

Ageing Evidence for Printed Photopolymers: Specimen State, Exposure History, and Requirements for Longitudinal Recordkeeping

Lifecycle assurance and responsible innovation

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Abstract

Ageing evidence for printed photopolymers is only interpretable when the material state and exposure history are explicit. The available evidence for this review consists of a polymer-additive-manufacturing degradation review that includes stereolithography within a wider process scope and a general polymer-degradation review spanning conventional processing, additive manufacturing and mechanical recycling [1,2]. Neither source establishes a longitudinal photopolymer database. This review therefore treats specimen state and exposure history as record fields that a future longitudinal evidence system must preserve, while censoring and reuse governance remain named requirements rather than established methods. The result is a minimum record architecture for ageing evidence without claiming that the present literature already supplies the required database. A proposed longitudinal event model preserves experimental units, exposure intervals, missing observations and censoring without assigning invented outcomes.

Keywords: ageing evidence · printed photopolymers · specimen state · exposure history · longitudinal recordkeeping · censoring · reuse governance

1. Scope and ownership

ER-481 concerns the structure of ageing evidence records for printed photopolymers. It does not claim that a longitudinal ageing database already exists. It also does not assign a method for censoring or reuse governance. Those remain requirements that a future database must define explicitly.

The evidence is not uniformly photopolymer-specific. Source [1] is a review of polymer components produced by additive manufacturing and includes stereolithography within that wider polymer-AM scope. Source [2] addresses polymer degradation across conventional processing, additive manufacturing and recycling and is not presented here as photopolymer-specific evidence.

2. Evidence base and transfer limit

Source [1] supports an ageing and degradation framework for polymer AM in which stereolithography is one covered route [1]. That coverage is useful for placing printed photopolymers inside a wider ageing problem, but it does not make every conclusion of a polymer-AM review specific to vat-photopolymerised materials. Source [2] provides adjacent mechanistic context for degradation and the relevance of processing history [2]. It is used here only at that general level.

3. The record begins with specimen state

An ageing result is incomplete if the tested state is not identifiable. A longitudinal record should preserve material identity, manufacturing route, relevant processing history, post-processing state, conditioning state, geometry or specimen class, and the time point at which the observation was made. The purpose is not to prescribe a universal schema but to prevent observations from different states being merged as if they were equivalent.

4. Exposure history is part of the evidence object

Ageing is inseparable from exposure history. A useful record should therefore retain the declared environment, duration or elapsed time, cycling or interruption history where applicable, and the sequence of relevant processing or service exposures. Source [2] is especially relevant to the general principle that degradation pathways depend on processing and material history, but this review does not transfer that general literature into a photopolymer-specific rate law [2].

5. Longitudinal linkage

A longitudinal system needs a stable way to connect repeated observations to the same specimen, lot, build, product state or defined cohort. Without that linkage, a time series can become a sequence of unrelated measurements. The minimum requirement is therefore a persistent record identity and a traceable relation between each observation and the state from which it was obtained.

6. Censoring is a named requirement, not a solved method

A long-duration evidence system will encounter incomplete follow-up, specimens removed from study, lost records and observations that end before failure. This review names censoring as a required field of governance but does not prescribe a statistical treatment, because the two controlled sources do not establish one for photopolymer ageing databases.

7. Reuse governance is also a named requirement

Reusing ageing observations across qualification questions can be valuable, but reuse can silently erase the state and exposure boundaries that make the evidence interpretable. A future database should therefore record whether an observation is original, reused or re-analysed, together with the state and exposure conditions attached to it. This is a recordkeeping requirement, not a claim that a validated reuse-governance method is established by the present evidence.

8. Minimum longitudinal record

At minimum, an ageing record should identify the material or material class, manufacturing route, specimen or product state, relevant processing history, exposure history, observation time, measured endpoint, measurement method, record identity, and whether the observation is censored or reused. Fields that are unknown should be marked as unknown rather than reconstructed by assumption.

9. Relationship to adjacent ageing reviews

ER-481 owns longitudinal record structure. It does not replace dedicated reviews of particular ageing environments or mechanisms. Exposure-specific articles can supply observations to such a record, but the database layer remains distinct from the science of any one degradation mechanism.

10. A longitudinal record that preserves the experimental unit

The proposed database separates a material lot, a manufactured build, a specimen and a measurement event. A specimen can have many observations, but those observations do not create additional independent specimens. A destructive test ends the measurement sequence for that specimen; another specimen tested later is part of a cohort comparison rather than a repeated measurement of the same physical object. The data model should make that distinction explicit.

Each observation would retain the manufacturing state, exposure interval, actual observation time, method, result and reason for any missing result. Planned time and actual time should be separate fields. A specimen measured late has a different exposure history from one measured on schedule. If the exposure changed, the history should be stored as intervals rather than replaced with a single cumulative label.

For a hypothetical example, ten specimens enter a programme and two fail before the final scheduled test. Reporting the mean property of the eight remaining specimens without the two earlier events describes survivors only. The apparent retention can therefore differ from the behaviour of the initial cohort. The proper record preserves all ten specimens and their different observation states.

11. Censoring is an observation condition, not an assumed outcome

A specimen still functioning when observation ends has a different record from one known to have failed between two inspections, and both differ from one lost for an unrelated reason. The proposed schema would preserve those conditions without assigning an invented failure time. A statistical method could then be selected according to the endpoint and the observation process; the database should not force every record into an exact-time format.

Data reuse also requires compatibility of the property being measured. A flexural result, a dimensional result and a functional failure event should remain separate endpoints even if they share a specimen history. A later analyst should be able to reconstruct the population selected for an analysis and identify which exclusions changed it.

A useful validation of the database would test whether a known change in specimen identity, exposure history or censoring status changes the corresponding analysis input. Merely storing more fields does not establish that the fields preserve the intended evidence. This architecture supports future longitudinal studies without claiming that an accelerated exposure can be converted into service life or that a universal degradation model has been established.

Additional critical synthesis: evidence, applicability and qualification: Ageing mechanisms require specimen-state resolution:

Ageing should not be recorded solely as time since manufacture. Photopolymer properties may respond to continuing reactions, uptake and loss of environmental species, thermal history, light exposure and physical relaxation. Distinguishing these processes requires explicit specimen state at the start of each experiment: geometry, cure protocol, solvent history, dry or conditioned mass, storage interval and testing environment. A tensile result measured immediately after post-curing and another measured after wet storage are not directly comparable without that history. Correlations should be evaluated for mechanistic plausibility rather than treated as universal accelerated-ageing laws.

Longitudinal design and censored observations: A credible ageing study uses more than one endpoint. Initial, intermediate and final observations can distinguish monotonic drift, transient conditioning and abrupt failure. Sacrificial specimens avoid repeatedly damaging one article, while repeated non-destructive measurements can characterise within-part evolution. Lost specimens and parts that fail before a planned endpoint must be explicitly reported because excluding them creates survivorship bias. Measurements should include uncertainty and acceptance thresholds specified before exposure begins. A percentage of retained strength has meaning only relative to a defined original specimen state and method.

Limits of accelerated exposure: Elevated temperature or aggressive moisture can speed some processes while activating pathways not dominant in intended service. An acceleration factor is not justified merely by observing faster failure. Transfer to real service requires evidence that the degradation mode and relevant boundary conditions remain comparable. In the absence of such evidence, accelerated tests are useful screening tools rather than reliable forecasts of lifetime. The review therefore calls for complementary field histories and side-by-side comparisons with representative use conditions.

Critical evidence synthesis: Longitudinal ageing evidence: separating mechanisms, exposure and outcome: Photopolymer ageing is not a single degradation mechanism. A change in tensile response after aqueous storage may be consistent with plasticisation, extraction, hydrolysis, or a changing post-cure state; the measured response alone does not discriminate between these mechanisms. A review should therefore link each ageing claim to independent observations such as mass change, extraction analysis, conversion or network-state measurements, and fracture morphology. Where such corroboration is absent, the defensible result is a conditional performance observation, not a mechanistic attribution.

Longitudinal datasets should distinguish a repeated measurement on the same specimen from destructive tests on different specimens at different exposure times. Geometry, surface finish, cure history, cleaning history and specimen age at baseline are potential confounders. Recording failures that prevent later measurements is particularly important: analysing only surviving specimens can make apparent retention of performance look stronger than it actually is. Any accelerated ageing interpretation needs an explicit justification for the assumed acceleration mechanism and should not silently equate elevated-temperature behaviour with field lifetime.

12. Designing a longitudinal ageing dataset

Ageing evidence is interpretable only when the material state at the start of exposure is known. Resin formulation, printing orientation, thickness, light exposure, washing, post-curing and conditioning should be versioned independently from the later environment. Nominal resin identity alone is insufficient to reconstruct the starting network state. For specimens exposed in service, transport and storage before testing can introduce additional uncontrolled history.

A longitudinal study should prespecify the sampling unit, repeated-measure schedule, exposure environment, destructive or non-destructive endpoints, and the definition of a failed or censored observation. Destructive tensile tests on different coupons are not repeated measurements of the same physical specimen, even when all coupons originate from one batch. Analysis must represent this clustering rather than artificially inflating independent sample size.

Quantitative ageing comparisons should report the distribution of baseline values and absolute property changes, not merely percentage retention. When an exposure continues after an interim failure, the handling rule must be specified. Missing measurements due to breakage, loss or withdrawal cannot automatically be assumed missing at random. This distinction is especially important if the most degraded specimens disappear from the dataset before the final scheduled test.

A publishable record should expose replicate counts, uncertainty, failure and censoring codes, calibration state and deviations from the original plan. The framework proposed here is a minimum design for future evidence collection, not a claim that existing photopolymer ageing data satisfy it.

13. Limitations

The two sources support polymer-AM ageing/degradation context and general polymer degradation mechanisms, but they do not constitute a longitudinal photopolymer database and do not establish censoring or reuse-governance methods. The article is therefore a bounded recordkeeping framework rather than a database-performance review.

14. Conclusions

The defensible unit of longitudinal ageing evidence is not a property value alone but a value tied to an identifiable specimen state and exposure history. The available literature supports that need at polymer-AM and polymer-degradation level, with stereolithography represented inside the wider AM evidence [1,2]. Censoring and reuse governance remain explicit requirements to be designed and validated rather than methods claimed here.

References

1. Solek C, Crespo-Sanchez J, Fuentes del Toro S, Ayllon J, Frigione M, Camacho AM, Rodriguez-Hernandez J, Rodriguez-Prieto A. Degradation and Long-Term Response Evaluation of Polymeric Components Produced by Additive Manufacturing. *Journal of Manufacturing and Materials Processing*. 2026;10(3):102. <https://doi.org/10.3390/jmmp10030102>.
2. Ceretti DVA, Edeleva M, Cardon L, D'hooge D. Molecular Pathways for Polymer Degradation during Conventional Processing, Additive Manufacturing, and Mechanical Recycling. *Molecules*. 2023;28(5):2344. <https://doi.org/10.3390/molecules28052344>.

Competing interests

The author is Founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L. The company develops and supplies photoresins and related process materials. No proprietary formulation, manufacturing sequence, process window or comparative product recommendation is disclosed.

Data availability

No new experimental dataset was generated.

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