Integration of microoptics on wafers with vertical emitting lasers

G. Mann, P. Dannberg, W. Buß and M. Popall*
* Fraunhofer Institut Silikattechnik Würzburg ISC

Arrays of vertical cavity surface emitting lasers (VCSELs) are available as light source for various optical systems such as optical networks, parallel optical interconnects at onboard- and on-chip level (see Fig. 1), high speed printing, display systems and more.
VCSELs are predestinate for use in arrays because of their vertical emission with low divergence and low threshold current /1/.
UV moulding enables for the generation of micro-optic elements on top of a wafer equipped with VCSELs by a wafer scale process. The process requires only one single alignment and replication step /2/.

Subject of the investigations are design, generation and characterization of microoptical elements directly on top of VCSELs on a wafer scale (see Fig.2).

The design calculations aim for lowest beam divergence of the VCSEL beam in order to avoid crosstalk between neighboring channels. Another goal is to reduce wavefront deviations, which hedge refocusing. The collimation characteristics is determined by the present VCSEL pitch (250 µm) and the laser N.A. (0.1 ... 0.2 according to the drive current). It turns out that an optimum distance between lens and VCSEL is like 350 µm (Fig. 3), the corresponding curvature radius is 150 µm. This leads to a 55% illumination of the lens aperture which theoretically means diffraction limitation and full beam power transmission. The beam propagation void of crosstalk is limited to 2,5 mm.The generation of the structure requires selection of a suitable polymer material and an appropriate uv-moulding process.
Thermal and mechanical stability, and optical characteristics like transparency and stability of the refractive index are deciding factors for choosing a polymer which embodies the microoptical structure.

A cooperative project with the ISC Würzburg /3/ discloses that ormocersä (organic-inorganic copolymers) in combination with photoinitiators are material class convenient concerning processing, stability and optical demands.

The lifetime of the polymer structure may decrease by duty in direct contact to the VCSEL emitter face. Absorption of light leads to yellowing and degradation which impairs the optical performance /4/. In order to test the longtime stability time acceleration is implemented by using much higher beam power density than at the VCSELs emitter face. Furthermore, the VCSELs wavelength of 873 nm is displaced by 488 nm, which increases the absorption.

Depending on the polymer composition the measured lifetimes spread from seconds to hours, as Fig. 4 shows. Estimation commits a resulting lifetime of 9 years for the favorite material combination, available for temperature and humidity in a laboratory's environment.

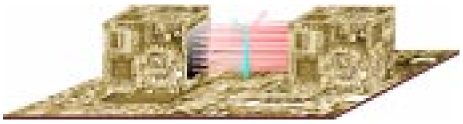

Fig. 1:
Application of 2D VCSEL arrays in an parallel optical interconnect at on-board-level

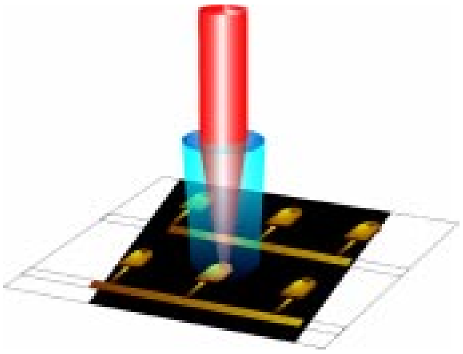

Fig. 2:
Beam shaping by microoptic elements (blue) on top of VCSELs (gold) on a wafer scale

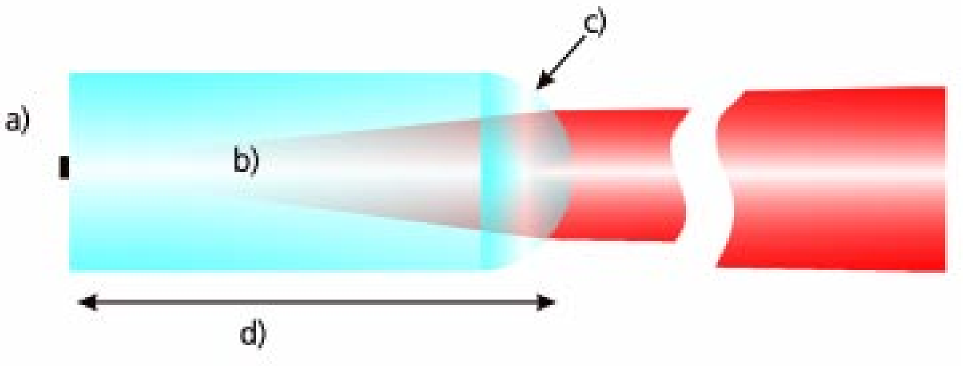

Fig. 3:
The optical system consists of the VCSEL emitter face a) and the polymer lens b), which is characterized by its length c) and its curvature radius d).

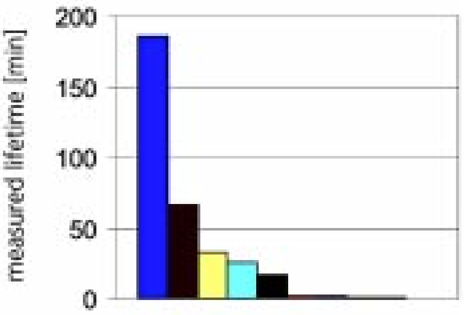

Fig. 4:
The lifetime of different polymers depends on their composition, notable variations occur

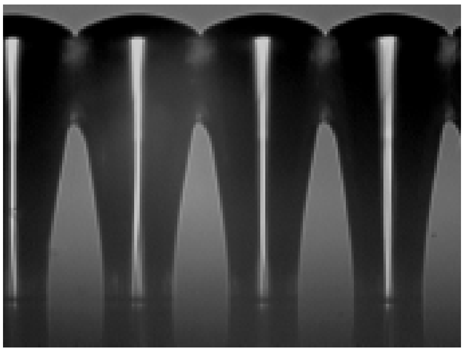

Fig. 5:
Photopolymerisation process is controlled by a exposure regime which generates clear, mechanical stabile structures

The generation of the microoptical structure is realized by photopolymerisation through a mask in combination with uv-moulding using a replication tool [2]. Optimizing the process achieves accurate surface replication, optical transparency and selective patterning. Selective processing allows to develop isolated structures, which are separated by free space e.g. for electrical bonding. By applying an exposure regime filamentary inhomogenities of the refractive index are suppressed, the generated structures in one- and two-dimensional arrays are shown in Fig. 5 and Fig. 6. The replication is reproducible with a lens curvature radius deviation of 2…5 µm.

The emission of a VCSEL array integrated with microoptical structures showed no intensity changes after the replication process and following 1700 hours operation. The optical performance of the system displays that proper alignment between mask and substrate is feasible. Fig. 7 shows the test setup. The residual beam spread is < 1°, which enables for transmission without crosstalk over 2,5 mm.

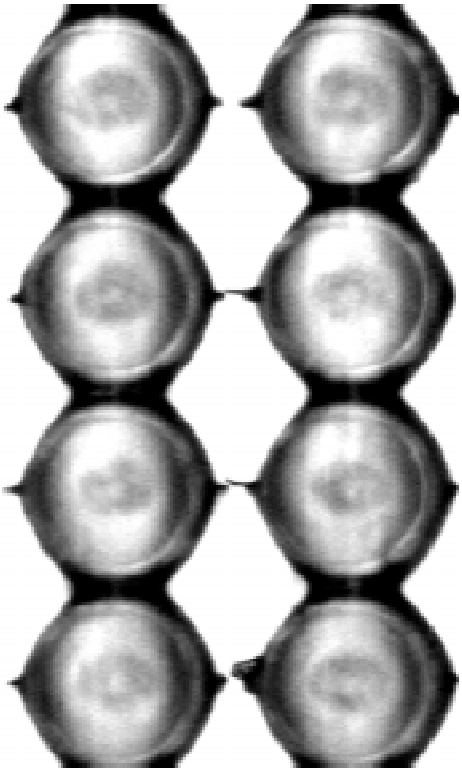

Fig. 6:
Generation of isolated structures in arrays is the most complicated application for selective photopolymerisation

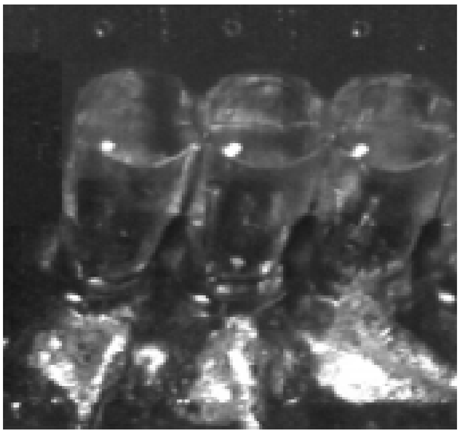

Fig. 7:
Test setup for 1D-array VCSELs with polymer lenses, the lasers are bonded to a board

References

/1/ Carl Wilmsen, Henryk Temkin, Larry A. Coldren: "Vertical Cavity Surface Emitting Lasers", Cambridge University Press (1999) pp. 334-412

/2/ P. Dannberg, L. Erdmann, R. Bierbaum, A. Krehl, A. Braeuer, E.B. Kley: „Micro-optical elements and their Integration to glass and optoelectronic wafers“, Springer Verlag, Microsystem Technologies 6 (1999) pp. 41-47

/3/ K. Rose, H. Wolter, W. Glaubitt. "Multifunctional acrylate alkoxysilanes for polymeric materials", Wat. Res. Symp. Proc. 271 (1992) 731 pp.

/4/ Norman S. Allen, Michele Edge: „Fundamentals of Polymer Degradation and Stabilisation“, Elsevier Applied Science (1992) pp. 75-102