



Dual one and two-photon hybrid photoresists: high resolution and grayscale 3D printing of silicon- and ceramics- based nanostructures

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Inorganic and hybrid materials are intensively investigated for different applications and especially in optics (bioimaging, sensors, filters, photocatalysis...). [1] Structuration of inorganic or hybrid materials at the nanoscale allows the design of complex multifunctional materials and combination of important properties (Optics, electronics, mechanics, catalysis, microfluidics..), thus becoming an important challenge in the scientific community. The use of nonlinear optical processes in stereolithography techniques allows 3D control of reactions with submicronic resolution. Control of sol-gel reaction using 2-photon activated photobase or photoacid and combination with organic radical polymerization in a synergetic way will be discussed in the context of high resolution 3D printing. [2-4] Also, the use of functional hybrid nanoparticles allows 3D printing of ceramics with nanometric resolution. [5] Examples of applications in optics or microfluidics will illustrate this approach. This approach offers a wide possibility of compositions of materials for applications in energy storage, catalysis, photocatalysis, optics, sensors.

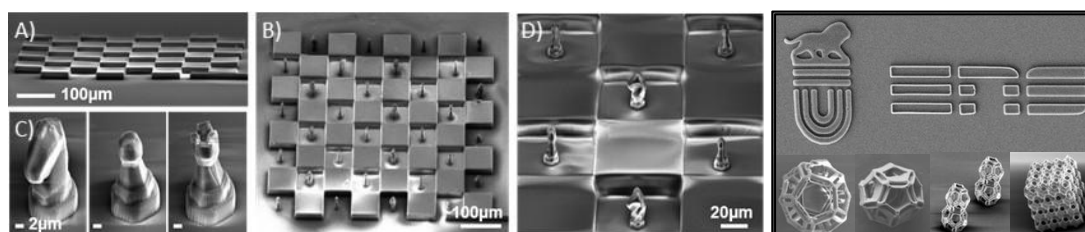


Figure 1 : example of silicon-based microstructures (A-D) prepared with dual approach and pure ceramics (E).

References

- [1] Optical Properties of Hybrid Organic-Inorganic Materials and their Applications, S. Parola, B. Julian-Lopez, L. D. Carlos, C. Sanchez, *Adv. Funct. Mater.*, 2016, 26 (36) 6506
- [2] Two-photon controlled sol-gel condensation for the 3D fabrication of silica and hybrid-based microstructures. Role of the photoacids and photobases, J. Kustra, E. Martin, D. Chateau, F. Lerouge, C. Monnereau, C. Andraud, M. Sitarz, P. L. Baldeck, S. Parola, *RSC Adv.* 2017, 7, 46615
- [3] Photoactivable hybrid organic-inorganic sol-gel resin for 3D printing, L. Chia Gomez, A. Banyasz, E. Santanach-Carreras, S. Parola, Patent PCT/FR2022/050436.
- [4] Dual one and two-photon hybrid photoresist for high resolution and grayscale 3D microprinting, L. P. Chía Gómez, D. Pitrat, Y. Bretonnière, F. Borondics, A. Banyasz, S. Parola, E. Santanach Carreras, 2023, under review
- [5] 3D printing and pyrolysis of optical ZrO₂ nanostructures by two-photon lithography: reduced shrinkages and crystallization mediated by nanoparticles seeds, A. Desponds, A. Banyasz, D. Chateau, A. Venier, S. Meille, G. Montagnac, J. Chevalier, C. Andraud, P. Baldeck, S. Parola, *Small*, 2021, 17, (42), 2102486