

# Coating and Encapsulation of Reactive Photopolymer Substrates

*Surface Cure State, Residual-Species Migration, Adhesion and Barrier Qualification*

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## Statement of significance

A printed photopolymer is not necessarily an inert substrate when a coating or encapsulant is applied. Surface conversion, mobile residual species and continuing dimensional change may each alter the interface, yet the controlled literature does not establish their coupled effect on adhesion and barrier performance in the same specimens. This review defines that evidence gap and a minimum experiment capable of closing it without converting adjacent findings into compatibility rules.

## Abstract

Coating a vat-photopolymerised part joins two evolving material systems. The printed substrate may retain an oxygen-affected surface, extractable or migrating species, and post-cure capacity; the applied film brings its own wetting, cure, transport and stress response. Evidence in the controlled corpus establishes these mechanisms separately, but no reliable direct study was recovered that varies the state of a still-reactive printed substrate and measures adhesion, migration or barrier response, and dimensional or stress evolution together. One candidate claiming relevant coating results [6] was screened but was not used as controlling evidence because its reported thermal values and method description could not be reconciled during the source assessment. ER-168 therefore presents an evidence-gap review. It specifies the state variables, causal couplings and minimum paired measurements needed to close the gap. It supplies no universal conversion threshold, waiting time, surface treatment, primer, adhesion value, coating thickness, residual-species limit or compatibility conclusion.

**Keywords:** vat photopolymerisation; coating; encapsulation; adhesion; oxygen inhibition; extractables; migration; post-cure shrinkage; barrier qualification; evidence gap

## 1. Scope and ownership

ER-168 asks how four states are coupled when a coating or encapsulant is applied to a completed but still chemically active SLA, DLP or LCD photopolymer substrate: surface cure state, mobile residual species, continuing post-cure shrinkage, and coating adhesion or barrier response. It also asks what evidence would demonstrate each coupling.

ER-079 retains metallisation and electroforming. ER-054 retains bulk permeability of printed parts, ER-097 wettability fundamentals, ER-088 surface topography, and ER-027 conversion metrology as a subject in its own right. Generic coating behaviour on inert wood, metal or conventional polymer cannot establish behaviour on a reactive printed photopolymer.

## 2. The interface has a history

The relevant substrate is not defined by resin trade name alone. Its interface carries formulation, delivered exposure, atmosphere, layer history, washing, drying, post-cure, elapsed time, storage and handling. Two parts made from the same nominal resin may therefore present different surface conversion, mobile-species populations and residual stress when coated.

The coating has a parallel history: composition, mixed state, pot life, application method, film build, cure conditions and conditioning. Qualification must preserve both histories. A statement that a coating “adheres to the resin” collapses the two state chains and is not an adequate evidence claim.

### 3. Coupling one: surface cure state and adhesion

Oxygen can suppress free-radical polymerisation near an exposed surface, with an effect governed by oxygen transport and replenishment as well as the initiating and reactive system [1,2]. The resulting surface need not share the conversion or network state of the interior. A coating can wet such a surface while still encountering a mechanically weak, compositionally mobile or incompletely developed boundary.

Adhesion measured after one arbitrary conditioning route cannot separate chemical bonding, mechanical interlocking, cohesive failure in the substrate skin and cohesive failure in the coating. A coupled study therefore needs position-resolved surface-state measurement made independently of the coating and a declared failure-locus determination after adhesion testing.

### 4. Coupling two: mobile residuals and transport

Printed photopolymers can release unreacted or transformed constituents after printing; washing and post-curing change but do not automatically eliminate this question [3,4]. When a film is added, a detected compound may originate in the substrate, the coating, or an interaction between them. Total mass loss alone cannot assign origin.

Barrier performance must therefore be paired with chemical attribution. The analytical design should distinguish substrate-derived species from coating-derived species and include the corresponding uncoated and coating-only controls. ER-168 does not infer that an applied coating reduces migration, increases it, or leaves it unchanged.

### 5. Coupling three: post-cure evolution beneath a film

Reaction and network evolution can continue after the printed geometry first becomes self-supporting. Additional cure may change conversion, modulus, dimensions and stress [5]. If a film has already formed, substrate shrinkage and coating shrinkage can load their interface differently from a coating placed on a fully conditioned substrate.

The scientific question is not whether post-curing is generally beneficial. It is whether the time-dependent substrate change beneath the specified film creates measurable interfacial stress, curvature, cracking, loss of adhesion or transport change. Those outcomes must be measured rather than inferred from a cure schedule.

### 6. Coupling four: barrier response depends on the coupled system

A low-permeability film tested by itself does not establish barrier performance on a reactive, rough or evolving substrate. For the assembled system, possible response paths include pinholes, edges, local delamination, swelling and interdiffusion. This enumeration is an inference that frames the coupled experiment, not a universal ranking of barrier mechanisms; ER-054 retains permeability and defects as transport pathways. Conversely, a high peel value does not prove low migration. Adhesion and barrier measurements answer different questions and neither substitutes for the other.

### 7. The direct-claim candidate was rejected

The screen examined Abdalwahab et al., *Photopolymer resin formulation and surface modification for enhanced coating applications in SLA-Printed devices* [6], because it appeared to address a directly relevant coating configuration. It was not silently omitted. The source was not used as controlling evidence because its reported thermal values and method description could not be reconciled during the source assessment. This is a reliability decision about that source, not proof that its subject has no effect and not a general judgement about all results in the paper.

## 8. Minimum experiment required to close the gap

A minimum coupled study should use one fully declared resin, one printer and one coating chemistry. The substrate state should be deliberately varied across at least three declared levels of post-cure and hold time. Surface conversion should be measured position-resolved and independently of the coating. The coating should then be applied after a declared washing-to-coating interval.

On the same specimen families and across the same substrate-state ladder, the study should measure: (1) adhesion by a declared method, including failure locus; (2) migration or barrier response by a method that distinguishes substrate-derived from coating-derived species; and (3) dimensional or stress evolution beneath the film over a declared period. Uncoated substrate and coating-only controls are necessary for attribution. Replication and specimen allocation should be defined before testing.

The design is intentionally coupled. Separate experiments that each use different resin states reproduce the present gap rather than close it.

## 9. Interpretation discipline

A result is bounded to the tested resin, printer, exposure, surface preparation, coating, geometry and conditioning. Improvement in one response does not license improvement in the others. Failure should likewise be assigned to the observed locus and state rather than to a generic incompatibility between material families.

The study should preserve unresolved outcomes. If two substrate histories produce indistinguishable measured responses, the correct finding is that the method did not discriminate them under the tested conditions.

## 10. What cannot presently be specified

The available evidence does not support a universal surface-conversion threshold, waiting or post-cure time, cleaning or activation procedure, primer, coating chemistry, adhesion value, barrier thickness, residual-monomer or photoinitiator-derived-species limit, shrinkage limit or compatibility rule. Manufacturer application instructions may support implementation in their declared system but are not promoted here to independent primary evidence.

## 11. Conclusions

Surface cure state [1,2], residual-species release [3,4], and post-cure evolution [5] are established separately. ER-054 retains bulk permeability and defects as transport pathways. Their junction in a coated still-reactive VPP substrate remains unclosed, and ER-168 treats the assembled barrier response as an inference to be tested rather than an established universal mechanism. The defensible response is a coupled state-resolved experiment, not a transferred parameter table. Surface conversion, migration or barrier response, adhesion failure locus and time-dependent dimensional or stress change must be measured on the same substrate-state ladder. Until then, coating qualification remains formulation-, process- and geometry-specific.

## Related Engineering Review boundaries

ER-168 owns the coupling of reactive substrate state to coating or encapsulant response. ER-027 retains conversion metrology; ER-031 post-cure shrinkage and residual stress; ER-054 bulk permeability; ER-079 metallisation and electroforming; ER-086 extractables method design; ER-088 surface topography; and ER-097 wettability fundamentals.

## References

1. Pynaert R, Buguet J, Croutxé-Barghorn C, Moireau P, Allonas X. Effect of reactive oxygen species on the kinetics of free radical photopolymerization. *Polymer Chemistry*. 2013;4:2475–2479. <https://doi.org/10.1039/C3PY21163K>

2. O'Brien AK, Cramer NB, Bowman CN. Oxygen inhibition in thiol-acrylate photopolymerizations. *Journal of Polymer Science Part A: Polymer Chemistry*. 2006;44:2007–2014. <https://doi.org/10.1002/pola.21304>
3. Oskui SM, Diamante G, Liao C, et al. Assessing and reducing the toxicity of 3D-printed parts. *Environmental Science & Technology Letters*. 2016;3:1–6. <https://doi.org/10.1021/acs.estlett.5b00249>
4. Macdonald NP, Zhu F, Hall CJ, et al. Assessment of biocompatibility of 3D printed photopolymers using zebrafish embryo toxicity assays. *Lab on a Chip*. 2016;16:291–297. <https://doi.org/10.1039/C5LC01374G>
5. Segurola J. Cure Shrinkage, Residual Stress and Warpage in VPP: A Qualification and Minimum-Reporting Note. ER-031. Zenodo. 2026. <https://doi.org/10.5281/zenodo.22048036>
6. Abdalwahab ST, Noor AD, Al-Saedi HFS, Mohammed M, Kadhim NS, Naji NF, Dawood II, Mohammed HA. Photopolymer resin formulation and surface modification for enhanced coating applications in SLA-Printed devices. *Applied Chemical Engineering*. 2025;8(4):ACE-5726. <https://doi.org/10.59429/ace.v8i4.5726>

### Competing interests

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

### Data availability

No new experimental dataset was generated. The source-screen and evidence limitations are stated in the text.

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