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High Density Optical Memory using Nano-aperture Probe and VCSEL with Integrated Microlens Array

Young-Joo Kim and Shinill Kang

Center for Information Storage Device (CISD)
Yonsei University, Seoul 120-749, KOREA

1. Introduction

For the next generation high density optical memory, several approaches have been studied, including near-field recording using solid immersion lens (SIL)^{1,2}, super-RENS³, multi-layer recording⁴, holographic memory and nano-aperture probe⁵. Among them, the near-field optical probe array has an advantage to increase the data capacity and data transfer rate since it can overcome the diffraction limit of current far-field optics and use multiple laser sources.⁵⁻⁶ Since the optical head have to be located to the media within 100 nm, however, it is strongly required to design and fabricate the compact optical head which consists of multiple light sources, nano-aperture probe array and/or microoptical components such as microlens. Thus, it is a good approach to miniaturize the head size using a monolithic integration process of microlens array on the surface emitting lasers. Since a vertical cavity surface emitting laser (VCSEL) is prepared with 2-D array structure on the wafer, it has an important merit to combine with other optical components easily on the wafer scale. As shown in Fig.1, the microlens array is first prepared directly on the emitting surface of VCSELs and followed by the attachment of the nano-aperture array which is prepared separately. In this paper, the design concept and fabrication method for the near-field optical array head is discussed with the emphasis on the monolithic integration process as well as the nano-aperture probe array of optical throughput enhancement.

2. Design and Fabrication of Nano-aperture Probe

The structure of high optical efficiency probe is based on the wave propagation theory in dielectric layer between two thin metal films. It has been reported that interference of guided modes in the metallic probe results in the maximum electric field intensity and minimum spot size at the cutoff diameter. The simulation results have shown that TEM wave is propagating in the multilayer structure approximately with a speed of light in dielectric medium.⁷ The microprobe structure has a pyramidal structure with two side metal coating of which parameters are optimized for the best optical throughput and small spot size in the nano-aperture. By the theoretical calculation, a small spot size of 40nm was realized with the field enhancement of 400 times and optical throughput of more than 2% at the 50 nm distance from the nano-aperture of the probe, as shown in Fig. 2. To realize the waveguide probe structure having nano-aperture, the micro fabrication processing has been studied with a dielectric layers as SiO₂. The microprobe fabrication includes many processes, including thermal oxidation, photolithography, wet etching of Si wafer and thin metal deposition, which will be included more detail in the presentation. Finally, the nano-aperture fabrication is followed to form tiny apertures on the microprobe tips and evaluated to get the optical throughput and spot size at the nano-aperture.

3. Integration of Microlens Array on VCSELs using Micro UV-molding

Since the focusing of laser from VCSEL on the inside of probe can enhance the optical efficiency, the microlens array was integrated on the VCSELs. Among the various methods to couple optoelectronic device with micro optics, the monolithic lithography integration is more suitable since it is a low cost process and will be free from the additional assembling process. In this research, thus a monolithic lithography integration using micro UV-molding has been designed and constructed to integrate the microlens array directly on the VCSELs.

Microlens array with a diameter of $40\text{ }\mu\text{m}$ and a sag height of $2.50\text{ }\mu\text{m}$ is designed and prepared on the VCSEL array using a UV-molding process. Fig. 3 shows the SEM images (a) UV-transparent mold and (b) integrated microlens array on VCSELs, respectively. A surface roughness of microlens prepared in this research shows a value of 1.24nm (rms), as shown in Fig. 3(c). More detailed processing issues and the evaluation test for the focused beam of VCSEL will be discussed in the presentation.

4. Summary

The design concept and fabrication process for the high density optical memory has been studied with an emphasis on the monolithic integration process as well as the nano-aperture probe array of optical throughput enhancement. The process of compact near-field optical head includes the microfabrication of nano-aperture probe of high optical efficiency and the monolithic lithography integration of microlens array on the VCSELs using a UV-molding. The evaluation result shows the strong possibility of applying the proposed near-field optical head to the future high density optical memory.

References:

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Fig.1. Schematic diagram of compact near-field optical head.

Fig.2. Theoretical optical throughput of probe

Fig.3. SEM images of (a) UV-transparent mold, (b) integratedd microlens array and (c) surface roughness