Suspended 3D Printed Polymer Waveguides for On-Chip Photonic Interconnects

Artur Andrishak, Bejoys Jacob, Tiago L. Alves, Christian Maibohm, Bruno Romeira and Jana B. Nieder*

INL - International Iberian Nanotechnology Laboratory, Ultrafast Bio- and Nanophotonics Group, Av. Mestre Veiga, s.n., 4715-330 Braga, Portugal.
*Corresponding author email: jana.nieder@inl.int

Efficient integration of novel ultracompact light sources and photodetectors is paramount for next-generation energy-efficient photonic integrated systems such as neuromorphic computational chips. However, integration of these photonic devices in emitter-receiver communication circuits remains challenging. 3D waveguides have been proposed as promising devices for on-chip optical interconnects [1]. Here we report versatile long, air-cladded suspended 3D polymer waveguides (OrmoCore), reaching 900 µm in length without intermediate mechanical support structures, suitable for on-chip out-of-plane light routing. This is achieved by applying a zig-zag voxel trajectory to the TPP microprinting. The waveguides show optical transmission losses of 1.93 dB mm^{-1} at λ=635 nm, and of 3.71 dB mm^{-1} at λ = 830 nm in range of GaAs-based microLEDs spectral emission. Crossing waveguides are arranged in a 3D superposition along the perpendicular direction to the substrate allowing for more complex interconnect networks. Furthermore, we devise an alignment method using the same laser source for sample imaging and fabrication, allowing accurate TPP 3D printing on microstructured chips. As a proof of concept, we optically interconnect two GaAs-based microLEDs via a microprinted 3D polymer waveguide. Such interconnected systems can serve as building blocks for future complex integrated heterogeneous photonic networks.

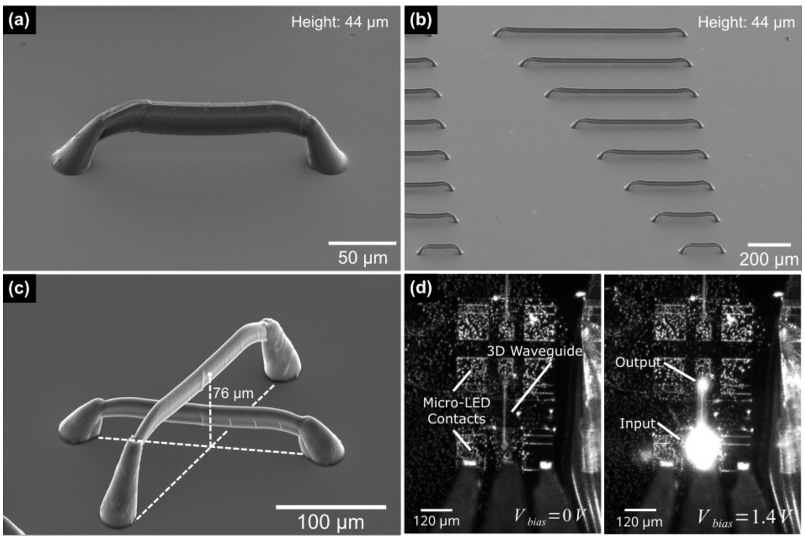

Figure 1. 3D Printed Polymer Waveguides. **(a)** A 44 µm high and 200 µm long 3D waveguide, with a rectangular core size of 9x33 µm². Printing parameters: zig-zag period T=1 µm, laser fluence F=16.5 mJ cm^{-2} for the waveguide core and F=19.8 mJ cm^{-2} for the tapers, v=100 µm s^{-1}. **(b)** Side view of fabricated waveguides with height 44 µm, with lengths ranging from 200 to 900 µm. **(c)** Tilted view of a set of crossing waveguides. The resulting waveguides have a core size of 9x28 µm². Printing parameters: zig-zag period T=0.3 µm, laser fluence F=8.8 mJ cm^{-2} for the waveguide core and F=19.8 mJ cm^{-2} for the tapers, stage velocity v=100 µm s^{-1}. **(d)** SCMOS camera image of a 250 µm long 3D polymer waveguide, interconnecting a pair of microLEDs with a circular pillar 14 µm diameter. When the bottom microLED is biased to a voltage of 1.4 V via a ground-signal-ground electrical probe, the emitting light is coupled to the 3D waveguide, reaching the output at the second microLED.

Acknowledgements: This research is funded by the European Commission (H2020-FET-OPEN No. 828841 “ChipAI”, and Horizon Europe Programme Project 101046790 “InsectNeuroNano”).

References:

[1] Ricardo M. R. Adão, Tiago L. Alves, Christian Maibohm, Bruno Romeira, and Jana B. Nieder, "Two-photon polymerization simulation and fabrication of 3D microprinted suspended waveguides for on-chip optical interconnects," Opt. Express 30, 9623-9642 (2022).