

Photopolymer Additive Manufacturing for Cultural-Heritage Replication and Conservation: Fidelity, Reversibility and Ageing

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Abstract

Photopolymer Additive Manufacturing for Cultural-Heritage Replication and Conservation is evaluated as the bounded decision of whether a photopolymer-based replica, mould or intervention is sufficiently faithful, reversible and stable for the declared conservation role. The controlled state comprises digital capture, print geometry, resin/cure state, direct or indirect contact, attachment, environment, light exposure, cleaning and intended intervention lifetime. For ER-290, the three cited sources are used only for the evidence roles stated below and only within their demonstrated scope. ER-290 defines measurements, transfer logic, failure modes and release gates specific to this subject; no universal process window, product recipe or compliance conclusion is inferred.

Keywords: cultural heritage; photopolymer; replication; conservation; reversibility; accelerated ageing; fidelity

1. Significance, scope and ownership

ER-290 owns whether a photopolymer-based replica, mould or intervention is sufficiently faithful, reversible and stable for the declared conservation role. The review is organised around the decision-specific evidence chain and leaves neighbouring ownership intact.

1.1. Corpus boundary

Conservation use imposes a different decision than ordinary service ageing or sacrificial removal. ER-72 retains environmental ageing and ER-09/ER-74 retain removal/disassembly mechanisms. ER-290 is limited to whether replication, moulding or intervention preserves fidelity and reversibility without introducing unacceptable ageing or residue risk to the heritage object.

2. Subject-specific state model and causal chain

For ER-290, causal interpretation begins by freezing digital capture, print geometry, resin/cure state, direct or indirect contact, attachment, environment, light exposure, cleaning and intended intervention lifetime. Fidelity and reversibility are assessed against conservation intent: a geometrically accurate replica can still be unsuitable if ageing, residue or removal creates an unacceptable interaction with the original.

3. Direct evidence and point-of-use source map

Higuera and co-workers directly studied accelerated ageing of liquid-photopolymer 3D-printing resins for cultural-heritage purposes and measured changes including colour, gloss, pH and VOC emissions. Niquet, Sánchez-López and Mas-Barberà demonstrated a reversible 3D-printed conservation prosthesis, while Sterp Moga and co-workers used printed moulds to reduce direct handling during facsimile and reintegration work. Reference [1] is used for accelerated ageing of liquid-photopolymer heritage resins. Reference [2] is used for reversible prosthesis/conservation evidence. Reference [3] is used for 3D-printed mould/facsimile conservation evidence.

4. Measurement architecture

The measurement architecture for ER-290 is built around geometric fidelity, colour/gloss where visible, VOC or contact-compatibility screening, ageing response, attachment/removal damage, documentation of original-vs-replica surfaces and reversibility after the intended interval. Surface, colour, dimensional and reversibility observations are tied to accelerated or natural ageing conditions and to the specific conservation role of the printed object.

5. Qualification and transfer

A conservation application is bridged by matching substrate sensitivity, intended duration, environmental exposure and reversibility method. A result on a stand-alone replica does not automatically qualify direct contact or intervention on an original object.

6. Failure modes and interpretation traps

The central interpretation trap in ER-290 is that visual similarity is called conservation compatibility; accelerated ageing is converted directly to service life; a removable design is called reversible without demonstrating removal and residue/damage state. Fidelity, ageing, reversibility, residue and conservation-role gates keep successful reproduction from being confused with suitability for intervention on heritage material.

7. Non-compensatory release gates

Gate	Minimum evidence	Blocking failure
Source fidelity	Reference object/geometry capture defined	Replica judged by appearance only
Print state	Material/color/finish documented	Generic resin
Surface/colour	Metrology, colour/gloss/texture measured as relevant	Subjective match only
Ageing	Light/thermal/humidity history represented	Fresh replica generalized
Reversibility	Removal method and endpoint verified	Removable assumed harmless
Interaction/residue	Original substrate/contact effects checked	No visible mark called reversible
Conservation role	Replica/mould/intervention purpose explicit	One criterion used for all roles
Documentation	Digital/material/process provenance retained	Intervention cannot be reconstructed

8. Minimum verification experiment

Create a reversible mock-up using the final print/cure/attachment route, document geometry and appearance, expose it to a bounded accelerated or representative environment, measure relevant chemical/visual changes, then remove it and inspect both prosthesis and substrate for residue, staining, deformation or surface damage.

9. Knowledge boundary

Accelerated ageing and reversible conservation interventions are demonstrated in bounded cases, but there is no universal equivalence between accelerated exposure and decades of museum service, nor a single reversibility criterion for all substrates/interventions.

10. Conclusions

ER-290 qualifies photopolymer use in cultural-heritage replication or conservation only when fidelity, ageing, reversibility and interaction with the original object are documented together.

References

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