# Fabrication of integrated structures for coupling VCSEL to fibre

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Thick photoresist is used for realisation of high quality opto-mechanical structures. In order to achieve a higher level of integration, optical functions like deflection should be included. By inclined exposure of the resist, we fabricated bevelled structures. One application is a combined fibre mount and coupling structure.

## 1 Introduction

Optical signal transmission through fibres in combination with VCSELs and photodiodes are a possibility to improve existing interconnects in computer systems. The coupling of VCSEL to fibre is either achieved by relatively large mechanical connectors, or by fibres polished in a specific way deflecting light by 90°. Since costs, alignment effort and level of integration are the most important criteria for industrial application, we developed opto-mechanical structures which can easily be manufactured and handled.

## 2 Coupling VCSELs to fibre

Bottom emitting VCSELs (**V**ertical **C**avity **S**urface **E**mitting **L**aser) on a glass substrate offer the possibility for coupling light into a fibre mounted parallel to the substrate as shown in Fig. 1. The advantage in comparison to perpendicular coupling is, that less space is needed which is important when considering interconnects between chips on the same board.

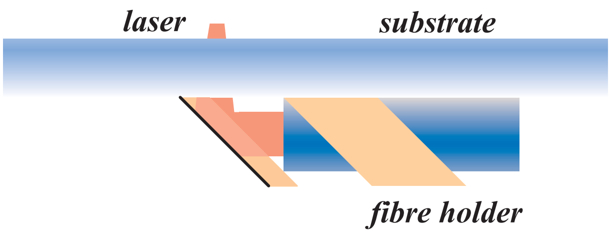


***Fig. 1*** *Coupling structure*

The deflection at the mirror can either be realised by total reflection on the back surface of the mirror or by a metal coated surface. For total reflection we need index matching between the mirror and the fibre. Therefore we chose an adhesive with a suitable refractive index which also fixes the fibre.

For using a multimode fibre, a structure height of 130 μm with a tolerance of less than 2 μm in all dimensions is needed. We developed a lithography process with thick resist and an angular illumination to match these conditions.

## 3 Lithography with negative photoresist (SU-8)

The epoxy based photoresist SU-8 with a refractive index of 1.69 is specified for structure heights of up to 1 mm and an aspect ratio of more than 1 to 100. The principle of angular exposure is shown in Fig. 2.

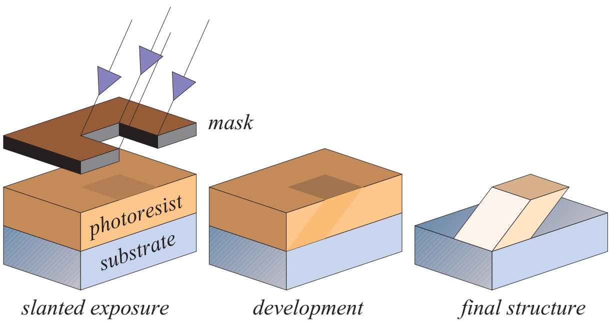


***Fig. 2*** *Principle of lithography using slanted exposure*

## 4 Limitation of exposure angle due to refraction

Considering Fig. 2, if the medium above the resist layer is air, the refraction at the interface makes it impossible for angle $\alpha$ (Fig. 3) to become smaller than 60° because of Snells Law. So, in order to achieve an illumination angle of 45° in the resist, a coupling prism is needed. The exposure angle is therefore $\delta = 31{,}1^\circ$.

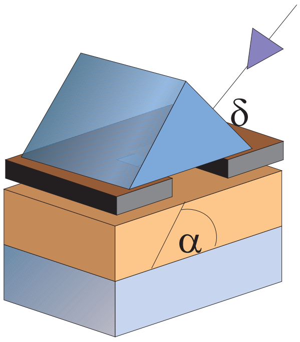


***Fig. 3*** *Illumination with a coupling prism*

## 5 Reflection from index boundaries

Index boundaries can cause total internal reflection and multiple, unwanted light contributions, which result in defects of structures. To avoid these unwanted effects, index matching is needed between every layer. We use a slanted arrangement (Fig. 4) with $H_2O$ for index matching, which is almost neutral to the resist and with a refractive index of 1.33 the total transmission is above 80%.

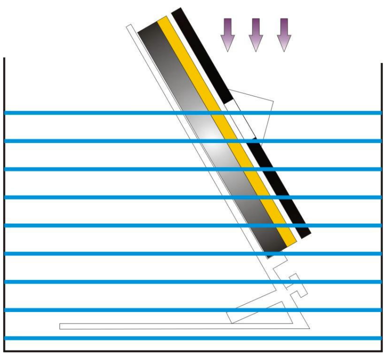

***Fig. 4*** *Exposure Setup*

## 6 Mask diffraction

The surface of a thick resist after spin coating is not planar. In our case the thickness varies from 125 μm at the center to more than 200 μm at the border. This difference causes a noticeable reduction of structure quality because the distance between mask and resist (Fig. 5) increases diffraction effects. Since the center part of the resist surface is almost planar, reduction of mask size, significantly decreases diffraction effects.

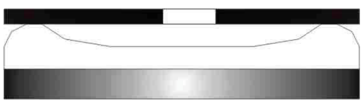

***Fig. 5*** *Surface of the resist*

## 7 Results

Fig. 6 shows the difference in quality of structure between standard and reduced mask size.

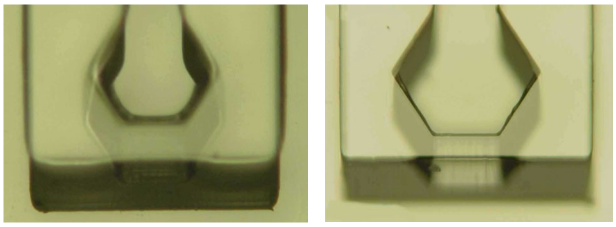

***Fig. 6*** *Final structure with full and reduced mask size ( image size 600 μm )*

The obtained angle was 45° ± 1°. The aspect ratio of the mirror is in the order of 1 to 4 (Fig. 7). First reflectivity tests are shown in Fig. 8. The left part is an array of mirrors and the right part shows a bottom view on an array structure with a light emitting fibre. The white spot represents the light reflected by the mirror.

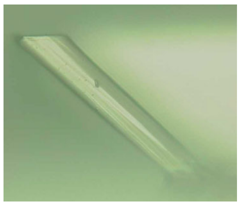

***Fig. 7*** *Sideview of the mirror ( image size 200 μm )*

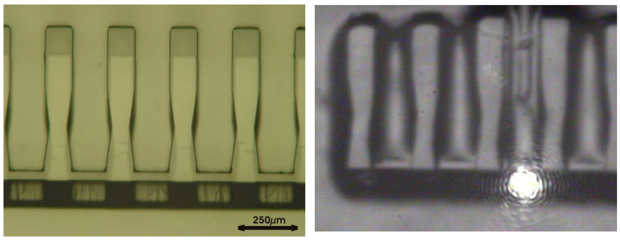


**Fig. 8** Mirror array, array with light emitting fibre *( image size 1000 μm )*

## 8 Conclusion

We have fabricated integrated opto-mechanical structures for coupling VCSELs to fibre by lithography in thick resist using slanted exposure. The measured coupling loss is smaller than 3 dB. Low cost mass production can be realised with molt injection.