EPJ Web of Conferences **389**, 08019 (2026) https://doi.org/10.1051/epjconf/202638908019
EOSAM 2026

Femtosecond Laser Fabrication Process for Optofluidic Waveguide-Based Refractive Index Sensors in Glass

Marco Roth[1]*, *David* Bischof[1], and *Markus* Michler[1]

[1]OST - Eastern Switzerland University of Applied Sciences, Institute for Microtechnology and Photonics IMP, Werdenbergstrasse 4, 9471 Buchs SG, Switzerland

Abstract. Femtosecond laser-based fabrication offers high design flexibility for integrating optical and microfluidic structures in glass substrates. This work presents a comprehensive manufacturing process for optofluidic refractive index sensors, combining Femtosecond Laser Direct Writing (FLDW) for waveguide inscription with Selective Laser-induced Etching (SLE) for fluidic channel realization. Sequential laser processing on a single system ensures precise alignment between waveguides and fluidic interfaces. The process chain, including laser writing, wet etching, and sealing, is demonstrated through the fabrication of Mach-Zehnder interferometer (MZI) evanescent field sensors. Process validation confirmed precise control of the waveguide–fluid interface distance. The fabricated devices achieved a minimum detectable refractive index difference of $\Delta n = 0.073$ relative to deionized water, confirming the suitability of the combined FLDW-SLE process for integrated optofluidic sensing platforms.

1 Introduction

Femtosecond laser–based fabrication techniques offer versatile capabilities for the realization of integrated optical, mechanical, and fluidic structures in glass substrates. In contrast to conventional planar photonics, Femtosecond Laser Direct Writing (FLDW) enables true 3D waveguide fabrication and rapid prototyping [1]. The seamless combination of FLDW with Selective Laser-induced Etching (SLE) unites the advantages of both methods, providing a high degree of design freedom. Mach–Zehnder interferometer (MZI)–based evanescent field sensors represent a key application of FLDW, particularly for detecting refractive index changes in biological samples [2]. However, existing FLDW-based approaches [2, 3] do not incorporate microfluidic structures. In this work, we present a combined fabrication process based on FLDW for waveguide inscription and SLE for the realization of fluidic channels, which is applied to fabricate MZI-based evanescent field sensors in Corning® Eagle XG®.

2 Fabrication Process and Experimental Results

The proposed fabrication process comprises the steps listed in Table 1, including post-processing steps 5–8. Fig. 1(a) illustrates the first six steps of the process chain. As all FLDW and SLE writing steps are performed sequentially on the same laser system, precise alignment between waveguides and fluidic channels is ensured. For process validation, several evanescent field sensors were fabricated. The MZI design consists of two 2×2 directional couplers acting as splitter and combiner. Both interferometer arms include a sensing

*Corresponding author: marco.roth@ost.ch

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

region where a fluidic channel is placed close to the waveguide, enabling evanescent field interaction. The channels, sealed with polydimethylsiloxane (PDMS), enable differential measurement of the refractive indices of a reference liquid and a sample liquid. Examples of fabricated substrates after process steps 6 and 8 are shown in Fig.1(b) and (c), respectively, while Fig.1(d) shows the cross-section of a sensing region in a test channel containing five waveguides. In the example shown, the measured distances d_{int} between the waveguides and the fluidic interface range from 3.9 µm to 4.4 µm, in good agreement with the target range of 3.0 µm to 7.0 µm. To verify sensor functionality, the refractive indices of various glycerol–water mixtures and solvents were measured. The process validation demonstrated a minimum detectable refractive-index difference $\Delta n = 0.073$ relative to deionized water.

Table 1. Femtosecond laser-based fabrication process chain

1.	SLE: Laser writing fluidic channels	5.	Sawing and facet polishing
2.	FLDW: Laser writing waveguides	6.	Sealing of channels with PDMS
3.	SLE: Laser writing marks & labels	7.	Fibre-based optical interfacing
4.	SLE: Wet etching to remove modified glass	8.	Fluidic assembly

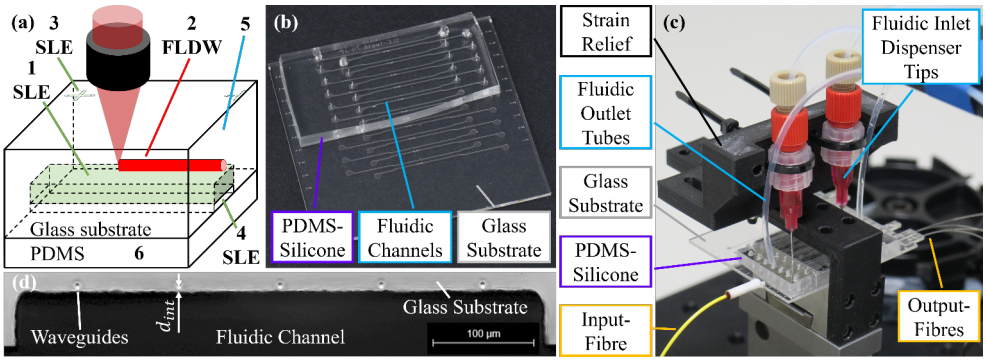


Figure 1. (a) Schematic of the first six process steps. (b) Fabricated substrate after step 6. (c) Complete sensor assembly. (d) Microscopic cross section of test waveguides showing the waveguide-channel interface in a sensing region.

In conclusion, combining FLDW-based MZIs with SLE-fabricated fluidic channels proved to be an effective approach for realizing the targeted optofluidic sensors in glass. The process offers high design flexibility and enables precise spatial alignment through sequential laser writing. Future work will focus on improving reproducibility.

References

[1] D. Tan, Z. Wang, B. Xu, J. Qiu, Photonic circuits written by femtosecond laser in glass: improved fabrication and recent progress in photonic devices, Adv. Photonics **3**, 024002 (2021). https://doi.org/10.1117/1.AP.3.2.024002

[2] L.A. Tapia-Licona, G.V. Vázquez, E. Rodríguez-Sevilla, R. Reséndiz-Ramírez, E. Morales-Narváez, R. Martínez Vázquez, R. Castro-Beltrán, R. Ramírez-Alarcón, Unbalanced mach–zehnder interferometer fabricated by femtosecond laser direct writing for sensing of urea concentrations via evanescent field interaction, Opt. Laser Technol. **183**, 112285 (2025). https://doi.org/10.1016/j.optlastec.2024.112285

[3] V.A. Amorim, J.M. Maia, D. Viveiros, P.V.S. Marques, Mach-zehnder interferometer-based evanescent refractometer inscribed at the surface of eagle2000 by femtosecond laser writing, IEEE Sens. J. **21**, 1603-1608 (2021). https://doi.org/10.1109/JSEN.2020.3021586