across the patterned area. Qualification should therefore include the assembled state whenever the intended application is sensitive to contact pressure or registration.

4. Mechanical design: compliance without uncontrolled deformation

4.1 Hardness is useful but insufficient

Shore hardness is widely used to describe elastomeric printing plates because it provides a practical indicator of indentation resistance. It does not uniquely determine compressive modulus, time-dependent recovery, tensile behaviour, tear resistance or local bending of fine relief elements. Two materials with similar Shore hardness can differ in viscoelasticity and solvent response, and a single hardness value cannot predict the deformation of a specific dot or wall under printing load.

Flexographic practice illustrates the trade-off. Greater compliance can improve contact on irregular substrates, but excessive deformation broadens features and can increase dot gain. Higher stiffness preserves geometry but can reduce conformity and increase sensitivity to height variation. The correct target is therefore application-specific compliance under the real pressure and time scale of contact, not maximum softness or maximum modulus.

4.2 Elastic recovery, creep and repeated compression

Printing is cyclic. A plate that performs well during the first impression can drift if viscoelastic creep, heating, solvent uptake or mechanical fatigue changes its thickness or surface state. For additively manufactured elastomers, layer orientation and post-cure can additionally influence recovery. Repeated compression tests should therefore measure residual set and dimensional change at a cycle count relevant to the intended validation stage. Short monotonic tensile data alone are inadequate evidence for durability.

The measurement should also be feature-aware. Bulk compression of a plaque does not replicate bending and buckling of isolated relief elements, and fatigue of a raised microline can differ from that of a solid region. Where fine features are critical, microscopy or profilometry before and after cycling provides more direct evidence than bulk mechanical properties alone.

5. Surface chemistry and ink transfer

5.1 Surface free energy, contact angle and release

A printing surface must first accept an ink from the preceding element and then release an appropriate fraction to the substrate. Surface free energy and contact angle are useful descriptors of this sequence but remain conditional on the actual ink chemistry. Tomašegović and co-workers showed that surface treatment of flexographic plates can alter coating and print features [4], while later work linked UV treatment, solvent exposure, swelling and surface-free-energy changes to printed-film behaviour [5]. A VPP plate should therefore be characterised after its final wash, post-cure and any surface treatment because those steps define the surface that contacts ink.

Contact-angle measurements should be made with relevant probe liquids or inks and interpreted together with surface roughness. Apparent wetting on a textured plate can include topographic effects, while ink transfer during rapid separation is dynamic rather than an equilibrium sessile-drop problem. Contact angle is therefore a useful input to qualification, not a stand-alone prediction of transfer efficiency.

5.2 Ink rheology and separation dynamics

Ink transfer is a fluid-mechanical event. Morgan and co-workers showed experimentally that extensional elasticity can change the uniformity and morphology of flexographically printed films even when shear viscosities are similar [7]. Deganello and co-workers likewise demonstrated the importance of metered ink volume for printed conductive networks [9]. These results place a boundary on resin-centric interpretation: a plate material cannot be described as universally high-transfer or low-transfer without specifying the ink and metering conditions.

For qualification, at least viscosity or rheological class, surface tension where available, anilox or ink-delivery condition, print speed and impression should accompany the plate result. Functional inks may require even tighter control because a small change in deposited thickness or line continuity can alter conductivity, optical response or biological function.

5.3 Substrate dependence

The substrate completes the transfer system. Valdec and co-workers observed different line and text reproduction on coated paper, uncoated paper and oriented polypropylene under otherwise controlled flexographic conditions [6]. The same plate can therefore yield different apparent fidelity on substrates with different roughness, porosity and wetting. A plate qualification that uses one smooth test substrate cannot be automatically transferred to corrugated board, films, textiles or biomedical surfaces.

6. Chemical resistance, swelling and cleaning durability

Printing plates experience repeated chemical exposure from inks, cleaners and storage procedures. Swelling is particularly important because a modest change in polymer volume can alter relief width, height, hardness and surface energy simultaneously. Tomašegović et al. demonstrated solvent-dependent swelling and property changes in photopolymer and EPDM flexographic plates [5]. The implication for VPP is direct: chemical compatibility should be measured on the final cured network under the intended exposure duration, not inferred from generic labels such as chemical resistant.

Chemical qualification should separate reversible sorption from permanent damage. Mass change, thickness or feature-height change, hardness, surface-energy shift and microscopy after exposure can reveal different mechanisms. A plate may recover its mass after drying while retaining cracked or softened relief features; conversely, a temporary dimensional change may be acceptable if the process includes controlled conditioning. Cleaning durability also matters because an aggressive solvent that removes ink effectively can accelerate plate ageing.

7. What current additive-manufacturing evidence demonstrates

7.1 Stereolithographic flexographic platemaking

The stereolithographic studies by Zheng and co-workers provide direct evidence that additive fabrication can be adapted to flexographic relief-tool production [1,2]. Their importance is methodological rather than as a universal performance benchmark. They treat plate geometry, material formulation and process conditions as coupled variables and show that successful transfer requires optimisation beyond the nominal capability of the printer. Because equipment, resin chemistry and test forms differ from modern VPP systems, their numerical results should not be converted into general minimum feature or screen-frequency claims.

7.2 Material-jetting evidence as a boundary comparison

The 2024 PolyJet study provides a useful cross-technology comparison because it evaluated printed plates through chemical resistance, contact angle and actual flexographic printing [3]. The printed rubber-like plates were capable of transferring lines and solid areas with water-based ink, but raster performance and solvent compatibility remained limiting in that specific material-process combination. The result is not evidence that material jetting is superior or inferior to VPP. It demonstrates the evidentiary standard that VPP plate studies should meet: print the tool, characterise the material, expose it to realistic chemistry and test the transferred image.

7.3 VPP-specific design implications

VPP adds optical and layerwise variables to the plate problem. Mask broadening, cure depth and feature polarity affect the relief; orientation and post-cure affect mechanical response; and layer texture can become part of the ink-transfer surface. Modern VPP compensation techniques can improve geometric fidelity [19], but compensation should be validated independently on the finished plate and again on the transferred print. A corrected CAD model that yields a dimensionally improved plate does not guarantee optimal ink transfer because the contact mechanics and surface state may still differ from the intended printing condition.

Study	Manufacturing / transfer route	Demonstrated contribution	Interpretive limit
Zheng et al. 2019 [1]	SLA flexographic platemaking	Feasibility of additive flexographic relief production.	Process and material are study-specific; not a universal resolution benchmark.
Zheng 2021 [2]	Surface-imaging stereolithography	Analysis of factors affecting SLA-based flexographic platemaking.	Conference-scale evidence; requires modern platform validation.
Izdebska-Podsiadły & Lasecki 2024 [3]	PolyJet flexible plates + flexographic printing	Chemical resistance, contact angle and real printed output compared with conventional plates.	Material jetting, not VPP; one rubber-like material and defined inks/substrates.
Tomašević et al. 2020 [5]	Conventional photopolymer / EPDM flexo plates	Solvent-induced swelling, hardness and surface effects linked to printing.	Not additively manufactured; mechanism remains relevant to cured polymers.
Kesan & Sahinbaskan 2024 [8]	Digitally imaged flexographic plates	Surface micro-patterns alter solid ink laydown and graininess.	Specific plate system and printing conditions.
Gimenez et al. 2022 [10]	Flexographic photopolymer mold -> PDMS μ CP stamp	Grayscale relief used to create contact-printing structures and cell patterns.	Indirect replication route; not direct VPP stamp fabrication.
Choi et al. 2025 [17]	3D-printed microstructured stamp	Configurable printed stamps transferred low-viscosity bioinks.	Biomedical patterning use case; not conventional flexographic duty cycle.
Usama et al. 2025 [18]	2PP hollow microneedle stamp	Directly printed capillary-stamping elements with replenishable ink supply.	Conference presentation and microscale specialised architecture.

Table 2. Representative evidence relevant to digital photopolymer printing plates and stamps.

8. Microcontact printing: lessons for directly printed stamps

8.1 Deformation can redefine the pattern

Microcontact printing provides the clearest demonstration that the unloaded stamp is not the same object as the stamp in contact. Hui et al. developed stability and contact maps for elastomeric stamps and identified vertical collapse, lateral collapse and buckling as geometry-dependent constraints [12]. Sharp et al. then compared theory and experiment and showed how roof collapse, buckling and lateral sticking alter the transferred pattern [11]. These mechanisms are directly relevant when VPP is used to print soft stamps with high-aspect-ratio surface structures.

The design implication is counterintuitive: higher geometric resolution is not always useful if the printed feature is mechanically unstable during contact. A very fine wall or pillar that is accurately fabricated but collapses under the required pressure has lower functional fidelity than a coarser, mechanically stable design. Minimum feature claims for stamps should therefore include the applied load, aspect ratio and material modulus.

8.2 Softness, rigidity and conformal contact

Soft stamps conform to non-planar or rough surfaces but are more vulnerable to deformation. Pla-Roca et al. demonstrated that rigid PMMA stamps can avoid some collapse modes and support high-aspect-ratio protein patterning when uniform pressure is supplied by a nanoimprint apparatus [13]. More recent work uses polymer brushes or modified PDMS chemistries to improve transfer on rough or capillary-active surfaces [14,15]. These studies show that stamp material should be selected together with the target topography and ink chemistry. PDMS is a useful reference platform, not a universal gold standard that every directly printed photopolymer must replace.

8.3 Emerging directly printed stamp architectures

Direct additive manufacture is beginning to broaden the stamp design space. Choi, Kim and Park reported configurable 3D-printed microstructured stamps for patterning low-viscosity bioinks [17]. Usama and co-workers used two-photon polymerisation to produce hollow microneedle arrays for capillary stamping, allowing ink supply through the stamp structure [18], and pre-strained soft elastomeric stamps have been used to reach submicron pattern scales at low cost [21]. These approaches are important because additive manufacturing can introduce functions that are difficult to obtain by simple replication, including internal channels, locally varied feature geometry and integrated holders. The relevant comparison is therefore not only whether a printed photopolymer can imitate a molded PDMS stamp, but whether digital fabrication enables a better-controlled transfer architecture for a defined task.

However, the same novelty increases the validation burden. Internal channels introduce flow resistance and clogging; directly printed photopolymers can have residual extractables or surface chemistry that differs from silicone; and very small structures can be sensitive to post-processing and swelling. Functional novelty should therefore be accompanied by dimensional, mechanical, chemical and transfer measurements rather than presented as a geometry demonstration alone.

9. From successful print to qualified tool

A single successful image demonstrates feasibility, not durability. Qualification requires a sequence of evidence in which each level answers a different question. The first level establishes whether the plate geometry exists. The second tests the mechanical contact state. The third demonstrates transfer under defined ink and substrate conditions. The fourth adds repeated cycling and chemical exposure. The fifth tests application-specific performance, such as barcode readability, conductive continuity or biological pattern fidelity. Skipping levels creates ambiguity about whether a failure originates in the tool, the ink, the substrate or the process.

Evidence level	Measurement	Claim supported	Claim not yet supported
1. Fabrication	Profilometry, microscopy, relief height, feature dimensions, flatness.	Realised plate/stamp geometry under defined post-processing.	Successful ink transfer or durability.
2. Contact mechanics	Hardness/modulus, compression, recovery, feature stability under load.	Mechanical suitability for the tested pressure and geometry.	Ink compatibility or print fidelity.
3. Transfer	Actual ink, defined substrate, pressure, speed, image analysis.	Transfer feasibility and fidelity for one process condition.	Long-term durability or broad ink compatibility.
4. Durability	Repeated cycles, solvent/cleaner exposure, wear and dimensional re-measurement.	Retention of function over the tested duty cycle.	Universal lifetime across presses and chemistries.
5. Application qualification	Barcode, graphic, electrical, biological or other functional endpoint.	Suitability for the validated application configuration.	Regulatory, food-contact or safety status without separate evidence.

Table 3. Evidence hierarchy for claims about digitally manufactured printing plates and stamps.

10. Proposed minimum reporting framework

The minimum reporting set should connect the state of the printed tool to the state of the printing process. Exact proprietary formulation percentages are not required, but the chemistry class and post-processing state must be sufficiently defined to interpret mechanical and chemical behaviour. Similarly, printer model alone is insufficient; exposure, orientation, layer thickness and compensation state determine the realised relief.

Reporting block	Minimum information	Why it matters	Claim boundary
Digital geometry	Relief height; positive/negative features; line/dot dimensions; test-form design.	Defines the intended transfer geometry.	Prevents one feature family from representing all relief.
VPP process	Process subtype; wavelength; layer thickness; orientation; exposure/compensation; build position.	Defines how CAD is converted into the plate.	Separates hardware descriptors from realised tool geometry.
Post-processing	Wash chemistry/time; drying; post-cure spectrum/time/temperature; ageing before test.	Controls conversion, dimensions and surface chemistry.	Avoids comparing different cure states as one material.
Tool mechanics	Hardness plus relevant modulus/compression/recovery; fixture or backing state.	Defines deformation during contact.	Hardness alone is not treated as complete mechanics.
Surface state	Roughness/topography; contact angle or surface-energy method; treatments/coatings.	Defines ink pickup and release interface.	Avoids generic wetting claims without ink context.
Ink / transfer process	Ink chemistry or class; viscosity/rheology; anilox/delivery; speed; pressure; temperature.	Defines the fluid-mechanical transfer condition.	Prevents transfer results from being universalised.
Substrate	Material; coating/porosity; roughness where relevant; conditioning.	Substrate changes spreading and contact.	Keeps plate and substrate contributions distinct.
Output metrology	Line/dot error; density/uniformity; edge quality; functional metric; n and statistics.	Measures the actual purpose of the tool.	A photograph alone is not a quantitative print claim.
Durability	Cycle count; cleaning/solvent exposure; dimensional and surface re-measurement; failure criterion.	Defines retention of function.	Avoids converting short trials into lifetime claims.

Table 4. Minimum reporting set for VPP printing-plate and stamp studies.

11. Critical boundaries for common claims

11.1 “High printer resolution means a high-resolution printing plate”

This statement is incomplete. Printer addressability is only one contributor to relief geometry, and relief geometry is only one contributor to transferred-image fidelity. Exposure, cure broadening, post-cure, feature polarity, mechanical compression, ink rheology and substrate spreading intervene between the digital pixel and the printed line. Resolution claims should therefore specify both the measured plate feature and the transferred feature under defined printing conditions.

11.2 “A softer plate always transfers ink better”

Greater compliance can improve conformity, but it also increases the risk of feature deformation, dot gain and collapse. Microcontact-printing mechanics make this particularly explicit [11,12], while flexographic studies show that impression pressure and substrate properties materially affect line and text reproduction [6]. The optimum mechanical state is therefore determined by feature geometry and target substrate rather than by a universal softness ranking.

11.3 “Chemical resistance means no print change”

A plate can remain macroscopically intact while solvent uptake changes hardness, dimensions or surface energy. Those changes can alter transfer before visible damage appears [5]. Chemical qualification should therefore include functional re-testing after exposure, not only visual inspection or mass retention.

11.4 “Directly printed stamps replace PDMS”

Direct printing can remove molding steps and enable internal or reconfigurable geometries, but PDMS and related elastomers provide a well-studied combination of conformity, permeability and surface chemistry. Printed photopolymers may offer different advantages and different liabilities. The evidence supports application-specific alternatives, not a universal replacement statement. The appropriate comparison is matched geometry, ink, substrate, load, transfer fidelity and reuse history.

12. Research priorities

Three gaps are particularly important. First, VPP-specific flexographic studies need matched comparisons against established plate systems using the same test form, ink, substrate, pressure and image-analysis method. The existing direct evidence is promising but too sparse for general performance envelopes. Second, durability datasets should combine repeated printing with realistic cleaning chemistry and re-measure both the relief and the transferred output. This would distinguish mechanical fatigue from chemical swelling and surface ageing. Third, directly printed microcontact stamps need systematic maps linking feature aspect ratio, local modulus, applied pressure and transfer fidelity. The classical PDMS stability maps provide a strong conceptual starting point, but modern VPP elastomers and multi-material architectures can occupy different mechanical regimes.

A fourth opportunity is deliberate surface engineering. Flexographic micro-pattern studies demonstrate that surface texture can improve specific ink-transfer outcomes [8], while microcontact studies show that polymer brushes and surface chemistry can suppress smearing or improve transfer on rough targets [14,15]. VPP can potentially encode geometry and surface texture in the same digital workflow. The research challenge is to demonstrate that such structures survive printing, post-processing, mounting and repeated transfer and to separate intentional texture from pixel or layer artefacts.

3Dresyns implementation examples

The 3Dresyns printing-plate portfolio spans a deliberately broad compliance range and therefore provides practical examples of the material-selection variables discussed in this review. Shore hardness and product positioning are useful screening descriptors, but they do not establish print quality, ink transfer, swelling resistance or service life without the application-specific tests described above.

3Dresyn PP FA30. An ultra-soft elastomeric printing-plate photopolymer with Shore A30 positioning, very low modulus and high flexibility. It illustrates the high-compliance end of the plate/stamp design space. [M1]

3Dresyn PP FA50. A flexible elastomeric printing-plate photopolymer with Shore A50 positioning, combining compliance and elastic recovery for repeated deformation. [M2]

NextGen 3Dresyn TFA70. Manufacturer documentation positions this as a tough, foldable Shore A70 photopolymer. It represents a firmer compliant route, but recovery and printing-plate durability still require application-specific measurement [M3].

3Dresyn PP TD90. An ultra-rigid tough printing-plate photopolymer with Shore D90 positioning for high-precision plates and structured surfaces requiring greater dimensional stability under load. It illustrates the rigid end of the portfolio rather than a universal optimum for transfer fidelity. [M4]

Source basis: current 3Dresyns product and Technical Data Sheet documentation, August 2026. These commercial examples are included to connect the review framework to implementation and are not substitutes for independent application-specific validation.

13. Conclusions

- Digital manufacture of a relief plate is only the first stage of qualification. The functional output is the material transferred by the plate under defined mechanical and chemical conditions.
- Plate geometry and printed-image fidelity are different measurands. Relief dimensions should be measured before interpreting line, dot, text or functional-pattern output.
- Mechanical compliance is application-specific. Hardness is useful, but modulus, recovery, creep and feature stability under load determine whether fine relief remains functional.
- Surface free energy, roughness, ink rheology and substrate properties form a coupled transfer system. No plate can be described as universally high-transfer independently of the ink and substrate.
- Chemical durability must include swelling, property changes and functional re-testing after exposure to inks and cleaners, not only visual survival.
- SLA and other additive studies establish feasibility for digital flexographic platemaking, while material-jetting and microcontact studies provide complementary evidence on chemical resistance and stamp mechanics. These routes should inform VPP qualification without being conflated.
- Microcontact printing shows that stamp deformation can redefine the transferred pattern through roof collapse, buckling, lateral sticking and adhesion. Directly printed soft stamps therefore require load-dependent geometric validation.

- A minimum reporting framework linking VPP process, post-processing, tool mechanics, surface state, ink, substrate, output metrology and durability would make claims about additively manufactured printing tools more comparable and defensible.

Limitations

This review is a methodological synthesis rather than a systematic review with a preregistered search protocol. Direct peer-reviewed evidence for VPP flexographic plates remains limited, so several design principles are drawn from conventional flexographic photopolymer studies, material-jetting plate studies and microcontact-printing mechanics. Those adjacent bodies of evidence are used to define mechanisms and validation requirements, not to claim direct equivalence between processes. The proposed framework has not yet been tested in a dedicated interlaboratory plate-printing study.

Author contributions

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

Competing interests

The author is affiliated with 3Dresyns by Resyner Technologies S.L. The review discusses the field at a materials-engineering and printing-process level and does not disclose proprietary formulation composition. Commercial materials are not treated as independently validated unless supported by cited public evidence.

Data availability

No new experimental dataset was generated for this review. Quantitative examples and mechanistic conclusions are attributed to the cited published studies.

Company information

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