Fabrication and Testing of a GaP SIL with NA = 2.64

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Abstract: A solid immersion lens (SIL) is described with NA = 2.64 that is fabricated from a two-step process using a large BK7 glass hemisphere and a small GaP hemisphere.

1. Introduction

In order to further increase the capacity of optical discs, many different technologies have been proposed. One strong candidate is near field optics.[1] By using a solid immersion lens (SIL) with a high refractive index material, the spot size can be reduced by a factor *n*, the SIL's refractive index, and thus increase the data density on the disc. Fabrication of very high index GaP micro-SILs has been proposed using a two-step process.[2][3] In this paper, a gallium phosphide (GaP) SIL with NA=2.64 is fabricated using a variation of the two-step process, and preliminary testing is reported.

2. NA=2.64 lens design and fabrication

The two-step process for fabricating high-index SILs proposed by Lang *et al.* is illustrated in Fig. 1.[3] The two-step process is better than fabricating a large singlet GaP lens, because ion-etching techniques can reliably etch arrays of micro-surfaces in the GaP wafer. By combining the GaP micro-SIL with a larger, easy-to-fabricate refractive SIL, handling is simplified and NA is large.

The process described in this report is similar, except that the refractive lens is not fabricated with a resist-melting step. Instead, individual GaP lenses are cut from the GaP substrate, as shown in Fig. 2(a), and they are mounted directly on the flat side of a 3mm diameter BK7 SIL. The GaP wafers are etched by MEMS Optical, Inc., to form microlenses with a 0.1140±0.0024mm radius on its surface. The pitch of the lenses is 1mm. The thickness if the BK7 SIL is reduced to accommodate the GaP SIL, such that both SIL surfaces are image centric. The combination is then mounted in a custom holder that is used for chamfering, lapping and polishing. Careful control in these steps is necessary in order to provide a high quality lens.

A BK7 glass hemisphere with 3mm diameter is first mounted on a holder and then lapped and polished to a thickness of 1.476mm, which allows for the GaP lens thickness and an epoxy layer. The GaP microlens is cemented in the center of the glass hemisphere with an index-matching epoxy, as shown in Fig. 2(b). Then, the GaP microlens is lapped and polished to the correct total thickness. Surface root-mean-square roughness (RMS) is such that RMS ~ 2nm, as measured by a WYKO NT2000 optical profiler in PSI mode that gives a vertical resolution of 0.3 nm. Two photos are shown in Fig. 3, where 3(a) is a photo of surface of the GaP SIL (RMS=8.69nm, area=130μm*100μm) and 3(b) is a photo of the subregion of the central part of the GaP SIL (RMS=0.86nm, area=35μm*30μm). These photos show that a small amount of residual curvature remains on the GaP SIL, but it is negligible in the small region in the central part of the GaP SIL where the lens is used for imaging. Also, the surface quality is adequate in this region.

After the polishing step, excess GaP material is removed and the assembly is faceted with 15 degree slope angles. The GaP SIL then is mounted on a flexure, as described by Chen *et al*. [4], which is inserted between the objective lens and sample in the microscope imaging system shown in Fig. 4. A pupil image of the induced polarization reflection captured by the CCD is shown in Fig. 5(a). A simulated pupil image is shown in Fig. 5(b), where the model is based on vector plane-wave decomposition of light emitted from the exit pupil [5][6][7]. The experiment is performed with the SIL mounted on an inverted Olympus IX70 microscope [4], which has a 100X, 0.8NA objective lens in air that illuminates the combination SIL. In this case, the GaP (n=3.3) SIL used with a 650nm laser source has NA=3.3×0.8≈2.64. The wide induced polarization pupil image for GaP SIL (NA=2.64) compares well with the simulation, but contamination of the epoxy layer with small air bubbles causes distortion of the pattern. A second two-step GaP SIL system is being constructed using an improved cementing technique. Hopefully, we will show a better experimental induced polarization pupil map and imaging results [8] at the conference.