

Resistive-Switching and Neuromorphic Devices Integrated with Photopolymer Platforms: Interfaces, Variability and Endurance

Qualification boundaries for photocured dielectrics, resin-device interfaces and additively manufactured memristive structures

Juan Segurola

3Dresyns by Resyner Technologies S.L.

© 2026 Juan Segurola. All Rights Reserved.

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

ER-430 · Engineering Review · Version 0.1 · 8 October 2026

Abstract

Photopolymers can enter resistive-switching and neuromorphic hardware in several fundamentally different roles: as an active polymeric switching medium, as a photocured dielectric, as a structural or encapsulating interface that modifies an oxide device, or as part of an additively manufactured conductor-polymer composite. These roles must not be collapsed into a single “printed memristor” category. Polymer memristors have a long history in solution-processed electronics, while recent work shows that UV-curable resin can chemically modify ZnO interfaces and shift switching from filamentary to more gradual interface-type behaviour. Separately, fully 3D-printed Cu-PLA crossbar devices demonstrate that additive polymer composites can exhibit resistive switching through electromigration-driven filament formation. This review maps those evidence classes to photopolymer integration and focuses on mechanism identification, cycle-to-cycle and device-to-device variability, retention, endurance, analogue weight-update linearity and interface ageing. A qualification framework is proposed in which electrical function is verified after photopolymer processing and environmental stress, with explicit separation of active switching layer, dielectric, encapsulant and structural platform.

Keywords: resistive switching; memristor; neuromorphic; photopolymer; UV-curable resin; interface; variability; endurance; additive manufacturing

1. Significance and scope

Resistive-switching devices are attractive for nonvolatile memory and neuromorphic computing because conductance can encode state in a compact two-terminal element. Photopolymer platforms can contribute structure, insulation, encapsulation, optical access or the switching medium itself. ER-430 treats these as distinct integration architectures. It does not infer memristive behaviour from conductivity, dielectric response or additive manufacture alone.

2. Mechanism must be established before neuromorphic interpretation

Polymer memristors span electronic, ionic, redox and filamentary mechanisms, as reviewed by Chen and co-workers [1]. Polymer-composite devices can additionally exploit ion-transport mediators and mixed organic phases, reinforcing that the active transport pathway must be identified rather than inferred from the polymer label [6]. Similar current-voltage hysteresis can arise from different physical processes. A neuromorphic label therefore requires more than a pinched loop or two resistance states. The switching polarity, forming behaviour, compliance-current dependence, area scaling, temperature response and electrode chemistry should be used to constrain the mechanism.

Mechanism matters because it sets variability and ageing. A metallic filament can switch abruptly and stochastically; an interface-modulated device may change conductance gradually; ionic polymer systems can retain history through ion redistribution. Device architecture and processing should be chosen around the desired state-update behaviour rather than around the existence of hysteresis alone.

3. UV-curable resin can be an active interface modifier

Yim, Park and Kim reported that treatment of ZnO resistive-switching devices with a UV-curable resin changed the observed behaviour from abrupt filament-type to more gradual interface-type switching [2]. Their chemical analyses linked the effect to resin-derived species, oxygen-vacancy passivation and carbonate formation. This result is directly relevant to photopolymer integration because it shows that a resin layer can chemically alter the switching interface rather than act as an inert encapsulant.

The engineering consequence is that encapsulation, adhesive or overprint steps must be electrically qualified as process steps. A resin that is benign for mechanical packaging may shift set/reset voltage, conductance distribution or retention. Pre- and post-resin electrical measurements, accompanied by chemical or interfacial analysis when behaviour changes, are therefore required.

4. Photocured dielectrics can support synaptic transistor functions

Photocrosslinked polymer dielectrics have been used in flexible organic transistor synapses, where cure state and polar groups influence interface traps and synaptic response [3]. This is not a two-terminal memristor architecture, but it demonstrates that UV-cured polymer dielectrics can actively shape neuromorphic device behaviour. The role should be described as dielectric/interface engineering rather than resistive switching unless the two-terminal switching criterion is actually met.

5. Additive manufacturing can create a switching composite, but process and mechanism remain specific

A recent all-3D-printed Cu-PLA crossbar memristor array used fused filament fabrication and attributed resistive switching to copper electromigration and filament formation through the polymer matrix [4]. This establishes that additive polymer composites can function as memristive devices. It is not evidence that a vat-photopolymerised conductive composite will behave similarly: conductor morphology, void structure, electrode contact, polymer chemistry and ion mobility are different.

Qualification axis	Required evidence	Failure if omitted
Architecture identity	Explicit role of photopolymer: active layer, dielectric, encapsulant, substrate or structural support	Different mechanisms can be collapsed into a misleading “printed memristor” category
Switching mechanism	I-V/pulse data plus controls for electrodes, area, compliance, temperature or chemistry as appropriate	Hysteresis alone may be misassigned to a physical mechanism
Variability	Cycle-to-cycle and device-to-device distributions of set/reset or conductance update	A best trace can conceal stochastic or process-driven spread
Endurance/retention	Defined pulse/read protocol, cycle count, retention time and failure criterion	Short demonstrations may not support memory or synaptic claims
Integration stability	Electrical re-test after UV cure, resin contact, post-cure and environmental stress	Photopolymer processing can chemically or mechanically alter the active interface

Table 1. Domain-specific qualification matrix for resistive-switching and neuromorphic devices integrated with photopolymer

6. Device-level verification

The electrical test protocol should match the claimed function. Binary memory requires state separability, retention and endurance; analogue synapses require repeatable incremental potentiation/depression, dynamic range, symmetry and nonlinearity; spiking or short-term plasticity claims require time-dependent pulse response. Read voltage and compliance should be chosen so that the measurement itself does not rewrite the state.

6.1 Variability is a primary output, not an error bar added later

Filamentary devices often show distributions of set/reset voltage and resistance because nucleation paths vary. Neuromorphic systems are particularly sensitive to update variability and asymmetric potentiation/depression. Qualification should report device-to-device and cycle-to-cycle statistics, including failed or non-switching devices, rather than selecting representative curves.

6.2 Endurance and retention answer different questions

Endurance measures repeated state transitions; retention measures state persistence without rewriting. A device can survive many cycles yet relax rapidly, or retain a state but fail after few updates. Both should use defined temperature, read conditions and failure thresholds. Accelerated retention extrapolation should be labelled as a model rather than direct lifetime evidence.

6.3 Photopolymer cure is a chemical and thermal process step

UV exposure, photoinitiator fragments, residual monomer, oxygen and post-cure can alter nearby oxides, metals or organic semiconductors. Yim et al. provide a direct example of resin-derived chemistry changing ZnO switching [2]. Integration studies should therefore include a control device that experiences the same light and thermal history without the resin where practicable, allowing photochemical and interfacial effects to be separated.

6.4 Electrode interfaces require independent control

Apparent switching can originate from electrode oxidation, ion injection, contact barriers or local heating. Electrode material, thickness, deposition route and contact area should be reported. If printed conductors are used, surface roughness and porosity can change the local electric field and must be considered part of the device geometry.

6.5 Analogue synaptic metrics should be extracted from pulse trains

Neuromorphic operation depends on how conductance evolves under repeated programming pulses, not only on quasi-static I-V sweeps. Potentiation/depression curves should report pulse amplitude, width, interval, number of states, dynamic range, nonlinearity and cycle variability. Network-simulation accuracy derived from measured devices should preserve the actual update distribution rather than substituting idealised weights.

6.6 Optical programming and UV sensitivity need a stability boundary

Some memristive and synaptic devices intentionally respond to light. A UV-regulated transparent memristor has been demonstrated for reconfigurable synapse-neuron functions [5]. In a photopolymer platform this creates both opportunity and risk: the same UV used for cure can precondition the device. The fabrication dose, operating optical dose and storage-light sensitivity should therefore be separated and documented.

6.7 Integration reliability includes mechanical stress

Flexible or three-dimensional platforms can strain electrodes and interfaces. Resistance changes from cracks or contact loss can mimic state drift. Mechanical bending, thermal cycling or package stress should be accompanied by control measurements of electrode continuity and by electrical state distributions before and after stress.

6.8 Forming, compliance and local heating require explicit control

Electroforming and high-current switching can create a local thermal history very different from the nominal chamber or substrate temperature. Compliance current, pulse energy and series resistance should therefore be reported together with the forming protocol. A transition that appears after a different compliance setting may reflect a different filament population rather than improved device quality. Where Joule heating is plausible, temperature dependence and pulse-width dependence provide useful mechanistic controls.

6.9 Statistical acceptance criteria should precede neuromorphic benchmarking

A network-level accuracy number can obscure a device population with broad switching or update distributions. Before simulation or hardware benchmarking, the acceptance population should be defined and the excluded fraction reported. Device-to-device spread, cycle-to-cycle spread and drift with elapsed time should remain separate datasets. This prevents post-selection of unusually smooth devices from being interpreted as a manufacturing-capable synaptic update rule.

7. Minimum qualification framework

A minimum report should define the device stack and the exact photopolymer role; electrode composition and geometry; UV/cure/post-cure exposure; forming and compliance conditions; switching polarity; cycle-to-cycle and device-to-device distributions; endurance; retention; analogue-update metrics when claimed; temperature and optical sensitivity; and electrical re-test after relevant environmental or mechanical stress.

The controlling state is device-stack-interface-process-history. A change in resin, photoinitiator, cure dose, electrode, oxide stoichiometry or encapsulation can change the switching mechanism and invalidates automatic transfer of prior endurance or neuromorphic metrics.

8. Engineering conclusions

Photopolymers can participate in neuromorphic hardware as active materials, dielectrics, interface modifiers, encapsulants or structural platforms, but these roles must remain explicit. Recent UV-resin/ZnO results demonstrate that a nominally packaging layer can change the switching mechanism, while printed Cu-PLA devices show that additive polymer composites can themselves support filamentary switching. Qualification should therefore start from mechanism and architecture, then quantify variability, endurance, retention and integration-induced drift under the exact photopolymer process history.

References

- [1] Y. Chen, G. Liu, C. Wang, W. Zhang, R.-W. Li, L. Wang, "Polymer memristor for information storage and neuromorphic applications," *Materials Horizons* 1 (2014) 489-506. <https://doi.org/10.1039/C4MH00067F>
- [2] S. Yim, H. B. Park, J. Kim, "UV-curable resin-induced transition to interface-type resistive switching in ZnO synaptic devices for neuromorphic computing," *Chemical Engineering Journal* 529 (2026) 172735. <https://doi.org/10.1016/j.cej.2026.172735>
- [3] Y. Liu, Z. Yin, C. Liu, Z. Liu, S. Liu, Q. Zheng, "Photo-crosslinked polymer dielectrics enabling flexible organic transistor synapses with excellent linearity for neuromorphic applications," *Chemical Engineering Journal* 507 (2025) 160538. <https://doi.org/10.1016/j.cej.2025.160538>
- [4] B. P. Bisht, V. Toutam, S. R. Dhakate, "All 3D-Printed Cu-PLA Composite Crossbar Memristor Array by Fused Filament Fabrication: Opportunities and Challenges," *ACS Applied Electronic Materials* 7 (2025) 696-705. <https://doi.org/10.1021/acsaelm.4c01774>
- [5] G. Zhang, Z. Zeng, Y. Yan, J. Tang, H. Wang, C. Su, X. Yi, X. Zhang, Y. Hu, H. Chen, "Ultraviolet-Regulated Synaptic-Neuronal Function Reconfigurable Transparent Memristor for Neuromorphic Computing Hardware," *Advanced Functional Materials* 36 (2026) e31113. <https://doi.org/10.1002/adfm.202531113>
- [6] C. D. Prado-Socorro, S. Giménez-Santamarina, L. Mardegan, L. Escalera-Moreno, H. J. Bolink, S. Cardona-Serra, E. Coronado, "Polymer-Based Composites for Engineering Organic Memristive Devices," *Advanced Electronic Materials* 8 (2022) 2101192. <https://doi.org/10.1002/aelm.202101192>

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.