

Photoresin Storage, Transfer and Dispensing Under Vacuum or Reduced Gravity: Volatility, Wetting and Contamination

Qualification of the uncured feedstock state before light-based manufacturing in space environments

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Abstract

The uncured photoresin is itself a spaceflight material system. Storage and transfer under reduced pressure can change composition through volatile loss, expand dissolved or trapped gases, alter viscosity and wetting, and generate condensable contamination on sensitive spacecraft surfaces. Reduced gravity removes passive drainage and buoyancy-based bubble separation. Recent high-vacuum screening of liquid photopolymers provides direct evidence that the liquid and cured states can have very different outgassing behaviour. This review defines a qualification framework for photoresin storage, transfer, metering, degassing, wetting, contamination control and recovery before cure.

Keywords: photoresin; vacuum; reduced gravity; outgassing; volatility; wetting; dispensing; degassing; contamination; storage

1. Significance and scope

A photoresin can meet terrestrial shelf-life and printability requirements yet be unsuitable for reduced-pressure handling. Vacuum changes gas solubility, volatile loss and bubble size before any exposure step begins [1-3].

ER-450 owns long-duration mission storage and recovery after months or years. This review owns the immediate uncured-feedstock operations: storage vessel, transfer, metering, degassing, dispensing, wetting and capture during a manufacturing event.

2. Liquid-resin volatility must be measured directly

High-vacuum screening demonstrates that liquid photopolymers can show substantial mass loss and viscosity change even when the corresponding cured material is comparatively vacuum compatible [1]. Liquid and cured states therefore require separate outgassing classifications.

Volatility should be quantified as a composition-dependent process, not only as total mass loss. Loss of a reactive diluent, inhibitor carrier or other minor component can shift cure behaviour even when the remaining resin still appears visually unchanged.

Transfer from a ground-filled cartridge to a reduced-pressure process volume can expand trapped headspace gas and nucleate dissolved gas. The resulting bubbles can interrupt dispensing or be carried into the build region [2].

3. Transfer requires gas and pressure management

Degassing history, fill procedure, headspace, pressure ramp and dwell time should be controlled. A “degassed” label without method and endpoint is not reproducible.

In reduced gravity, capillarity and contact angle govern liquid placement more strongly because weight provides little drainage. Wetting of tubing, valves, windows and reservoir walls can retain resin in places that drain cleanly on Earth.

4. Wetting replaces passive drainage

Surface treatment and material compatibility should therefore be assessed with the actual resin after vacuum conditioning. Contact angle measured with a surrogate liquid or at atmospheric pressure may not predict retained-film behaviour.

Dispensing accuracy should be measured as delivered mass or volume under the intended pressure and acceleration sequence. Pump command or valve-open time is an input, not an output.

Volatile or aerosolized species can contaminate optical windows, radiators, detectors and solar surfaces outside the manufacturing envelope. Contamination risk therefore belongs in machine qualification even when the printed part itself is acceptable.

Vacuum-compatible printed polymers demonstrate that post-processing and bake history can strongly affect outgassing of solid VPP components [3]. That evidence should not be transferred backward to the uncured liquid, whose composition and transport are different.

5. Dispensing contamination and device-level verification

Recovery of unused resin should be qualified as deliberately as dispensing. Returning exposed or thermally conditioned resin to a common reservoir can change future lots and defeat traceability.

Device-level verification should run multiple fill-dispense-recover cycles and monitor mass balance, bubbles, viscosity, leakage and contamination witnesses. A single successful dispense does not establish reusable operation.

Failure testing should address stuck valves, gas ingestion, partial vacuum loss and accidental free-surface formation. The containment system should default to a captured state rather than releasing uncured resin.

Axis	Measurement	Failure mode
Volatility	liquid mass loss and composition shift	cured-material vacuum data transferred to liquid
Gas state	degassing, headspace, pressure ramp	ambient bubble-free state assumed
Wetting	contact angle and retained films	gravity drainage assumed
Dispensing	delivered mass/volume and repeatability	commanded dose used as delivered dose
Contamination	witnesses, leakage, recovery mass balance	printer success treated as spacecraft cleanliness

Table 1. Domain-specific qualification matrix for photoresin storage, transfer and dispensing under vacuum or reduced gravity.

6. Transfer limits and minimum reporting dataset

Materials in contact with the liquid resin should be screened for swelling, extractables and photochemical compatibility after the combined pressure and temperature history.

Report resin lot and age, cartridge history, pressure ramp, temperature, headspace, degassing method, wetted materials, contact angle or wetting observation, delivered quantity and recovered quantity.

Add residual-gas or contamination-witness data where sensitive spacecraft surfaces are exposed, and keep liquid-resin and cured-material outgassing results separate.

7. Minimum qualification framework

A minimum handling qualification should couple mass-loss measurement with pressure, temperature and exposure time, then inspect whether the remaining liquid has changed viscosity, optical cure response or composition. Transfer hardware should be evaluated with the same resin because seal materials, dead volumes and wetting surfaces can dominate contamination and gas entrainment.

Dispensing tests should include start-stop operation, partial reservoir depletion and representative acceleration or reduced-gravity phases. Acceptance criteria should distinguish reversible redistribution from irreversible volatile loss, phase separation, contamination or cure drift, and should define whether re-mixing or thermal conditioning is permitted.

8. Engineering conclusions

Photoresin handling under vacuum or reduced gravity is therefore a controlled fluid-management problem. A formulation is not mission-ready merely because it survives static vacuum exposure; storage, transfer, wetting, gas management and post-transfer cure performance must remain inside one qualified operating envelope.

References

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Competing interest

Juan Segurola is founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L., which develops and commercialises photopolymer materials and related additive-manufacturing technologies. This review is an engineering analysis and does not constitute a product-performance claim or a device qualification.