SCHICHTWERK · WERKSTOFFWERK

SLA / DLP / MSLA

Engineering Reference – Polymer Technology

Photopolymers · Materials Science · Metrics · Post-processing · Finishing · Surface Quality

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Part 1 · Fundamentals of Photopolymerization

1.1 Working principle

In vat photopolymerization, liquid photopolymer resin is selectively cured layer by layer by light. A photoinitiator absorbs UV light (typically < 405 nm) and starts a free-radical chain polymerization of the acrylate/methacrylate monomers, forming a crosslinked solid. The build platform lifts the part out of the resin vat layer by layer.

1.2 Process variants

Variant	Light source	Exposure	Characteristic
SLA (laser)	UV laser + galvo mirror	point-wise	high detail, slower over area
DLP	projector (DMD chip)	whole layer at once	fast, pixel raster (voxel)
MSLA	LCD mask + UV-LED array	masked whole layer	low-cost, high resolution, common

1.3 Process chain

Phase	Step	Critical quantity
Preparation	CAD → STL → supports + slicing	orientation, cavity, venting
Exposure	layer-wise curing	exposure time, light power
Green part	part from vat	adhesion, peel forces
Cleaning	washing (IPA/water-based)	residual-resin removal
Post-curing	UV post-cure	degree of conversion
Finish	support removal, sanding	surface, dimensional accuracy

Part 2 · Materials Science of Photopolymers

2.1 Composition of a photopolymer

Component	Function	Influences
Monomers (reactive diluent)	viscosity, crosslinking	brittleness, shrinkage
Oligomers (urethane acrylate etc.)	backbone, mech. properties	toughness, strength
Photoinitiator (e.g. TPO)	starts polymerization	cure speed
Absorber/dye	limits penetration depth	resolution, over-cure
Additives/fillers	function (tough, temp, ESD)	specific properties

2.2 Resin classes & properties

Resin type	Tensile MPa	E-mod GPa	Elong. %	Shore	Character
Standard	45–65	2.5–3.5	2–5	D80–85	fine, brittle
Tough/ABS-like	45–70	2.0–2.8	8–20	D75–82	tougher
Engineering	55–80	2.5–4.0	4–12	D78–86	functional
High-temp	50–80	3.0–4.5	1–3	D85–92	HDT to ~180 °C
Flexible/elastic	5–25	0.005–0.1	50–200+	A30–80	rubber-like
Dental/medical*	80–120	3.5–5.0	3–8	D82–88	certified*

** Medical/dental resins only with appropriate approval and validated process; own regulatory requirements (see SICHERHEITSWERK).*

2.3 Cure chemistry & degree of conversion

The degree of conversion (DoC) determines the final mechanical properties and residual-monomer content. Freshly printed green parts are only partially crosslinked; post-curing raises DoC, strength and hardness, but can increase brittleness and yellowing. Both over- and under-curing are quality risks.

DoC – the central quality parameter

Under-cure: soft part, high residual monomer (toxicologically + mechanically unfavourable).

Optimal cure: max. strength at acceptable brittleness.

Over-cure: embrittlement, micro-cracks, yellowing, dimensional change.

Influences: UV wavelength (< 405 nm), duration, temperature, geometry/layer thickness.

Part 3 · Process Metrics & Parameters

3.1 Key parameters

Parameter	Typ. range	Effect	Trade-off
Layer height	0.025–0.10 mm	Z-resolution, time	fine ↔ fast
Exposure/layer	1.5–4 s (MSLA)	curing, detail	adhesion ↔ over-cure
Bottom-layer exposure	20–60 s	platform adhesion	adhesion ↔ elephant foot
Lift speed/height	device-specific	peel forces, detail	fast ↔ detachment
Anti-aliasing/grey	0–8	edge smoothing	smoothing ↔ detail loss
Resin temperature	25–35 °C	viscosity, curing	flow ↔ reactivity

3.2 Resolution & isotropy

Lateral resolution (XY) for MSLA/DLP derives from the display/projector pixel size (typically 18–50 µm), for SLA from the laser-spot diameter. Z-resolution equals the layer height. Unlike FDM, layer bonding is chemical (continuous crosslinking), so SLA parts are largely isotropic.

3.3 Reproducibility

Influences on reproducibility (SLA)

Resin batch & ageing (reactivity changes, sedimentation with filled resins).
FEP/nFEP film: clouding and wear change light transmission → adjust exposure.
LCD display ageing: declining transmission over lifetime (exposure drifts).
Resin temperature & room climate: viscosity and curing temperature-dependent.
Validation: exposure test per batch/material.

Part 4 · Post-processing

4.1 Cleaning

The green part is wetted with uncured resin that must be fully removed before post-curing. Media: isopropanol (IPA 99.9 %), water-based cleaners, or water for water-washable resins. Ultrasonic or agitated baths improve cleaning in cavities.

- Design cavities and blind holes with vent/drain holes.
- Cleaning medium ages (resin saturation) → replace in time.
- Fully dry after washing before post-curing.

4.2 Post-curing

Method	Wavelength	Note
UV cure chamber	365/405 nm	controlled dose, rotating/turning
Water bath + UV	405 nm	reduced oxygen inhibition → better surface
Sunlight	variable	uncontrolled, not reproducible (under-cure)

4.3 Support removal & finish

- Supports easier to remove in green state, but: uncured resin = protective gloves.
- Sand contact points (support marks): grit 400→2000, wet.
- Fill with UV resin + spot-cure for seamless repair.

Part 5 · Finishing & Surface Quality

5.1 Surface quality

SLA/DLP surfaces are very smooth (Ra typ. 0.5–3 µm), often near print-ready on vertical and fine-detail faces. Sloped faces show fine layering depending on layer height; with low layer heights (25–50 µm) this is minimal.

Surface	Layer height	Ra (typ.)	Visibility
SLA standard	0.05 mm	Ra 0.5–3 µm	minimal
SLA fine	0.025–0.035 mm	Ra 0.1–1 µm	barely
after sanding/primer	—	Ra < 0.5 µm	mirror-smooth possible

5.2 Painting & coating

- Excellent paintability due to fine surface; primer recommended for adhesion.
- Clear/UV protective coat against yellowing and UV embrittlement (SLA parts age under UV).
- Metallization/electroplating for jewellery masters and functional parts.

Goal	Measure	Note
UV stability	clear coat, UV-stable resin	standard resins yellow/embrittle in light
Temperature resistance	high-temp resin + post-cure	HDT to ~180 °C possible
Transparency	clear resin + sanding + clear coat	multi-stage polishing
Casting	castable resin (residue-free)	jewellery/dental masters

Part 6 · Defects & Remedies

Defect	Cause	Remedy
Part detaches from plate	short bottom exposure, plate uncalibrated	bottom layer ↑, level platform
Layer shift	peel forces, loose mechanics	slower lift, check mechanics
Sagging details	missing supports, large area	support density ↑, change orientation
Cupping (suction)	cavity without vent	add drain/vent hole
Over-cure/detail loss	long exposure, low absorber	exposure ↓, check anti-aliasing
Tacky surface	oxygen inhibition, under-cure	water-bath cure, post-cure ↑
Brittle fracture	over-cure, standard resin	tough resin, optimize post-cure

Part 7 · Application Classes & Resin Choice

Application	Example	Resin	Note
Miniatures/figurines	tabletop, collectibles	standard, high detail	post-cure + prime
Jewellery master	casting pattern	castable (residue-free)	for investment casting
Functional prototype	fit parts, housings	tough/engineering	isotropic, load-bearing
High temperature	jigs, moulds	high-temp resin	HDT verification
Flexible parts	seals, dampers	flexible/elastic	shore choice
Dental/medical	models, splints*	certified resin*	approval only*

Process limits & safety

Uncured resin is a hazardous substance – always PPE (see SICHERHEITSWERK).

No food contact; standard/engineering resins are not food-safe.

Medical/dental: only certified resins under validated, approved process (MDR).

SLA parts age under UV – UV clear coat or UV-stable resin for permanent light exposure.

Reference

Volume I covers the FDM/FFF process. Health, occupational and legal safety are described in the SICHERHEITSWERK compendium.

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