

Investigation of Micro Solid Immersion Lens Mounting Systems

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Concept, design and analysis of several solid immersion lens (SIL) mounting systems utilizing high-index refractive micro SILs are described. This paper proposes several designs for wafer-scale SIL assemblies capable of a numerical aperture of 2.2. [DOI: 10.1143/JJAP.46.3737]

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1. Introduction

The need for higher resolution has given rise to systems that employ solid immersion lens (SIL) technology.^{1,2} A SIL is a lens that is inserted in an optical system after a focusing objective, very close to the object or data layer. Compared to a system in air, the SIL improves resolution by a factor equal to the SIL's index of refraction n , where resolution = $0.61\lambda/(n \sin \theta)$, λ is the wavelength in air and θ is the marginal ray angle. For common glass SILs, n is limited to below 2.0. High-index materials, like gallium phosphide (GaP, $n = 3.3$) can increase resolution further and have been successfully made into SILs.³ SILs can also be lithographically fabricated to micro-sized dimensions though wafer-scale processing.⁴ However, micro-SILs are difficult to handle and require novel methods of mounting near the system focus. This paper examines several such methods of mounting, comparing the limitations and constraints for each design.

2. μ SIL Mounting and Handling

The starting point for design is a high-index micro-SIL (μ SIL) array consisting of lithographically printed lenses etched into a bulk wafer.⁴ One method for mounting μ SILs is shown in Fig. 1, where a flat, low-index support layer is first bonded to the μ SIL wafer, then the wafer is polished to access the SIL center of curvature. The bonding agent is index-matched to the support layer. While this solution preserves wafer-scale processing of the μ SILs, there are two problems with this design: 1) loss of numerical aperture (NA) due to refraction at the top of the support layer, $NA = (n/n_g)NA_{air}$; and 2) induced spherical aberration introduced by the support layer,

$$W_{040} = NA_{air}^4 \frac{t(n_g^2 - 1)}{8n_g^3}, \quad (1)$$

where t and n_g are the thickness and index of the support layer, respectively, as shown in Fig. 1. For example, a 21 μ m radius GaP μ SIL with an $NA_{air} = 0.55$ has $NA = 1.82$. The same system with an attached glass support layer where $n_g = 1.5$ and $t = 500 \mu$ m, results in $NA = 1.21$ and $W_{040} = 2.12 \mu$ m. In this example, the focusing objective should be designed to correct for the induced spherical aberration.

3. Increased Performance Systems

To increase performance beyond that achieved with a flat

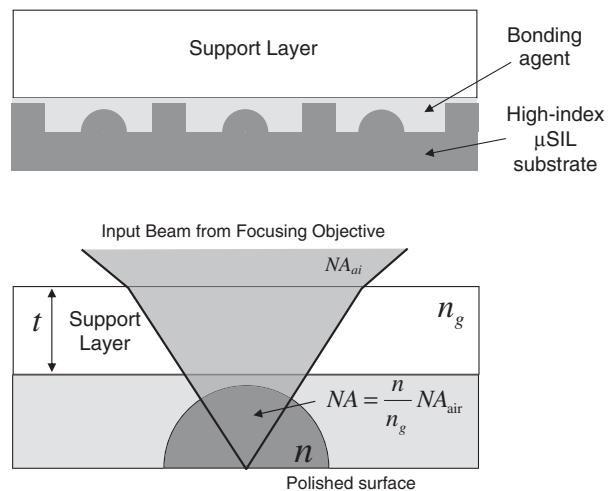


Fig. 1. Schematic showing reduction of system NA when propagating through a support layer.

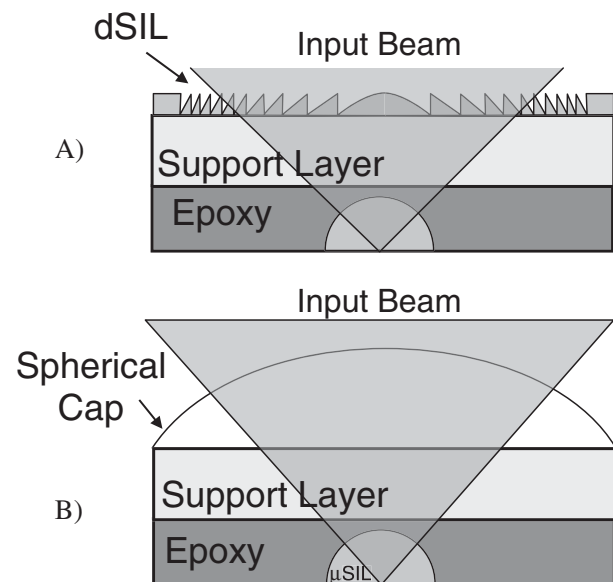


Fig. 2. Diagram of the dSIL (a) and refractive cap (b) mounting methods.

support layer, two designs are investigated, as shown in Fig. 2. The first design uses a diffractive optical element (DOE) to correct refraction and the induced aberration at the top of the support layer. Since the marginal ray angle does

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