

Primer Chemistry for Photocurable Interfaces: Coupling Reactions, Film Thickness, Cure Compatibility and Recoat Windows

A two-sided interphase qualification framework from deposited film state to locus-resolved recoat performance

Juan Seguro

3Dresyns by Resyner Technologies S.L.

© 2026 Juan Seguro. All Rights Reserved.

Correspondence: info@3Dresyns.com · www.3Dresyns.com

ER-224 · Engineering Review · Version 0.2 · 18 September 2026

Abstract

A primer is not qualified by its name, nominal concentration or initial contact angle. It is an interphase whose substrate-facing anchoring, deposited mass and continuity, drying or condensation state, outward-facing functionality and compatibility with the overlying photocure must all be demonstrated. Time between priming and coating is likewise not a universal open time: the surface changes through reaction, adsorption, migration, contamination and physical ageing.

This review defines a state-resolved primer qualification framework. It separates substrate anchoring from coating-facing reactivity; treats thickness, coverage and surface segregation as measured variables; checks whether the primer inhibits, absorbs, consumes or participates in the photocure; and maps recoat performance against both elapsed time and interphase state. Mechanical evidence is interpreted with conversion, chemistry, morphology and failure locus. The evidence supports two-sided verification across silane, polyolefin, coating and polymerisable primer systems. It does not establish a commercial formulation, universal film thickness, drying schedule, recoat window, cure compatibility rule, adhesion threshold or durability claim.

Keywords: primer; photopolymer interface; coupling reaction; film thickness; cure compatibility; recoat window; intercoat adhesion; failure locus

1. Significance and scope

Primers are used to connect materials whose surface chemistry and cure behaviour are otherwise incompatible. Their apparent simplicity hides at least two interfaces and a finite film. A primer may attach strongly to the substrate but present an inert or contaminated outer surface. It may carry polymerisable groups but remain weakly anchored. It may improve initial wetting while inhibiting the overlying radical or cationic cure. It may also change during storage or after deposition.

ER-224 addresses the primer as an independently qualified interphase for photocurable coatings and bondlines. It does not prescribe a formulation or supplier-specific application process. Its central question is whether substrate anchoring, deposited film state, coating-facing chemistry, cure compatibility, elapsed-time state and locus-resolved mechanics jointly support the intended interface.

1.1 Corpus boundary

ER-053 retains generic substrate and build-platform adhesion. ER-165 and ER-186 retain structural joint design and general light-curable adhesive or bondline formulation. ER-168 retains coatings on reactive printed photopolymers where residual-species migration and barrier performance are central. ER-190 retains intentionally undercured pressure-sensitive layers, ER-195 retains generic cure-shrinkage stress, and ER-208 retains general surface-chemistry measurement. ER-221, ER-222 and ER-223 retain metal-, polymer- and glass/ceramic-specific adhesion qualification. ER-225 retains plasma, corona and UV-ozone activation, while ER-230 retains repair and recoat qualification on aged photopolymers. ER-224 is restricted to primer coupling, deposited film state, photocure compatibility and state-resolved recoat performance across substrate families.

2. Define the primer as a deposited material state

A primer record should identify chemical class, functional groups, carrier, solids basis, mixing and ageing history where relevant, application method, deposited mass or thickness, drying or reaction conditions, time to coating and storage environment. A nominal solution concentration does not determine the retained surface film. Volatile loss, adsorption, reaction, drainage and lateral nonuniformity can produce different states from the same bath.

Qualification therefore begins after deposition. Pan and co-workers linked aminosilane composition with hydrolysis or condensation, primer-film morphology, thickness and adhesion in a silicone thermal-protection system [2]. The chemistry and timings are adjacent to photocurable use, but the study demonstrates that the deposited film, not the mixing label, is the relevant object.

3. Verify substrate-facing anchoring

Substrate anchoring can involve adsorption, acid–base interaction, ionic association, coordination, hydrogen bonding, covalent coupling or mechanical retention. The proposed route should be supported by a measurement and an appropriate control. A contact-angle change or the presence of a functional group in the bulk primer does not prove attachment.

Morgese and co-workers designed a polyolefin primer whose substrate anchoring and adhesive-facing function could be examined separately, together with mechanical response, failure locus and storage durability [1]. That two-sided logic is transferable even though the PFPA chemistry and PE/PP results are system-specific. Useful controls include the unprimed substrate, a primer lacking the anchoring motif and a washed or extracted primed surface.

4. Verify coating-facing functionality

The primer surface presented to the coating may differ from its bulk composition. Reactive groups can orient, become buried, hydrolyse, oxidise, react during drying or be masked by low-energy species. The overlying liquid may dissolve or swell the film before cure. A substrate-bound primer is not qualified until its outward-facing state supports the declared coating chemistry.

Sinaweil and co-workers investigated primers combining an adhesion motif with a polymerisable group in light-cured thiol-ene bone-adhesive systems [8]. This adjacent biomedical work supports the principle that anchoring and polymerisable functionality can be designed and tested independently. It does not authorise a biomedical recommendation or transfer its primer chemistry.

5. Measure thickness, coverage and continuity

Primer thickness can affect coverage, defect bridging, internal cohesion, solvent retention, light absorption and stress. Too little material may leave discontinuities; excess material may form a weak cohesive layer or change the cure at the overcoat interface. Because deposition is rarely uniform, a single mean value may conceal uncovered or over-thick regions.

Report the measurement method, spatial sampling and whether the value refers to wet application, dry mass or final thickness. Pan and co-workers associated morphology and thickness with composition-dependent interfacial response [2]. Šolić and co-workers varied dry film thickness and conditioning in an anticorrosive primer system before pull-off assessment [5]. Neither study establishes a universal optimum; together they show why thickness and conditioning must travel with every adhesion result.

6. Establish compatibility with the photocure

A primer can inhibit, absorb, scatter, quench, catalyse or participate in cure. Amines, acids, moisture, oxygen, pigments and residual solvents may alter initiation or propagation. A primer that remains attached but suppresses conversion at the coating-facing interface has not passed the interphase gate.

Report the primer state, overlying formulation, spectrum, irradiance, exposure, atmosphere, temperature, film thickness and post-cure. Measure conversion or another validated network endpoint near the interface when a mechanism is claimed. Zhang and co-workers showed coupled effects of photoinitiator concentration and film thickness on conversion-related and surface properties in a UV-curable coating over a primed wood-based substrate [7]. Their finishing system is adjacent evidence, not a general primer rule.

7. Detect surface segregation and weak boundary layers

Low-surface-energy components, additives and incompletely reacted species can enrich the primer or undercoat surface. The composition governing intercoat adhesion may therefore differ from the bulk. Cleaning or abrasion may remove a weak layer but can also alter chemistry and topography, so the before-and-after state must be measured.

Hinder and co-workers used X-ray photoelectron spectroscopy to attribute intercoat failure in a multilayer organic coating to surface and cure-state effects [3]. Haartsen and co-workers mapped additive-related surface and bulk differences and nanoscale adhesive work in UV-cured thin films [6]. These studies support surface-specific analysis, while also showing that nanoscale adhesive work does not equal macroscopic peel, pull-off or durable joint performance.

8. Treat the recoat window as a state window

Elapsed time is a convenient coordinate but not the mechanism. During the interval between primer application and coating, solvent evaporates, condensation continues, reactive groups are consumed, contaminants adsorb, additives migrate and the film physically ages. Temperature, humidity, atmosphere and packaging can alter all of these. The same elapsed time can therefore represent different interphase states.

Tsubota and co-workers combined controlled recoat intervals with surface analysis in an amino-alkyd coating system [4]. Hinder and co-workers linked undercoat surface chemistry and cure state to intercoat failure [3]. Historical thermal-cure systems do not set a photocurable recoat interval, but they support mapping time to measured chemistry rather than treating time alone as an acceptance criterion.

9. Separate primer storage from the applied-film interval

Shelf history before application and elapsed time after deposition are different controls. A primer solution may change through hydrolysis, association or contamination. An applied film may continue drying, condensing or reacting. Both histories should be declared, and neither can be inferred from the other.

Morgese and co-workers examined durability and storage of a primed polyolefin state [1]. Pan and co-workers measured time-dependent chemical and morphological aspects of a silane primer [2]. These studies support separate solution-age and film-age records but do not establish a universal shelf life or open time.

10. Preserve the meaning of each mechanical method

Cross-cut, pull-off, lap shear, peel, probe or atomic-force measurements load different volumes and failure processes. A higher value from one method cannot be substituted for another. Substrate deformation, fixture compliance, coating thickness and edge geometry may govern the response.

Šolić and co-workers used pull-off response after controlled film preparation and exposure [5]. Haartsen and co-workers measured nanoscale adhesive work [6]. Zhang and co-workers reported coating-performance and cross-cut observations in a UV-cured system [7]. These are non-equivalent measurands. Each result must retain its scale, geometry, rate, environment and failure locus.

11. Resolve the failure locus

Post-test evidence should distinguish separation at the substrate–primer boundary, cohesive failure within the primer, separation at the primer–photopolymer boundary, cohesive failure in the photocured material, substrate failure and fixture-related failure. Mixed failure should be quantified or bounded. Thin residue may require spectroscopy, microscopy or elemental mapping.

A primer that shifts failure from the substrate boundary into a strong cohesive region represents a different outcome from one that increases the measured load without changing locus. Morgese and co-workers paired mechanical results with locus information [1], and Hinder and co-workers used surface analysis to identify an intercoat weak boundary [3]. Mechanistic claims require this pairing.

12. Build a non-compensatory qualification matrix

Gate	Required evidence	Unsupported shortcut prevented
Substrate anchoring	Surface-specific chemistry and resistant attachment	Treating contact angle or primer name as proof
Deposited film	Coverage, thickness, continuity and drying/condensation state	Treating solution concentration as film state
Coating-facing function	Accessible reactive groups and compatible liquid contact	Assuming bulk functionality remains at the surface
Photocure	Near-interface conversion or justified network endpoint	Accepting primer adhesion while cure is inhibited
Recoat and durability	Measured state versus delay, conditioning and locus-resolved mechanics	Declaring a universal open time from initial strength

The gates are independent. Strong substrate anchoring cannot compensate for cure inhibition, and favourable initial pull-off cannot waive film-state or ageing controls.

13. Minimum reporting set

Report substrate identity and state; primer chemical class and functional motifs; carrier and solids basis; solution mixing and storage history; application method; deposited mass, thickness, coverage and continuity; drying, condensation or reaction conditions; time and environment before coating; surface composition and topography; overlying photocurable formulation; liquid-contact interval; source spectrum, irradiance, exposure, atmosphere, temperature and post-cure; conversion or network endpoint where relevant; mechanical method, geometry, rate, replicates and uncertainty; failure locus; conditioning history; and application-specific acceptance criteria.

Every numerical result must preserve primer film state, substrate, overcoat chemistry, delay, cure, geometry and locus. No thickness, time or strength value is transferable when those qualifiers change.

14. Knowledge boundary

The evidence establishes that substrate anchoring and coating-facing function require separate verification [1,8]; that primer morphology, thickness and conditioning are state variables [2,5]; that surface segregation and cure state can govern intercoat failure [3,6]; that elapsed time must be interpreted through evolving surface chemistry [3,4]; and that photocure response depends on film and initiation conditions [7]. These propositions are bounded against substrate-family adhesion, general adhesive formulation, activation methods and aged-photopolymer repair owned by neighbouring ERs.

15. Limitations

The sources span polyolefin primers, silane thermal-protection primers, thermally cured multilayer coatings, historical alkyd recoating, anticorrosive primers, UV-cured thin films, wood finishing and experimental light-cured bone adhesives. All eight sources were inspected at full-text or repository-full depth. Their substrates, chemistries, film scales and test methods are heterogeneous. No common round-robin primer, overcoat, recoat protocol or durability model is established. The corpus does not establish a commercial primer formulation, universal thickness, coverage, drying state, recoat window, cure-compatibility rule, adhesion threshold, acceleration factor or service life.

16. Conclusions

A primer for a photocurable interface must be qualified as a finite, evolving, two-sided interphase. Substrate anchoring, deposited film state and coating-facing functionality require separate evidence. Thickness, coverage and surface segregation must be measured rather than inferred from solution concentration. Primer chemistry can alter near-interface photocure, so attachment alone is insufficient. Recoat intervals are state windows controlled by chemistry, environment and ageing, not universal elapsed times. Mechanical methods are non-equivalent and require failure-locus evidence. The resulting qualification is specific to the substrate, primer, overcoat, cure, delay, environment and test and provides no universal recipe or threshold.

References

- 1 Morgese G, Siegmann K, Winkler M. Specific, nondestructive, and durable adhesion primer for polyolefins. *Journal of Coatings Technology and Research*. 2024;21:1921–1930. <https://doi.org/10.1007/s11998-024-00938-z>
- 2 Pan T, Su Z, Yan Y, Zhu X, Qi F, Wu L. The synergistic effects of aminosilane coupling agent on the adhesion performance of silane primer for silicone resin thermal protection coating. *Polymers*. 2023;15:2361. <https://doi.org/10.3390/polym15102361>
- 3 Hinder SJ, Lowe C, Maxted JT, Perruchot C, Watts JF. Intercoat adhesion failure in a multilayer organic coating system: an X-ray photoelectron spectroscopy study. *Progress in Organic Coatings*. 2005;54:20–27. <https://doi.org/10.1016/j.porgcoat.2005.03.012>
- 4 Tsubota M, Arase M, Tomita H, Motoyama K. Intercoat adhesion of amino-alkyd resin paint. *Journal of the Japan Society of Colour Material*. 1985;58:675–682. <https://doi.org/10.4011/shikizai1937.58.675>
- 5 Šolić T, Marić D, Novoselović D, Samardžić I. Optimization of parameters for protection of materials by primer application. *Coatings*. 2022;12:413. <https://doi.org/10.3390/coatings12030413>
- 6 Haartsen S, Wille I, Jasper H, Zandvliet HJW, Aprojanz J, Bampoulis P. Tailoring the adhesion properties of thin polymeric films using additives: an AFM study. *Nanoscale Advances*. 2026;8:1273–1280. <https://doi.org/10.1039/D5NA00956A>
- 7 Zhang H, Feng X, Wu Y, Wu Z. Effect of photoinitiator concentration and film thickness on the properties of UV-curable self-matting coating for wood-based panels. *Forests*. 2023;14:1189. <https://doi.org/10.3390/f14061189>
- 8 Sinaweil L, Steinbauer P, Kojic D, Slezak P, Redl H, Baudis S. Ternary thiol–ene systems as high-performance bone adhesives for potential clinical use. *RSC Applied Polymers*. 2025;3:137–145. <https://doi.org/10.1039/D4LP00094C>

Copyright · © 2026 Juan Seguro. All Rights Reserved.