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Consideration and Control of Writing Conditions with Near-Field Aperture Solid Immersion Lens Probe

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Control of writing conditions for near-field aperture-SIL (APSIL) probe is investigated with respect to polarization, axial focus position of the objective lens and beam transverse misalignment. Both FDTD simulations and edge-scan experiments are used in the investigation. The TE direction is the optimal writing polarization direction, and the probe exit plane is the optimum focus position of the illuminating lens. Spot size change and spot position shift relative to the center of the probe are observed with TE polarization when the writing beam is transversely misaligned. [DOI: 10.1143/JJAP.42.1090]

KEYWORDS: near-field aperture SIL probe, optical data storage, polarization, axial focus position, beam transverse alignment, spot profile

1. Introduction

The solid immersion lens (SIL) and aperture probes are two near-field optical techniques that are capable of generating a smaller spot size at the $1/e^2$ power diameter than that of classical optical systems.[1,2] Neither technique can both generate an ultra-small spot size and exhibit high optical efficiency. A small spot size produces higher contrast signals, which leads to an increase in the signal-to-noise ratio (SNR) and an enhanced capacity of the optical disk. Higher optical efficiency gives higher throughput in the optical system, which improves the data rate. Small spot size and high efficiency are particularly important in a reflective-type optical data storage system, which is the application of the near-field aperture SILs (APSILs) discussed in this paper.

The technique of APSIL, which combines a dielectric conical probe and a SIL, is a promising method for achieving both a small spot size and high optical efficiency.[3] Our prior experiment with an edge-scan test demonstrates that the APSIL exhibits a resolution of 200 nm full-width $1/e^2$ spot size and 50% optical efficiency in reflection.[4] The 200 nm spot size is one-fifth of the spot size in commercial digital versatile disc (DVD) drives (1080 nm full-width $1/e^2$ spot size). In other words, the areal density of an APSIL probe disk system has the potential to be 25 times larger than that of a DVD. With such significant progress of the APSIL system, it is important to understand the consideration and control of writing conditions with an APSIL probe. In particular, study of the writing conditions provides information about the tolerance of the system alignments, which determines the value of the designed system in practical use.

This paper investigates control of the writing conditions with respect to the polarization direction of the illumination source, axial focus position of the objective lens, and beam transverse shift relative to the center of the probe by simulations and experiments. The figure of merit for investigated parameters is the quality of the spot generated by the probe, including the spot size and position. A finite difference time domain (FDTD) simulation tool, providing a rigorous vector EM treatment, is used for the investigation. In the experiments, an edge-scan test on a phase grating is adopted. Both simulation and experimental results are compared to verify the consistency.

2. Optical Setup for Simulation and Experiment

The basic geometry of the APSIL is a conical dielectric probe attached to the bottom of a SIL with refractive index 1.843. As shown in Fig. 1, light from an objective lens of 0.5 numerical aperture (NA) is focused through the small aperture probe and propagates to the recording layers. The entrance diameter and the exit diameter of the probe are 320 nm and 200 nm, respectively. The probe height is 400 nm. Details of the probe design can be found in ref. 5. We use a 488 nm wavelength Argon laser as the light source, and thus the effective NA (NA_{EFF}) of the APSIL is 2.4.

The illumination setting for FDTD simulation is shown in Fig. 2. A small current source, whose length is much smaller

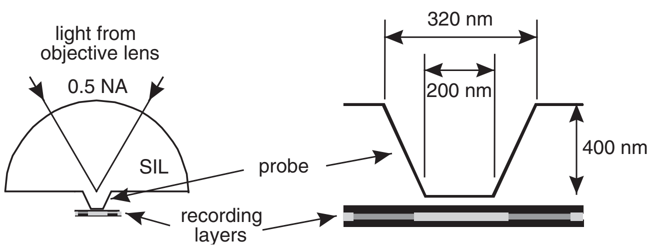

Fig. 1. Geometry of an APSIL. The entrance of the APSIL probe is 320 nm in diameter. The exit of the APSIL probe is 200 nm. The probe height is 400 nm.

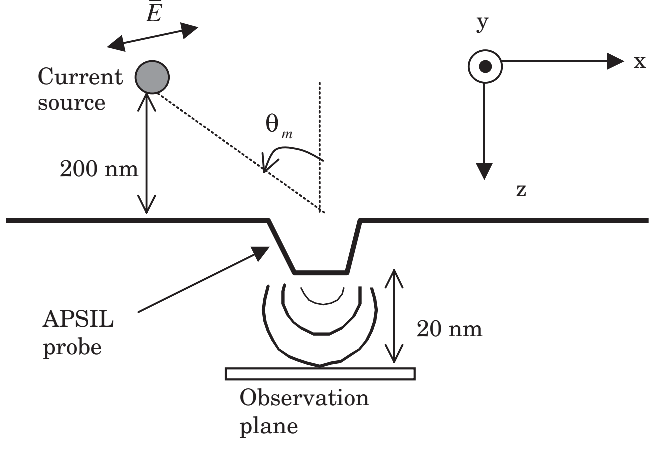

Fig. 2. Illumination setting used in the FDTD simulation.