Flexible photopolymer based optical waveguides for optogenetic applications

C. Helke, M. Arnold, F. Schwenzer, D. Reuter, H. Kuhn
Chemnitz University of Technology, Center for Microtechnologies (ZfM), Reichenhainer Str. 70, 09126 Chemnitz, Saxony, Germany
christian.helke@zfm.tu-chemnitz.de

C. Goßler, M. Reinhardt, M. Wachs, U. Schwarz
Chemnitz University of Technology, Experimental Sensors, Reichenhainer Str. 70, 09126 Chemnitz, Saxony, Germany

D. Keppeler, T. Moser
Institute for Auditory Neuroscience and InnerEarLab, University Medical Center Göttingen, 37075 Göttingen, Germany

Since the last decades, implantable medical devices have played an important role to improve health conditions, monitoring and diagnosis. In case of malfunctions in the inner ear hair cells, cochlear implants help to hear again. Clinically established microelectronic cochlear implants are based on electrical stimulation[1]. However, the resolution of the electrical stimulation is limited. By employing optical stimulation, the spatial resolution of the nerve excitation can be improved. However, the auditory nerves are not sensitive for optical stimulations. With a genetic modification, the so-called optogenetics, it is possible to render the nerves sensible for optical stimulation[2]. An optogenetic tool with photopolymer-based optical waveguides in combination with laser diodes is possible for transporting light from the source to the nerve cells[3].
In this work, the fabrication of optical waveguides for the final use in cochlea implants will be shown. Two polymers with different refractive indices are needed for ensuring total internal reflection between core and cladding layer. The fabrication of the polymers is done by lithography and post processed by different microelectronic fabrication steps at 6" silicon wafers. A material combination of PMMA/SU8/PMMA was applied (figure 1). Cracks occurred after development of SU8 in the lower PMMA when SU8 was directly processed on top of PMMA. Additionally, PMMA showed orange peel formation during temperature treatments. The work shows how to avoid these cracks and orange peel formation without change of the core materials. To structure the waveguide the SU8 layer was patterned by UV-based lithography and by dry etching. The implants are designed as bendable and flexible devices. Therefore, polymer structures have to be removed from the substrate after the fabrication process. Two approaches for the sacrificial layer will be presented. Figure 2 shows the final optical waveguide structure and figure 3 the final coupling structures.

---

[1] F. Zeng et al *IEEE Reviews in Biomedical Engineering* **2008**, 1, 115-142
[2] S. Kleinlogel et al *Physiological Reviews* **2020**, 100, 1467-1525
[3] M. Schwaerzle et al *Journal of Micromechanics and Microengineering* **2017**, 27, 1-11

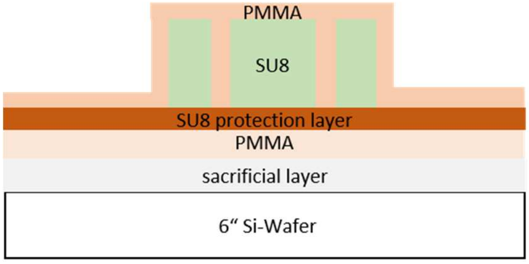

Figure 1: Layer stack of the optical waveguides with the PMMA/SU8/PMMA layer stack and the sacrificial layer for releasing: To avoid the described cracks in the layer stack an additional protection layer of thin SU8 was spin coated between the lower cladding layer and the core layer.

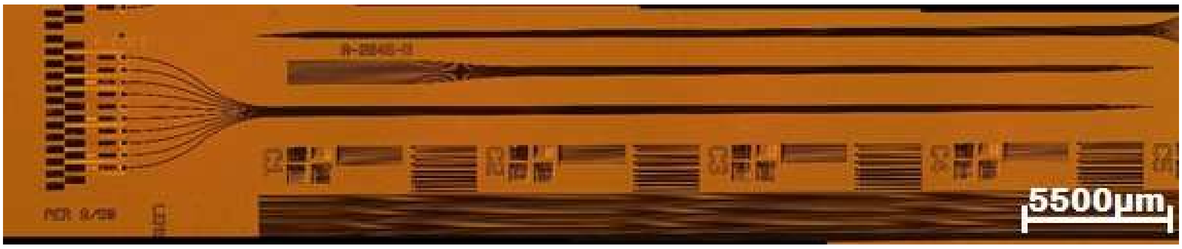

Figure 2: Overview of optical waveguide probe on substrate wafer: The structure starts from the left-hand side with bond pads for laser diode chip integration and ends on the right-hand side with the optical outcoupling structures to be placed in the cochlea.

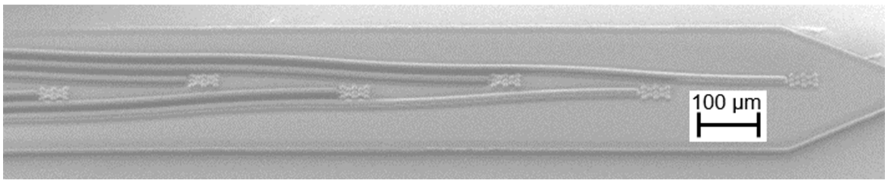

Figure 3: Outcoupling structures of finalized optical waveguide probe: The spacing between the 10-µm-broad waveguides is 15 µm.