Combination of Flexographic and Aerosol Jet Printing for Integrated Polymer Optical Step Index Waveguides

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This paper describes the two stage fabrication of step index waveguides featuring parabolic cross sections with minimum widths down to 10 µm and aspect ratios of about 0.3. The waveguide itself is produced by aerosol jet printing on pre-conditioned areas with different surface energies which are generated on flexible substrates with an adapted flexographic printing mechanism.

1 Introduction

Optical data transmission is established in many fields of industry not at least because of its low susceptibility against electromagnetic fields. More than that it is part of recent research and development and may become a key enabling technology in the future [1].

The additive and three dimensional fabrication of polymer optical waveguides and signal transmission at junction points of photonic networks cannot be ensured sufficiently by current techniques. These waveguides are suitable for short distance data transmission because of their mechanical flexibility and optical properties and qualified for the use in packaging technology. When it is possible to establish an efficient production process a versatile scope of applications is possible. Furthermore passive coupling strategies allow for development of three-dimensional optical interconnect devices. The following chapter describes an approach for its implementation.

2 Fabrication of polymer optical waveguides

The fabrication process of polymer optical waveguides (POW) described in this paper is achieved by a two stage process. The waveguides are printed onto flexible polymer substrate to provide an application in three-dimensional optical interconnect devices. In the first step a relief printing mechanism is used to adjust the surface energy of the polymer foil by printing conditioning lines. In a subsequent process the waveguide itself is applied in between these lines by aerosol jet printing (**Fig. 1**). This enables high speed fabrication of waveguides with a smooth surface and high aspect ratios.

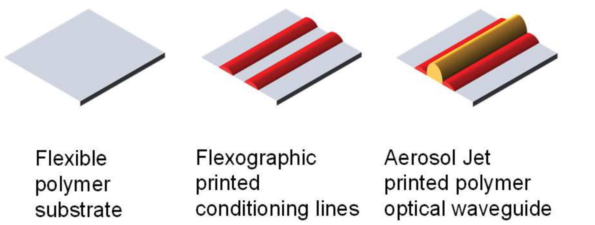

Fig. 1 *Two stage fabrication process of polymer optical waveguides.*

3 Flexographic printing of conditioning lines

Compared to other research projects concerning printing of polymer optical waveguides [2] the approach in this work is to use the flexographic printing mechanism to adjust the surface energy of the flexible substrate. By the use of functional polymer containing silicone, a pair of conditioning lines with hydrophobic behaviour is printed onto the foil. The distance between the lines as well as its width is adapted by the use of different printing forms. The quality of the conditioning line directly affects the waveguide produced afterwards. This process allows for a high output of conditioned areas with a resolution up to 10 µm width.

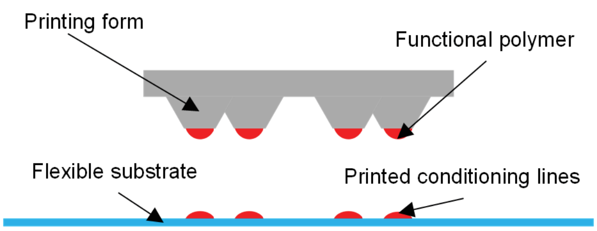

Fig. 2 *Flexographic printing of conditioning lines.*

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4 Aerosol jet printing

Aerosol jet application allows for printing various liquid materials on different substrate materials. There are restrictions concerning the viscosity ν of the ink ($1 < \nu < 1000$ cP). Additional to that the material has to be shear thinning or newtonian [3]. To focus the aerosol stream onto the substrate a sheath gas is surrounding it and leads through a nozzle with a diameter of 200 µm. Depending on the distance between the conditioning lines the amount of aerosol is set to fill the gap and to allow for self-assembly [4] without exceeding the maximum contact angle possible. Current results show waveguides with parabolic cross sections and about 290 µm width and a height of about 50 µm as seen in Fig. **3**. Measurements of the light intensity distribution show typical multimodal behaviour. The light is guided in the core and does not decouple into the substrate. As also seen in Fig. **3** the highest intensity concentration is located in the centre of the waveguide when measuring with LED light source.

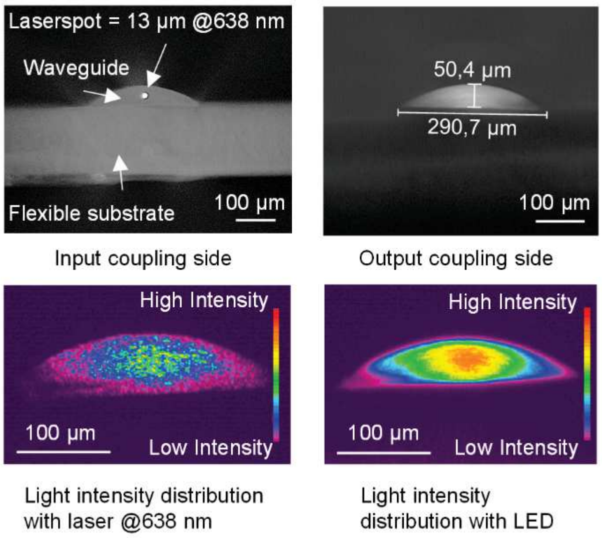

Fig. 3 *Results of the optical measurements of a polymer optical waveguide fabricated with two stage process.*

5 Optical Bending Coupler

To achieve signal transmission at junction points an optical bending coupler concept is used [5] (Fig. 4). A physical contact between two waveguides is created by an overlap of the cores and a defined force from above. Simulation results show that coupling efficiency varies dependent on the over-lap length and curvature radius. The efficiency reaches 30 % and allows for optical short range transmission. An important factor for successful coupling is the positioning of the cores to each other.

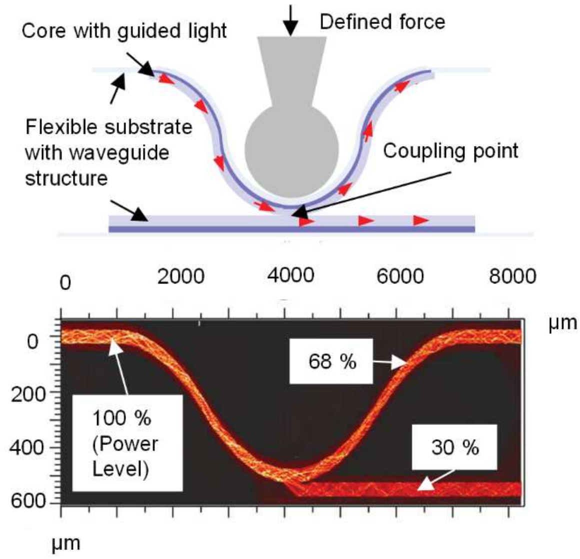

Fig. 4 *Concept and simulation model of optical bending coupler.*

6 Summary

This paper shows a fabrication process for polymer optical waveguides with a parabolic cross section that could offer an efficient production technique in the future. To achieve signal transmission at junction points an optical bending coupler concept is shown. With these technologies a three-dimensional optical interconnect device can be realized. Measurements show high quality optical characteristics and typical multimodal behaviour of the waveguides.

Literatur

[1] Michael Mertin: Photonics21 Towards 2020 – Photonics driving economic growth in Europe (2016)

[2] Wolfer T, Bollgruen P, Mager D, Overmeyer L, Korvink J. G.: Printing and preparation of integrated optical waveguides for optronic sensor networks, Mechatronics, (2015)

[3] Reitberger T, Hoerber J, Schramm R, Sennefelder S, Franke J.: Aerosol Jet® Printing of Optical Waveguides, 38th International Spring Seminar on Electronics Technology (ISSE), Eger, Hungary; (2015)

[4] Kim E, Whitesides G. M, Lee L. K, Smith S. P, Prentiss M.: Fabrication of Arrays of Channel Waveguides by Self-Assembly Using Patterned Organic Monolayers as Templates, Adv. Mater. 1996, 45(3), 123-13 (2000)

[5] L. Lorenz, K. Nieweglowski, K.-J. Wolter, K. Bock: Analysis of bending effects for optical-bus-couplers, in Proc. of IEEE 66th Electronic Components and Technology Conference (ECTC), Las Vegas, 2016.

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