

Multimaterial VPP Interfaces and Functionally Graded Networks: Qualification and Failure-Mode Controls

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Statement of Significance

Printing two materials in one object does not establish interface adhesion, isolation or durability. Qualification must identify the spatial transition, loading mode, failure location, post-cure mismatch and finished-article function.

Keywords: multimaterial VPP; interface; graded network; adhesion; fracture; microfluidics; qualification.

Abstract

Three topical sources address multimaterial VPP architectures, programmed heterogeneous micro-environments and tunable-resin microfluidic actuators. The evidence supports controlled multimaterial and graded structures, but not a universal interface strength or biological-suitability claim. This note defines spatial mapping, geometry-specific adhesion/fracture testing, differential dimensional control and interface-focused durability requirements. Biological evaluation, where relevant, remains a separate finished-article process under ISO 10993-1:2025. RP-02 supplies the shared qualification method.

1. Evidence boundary

Sampson et al. review multimaterial VPP routes and graded structures [1]. Yin et al. demonstrate programmed heterogeneous micro-mechano-environments and geometries [2]. Ahmadianyazdi et al. develop tunable-modulus resins for multimaterial microfluidic actuators [3]. These sources use different chemistries, exchange strategies, scales and functions; their numerical properties are not transferable to an unspecified 3Dresyns material pair or interface.

2. Topic-specific findings

- Material exchange, residual carryover and cure sequence define the chemical and geometric interface [1].
- Spatial programming can create heterogeneous mechanical environments, but the achieved transition must be mapped rather than inferred from CAD [2].
- Tunable-modulus multimaterial systems can enable microfluidic actuation within a defined formulation and process window [3].
- A deliberate gradient trades a nominally sharp boundary for a spatially controlled transition whose width and properties require measurement [1].

3. Minimum measurement and reporting set

Control	Method and minimum record	Required interpretation
Interface geometry	Microscopy, spectroscopy or labelled spatial mapping	Report transition width, registration, sampling resolution and multiple locations
Adhesion/fracture	Named geometry-specific lap shear, T-peel, mode-I DCB or mode-II ENF test	State loading mode and fracture surface; cohesive and adhesive failures must be distinguished
Composition	Spatial chemical/functional mapping before and after exchange/cleaning	Verify carryover and isolation rather than assuming material identity from feed sequence
Dimensional state	Pre/post-cure metrology of each material and the joined article	Account for differential shrinkage, swelling and residual stress
Durability/function	Wet, thermal or cyclic conditioning of the actual interface and representative function	Do not qualify an interface using only separate bulk coupons

4. Interpretation limits

- Values from lap shear, peel, mode-I and mode-II fracture geometries are not interchangeable.

- A high apparent interface strength can reflect cohesive failure in the weaker bulk material; retain the fracture surface and failure map.
- A graded transition is not automatically more durable than a sharp interface and may broaden dimensional or compositional uncertainty.
- Where tissue or fluid contact is intended, ISO 10993-1:2025 finished-article biological evaluation is an additional gate that no interface test satisfies.

5. 3Dresyns implementation examples

Combinations of rigid, flexible, elastic, optical or functional 3Dresyns grades are manufacturer-controlled implementation candidates, not independent evidence of interface performance. Any named pair must identify exact grades and controlled TDS/IFU revisions, printer/exchange sequence, cleaning, exposure and post-cure state, then pass geometry-specific interface, leakage/isolation and durability criteria. Corrected WP-13/WP-24 may provide context but cannot qualify a pair.

6. Limitations and priorities

The evidence is route- and scale-specific. Priorities are traceable multimaterial reference artefacts, spatially resolved conversion/composition, mixed-mode fracture, carryover quantification and long-term interface testing in the actual thermal or fluid environment.

7. Conclusions

- Multimaterial print completion is not interface qualification.
- Every adhesion value must state the geometry, loading mode and failure location.
- Graded networks require measured transition width and property mapping.
- Biological suitability and product-specific performance remain separate finished-article gates.

Declarations

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Standard

ISO 10993-1:2025. Biological evaluation of medical devices - Requirements and general principles for biological-safety evaluation within a risk management process. <https://www.iso.org/standard/10993-1>