Chapter 1

Introduction

1.1 Motivation

The high density data storage technologies have attracted lots of attention continuously. A large number of data to be recorded with an efficient method is always needed. The optical data storage technique is a very popular method to achieve this goal. In optical data storage system, the pick-up head is the key element for high density recording. Due to the diffraction, the spot size of conventional optical data storage system (far field recording) is limited to the wavelength of the incident light. In order to overcome the diffraction limit, various novel approaches have been proposed toward near-field recording. The near-field recording is attractive because the spot size is not restricted by the diffraction limit. Therefore, the recording density in near-field recording is greater than conventional recording technology (far-field recording). Hence the designed fabrication of a pick-up head for near-field optical data storage becomes an important issue.

1.2 Related Researches

Many applications in near-field technology have been demonstrated, for example, the Near-Field Scanning Optical Microscopy (NSOM), Atomic Force Microscopy (AFM), and Magneto-Optic (MO) Pick-Up Head etc.. In high density data storage, some key components were proposed to reduce the spot size, including SIL (Solid Immersion Lens), SSIL (Super-hemispherical Solid Immersion Lens), and sub-micro aperture. Various fabrication methods of SIL/SSIL and aperture will be described in this section. Also, the related researches on integrated structure of MO pick-up head will be reported.

1.2.1 Fabrication of Microlens

In 2000, Lee et al. reported a bulk micromachining technology to form a microlens by high doping concentration, as shown in Fig.1-1. They utilized different selectivity of etching rate between doped and undoped silicon region. Finally, a hemispherical microlens was formed by EDP etching step. In this case, the diffusion diameter and diffusion parameters such as temperature/time controlled the diameter and height of the microlens.

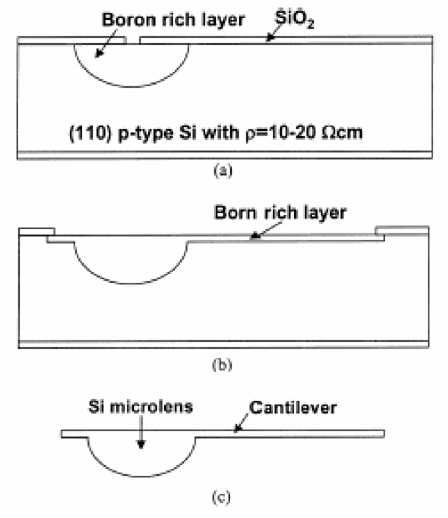


Fig.1-1 Fabrication process of Si microlens by selective etching (Lee et al., 2000)

In 2000, Yee et al. reported another attractive molding method to fabricate the microlens array. The hemisphere fillisters were made by isotropy wet etching on (100) silicon substrate. An optical-grade PMMA powder was put into the micromachined mold insert mounted on a hydraulic press machine. The mold was heated above the glass transition temperature (Tg) of PMMA. After cooling down and releasing process, the microlens array was obtained and shown in Fig.1-2.

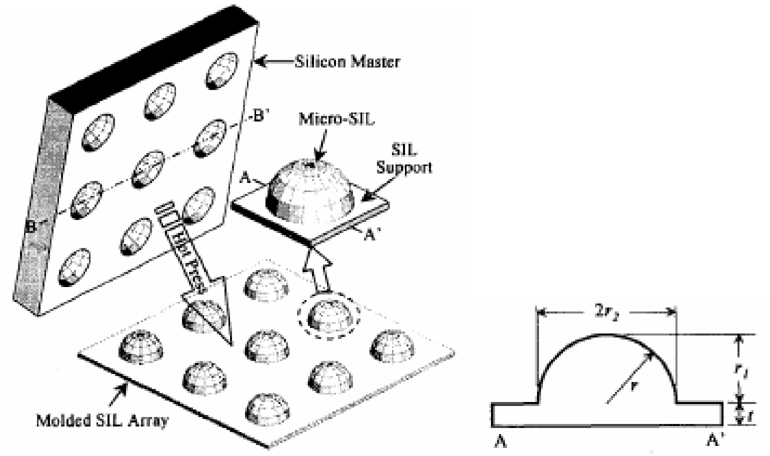


Fig.1-2 Fabrication of the SIL by press molding (Yee et al., 2000)

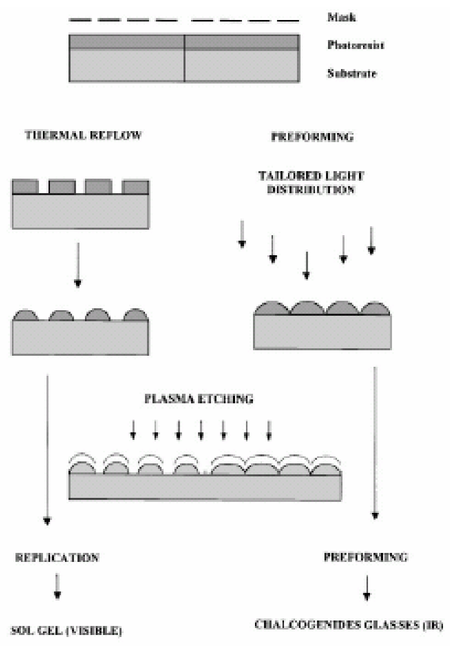


Fig.1-3 Schemes of microlens arrays fabrications (Eisenberg et al., 2000)

In 2000, Eisenberg et al. presented two different methods to fabricate microlens array. The first method was to coat the photoresist (PR) on the substrate. By the lithography process, the photoresist was patterned with pillar structures. When the photoresist patterns were heated over glass transition temperature (Tg), it begins to melt and liquid-like photoresist tends to minimize its surface in order to reduce the surface energy. So the microlens array was formed. The second method, the desired shape was created directly by using a tailored distribution of light. A tailored distribution of light could be obtained by a “modified” proximity method (i.e. changing the distance between the mask and the photoresist) or by the use of halftone or by the continuous tone masks. Finally, the Reactive Ion Etching (RIE) was applied to transfer the photoresist microlens structure into the substrate material with good optic property. The fabrication process was shown in Fig.1-3.

In 2001, Lin et al. presented a process to fabricate microlens array by thermal reflow. The fabrication process was shown in Fig.1-4. First, polyimide was spin-coated on substrate. Then the thick photoresist AZ-4620 column array was patterned on the polyimide film by UV lithography. At the same time, polyimide was etched during development. When the reflow temperature was heated over the glass transition temperature of photoresist AZ-4620, a microlens array could be obtained. This is due to the glass transition temperature of photoresist AZ-4620 was less than the polyimide.

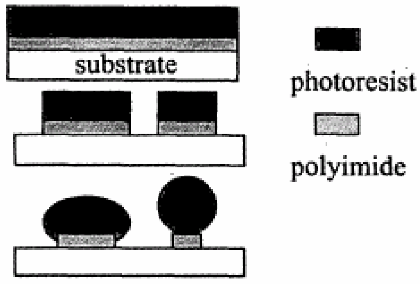


Fig.1-4 Fabrication process of microlens array (Lin et al., 2001)

1.2.2 Fabrication of Aperture

In 1996, Takuya et al. presented approach to make an optical fiber tip, as shown in Fig.1-5. These tips were made of stretched or sharpened optical fiber, usually in pipette shape. At the end of the tip, a metal layer was coated. Then, the metal at the end of the tip was etched by chemical solution. So a tiny aperture was formed.

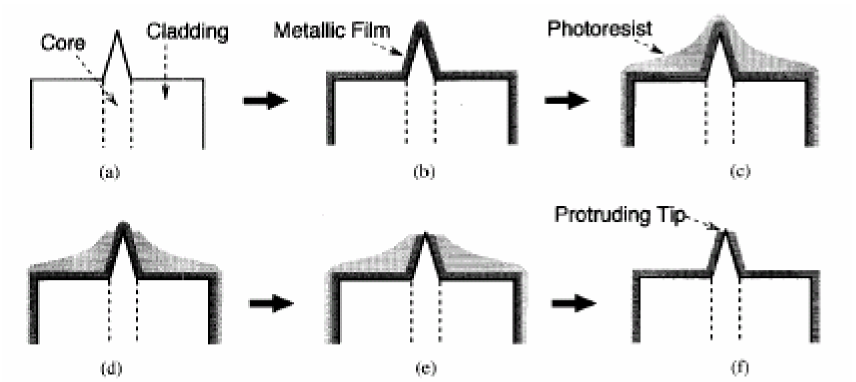


Fig.1-5 Fabrication of a fiber tip by chemical etching (Takuya et al., 1996)

The removal process of the metallic film at the apex was shown in Fig.1-6. The photoresist was exposed by the evanescent wave effect. The diameter of the foot of the protruding tip, i.e. the diameter of the aperture of the metallic film, could be about 30nm, if the exposing process were well controlled.

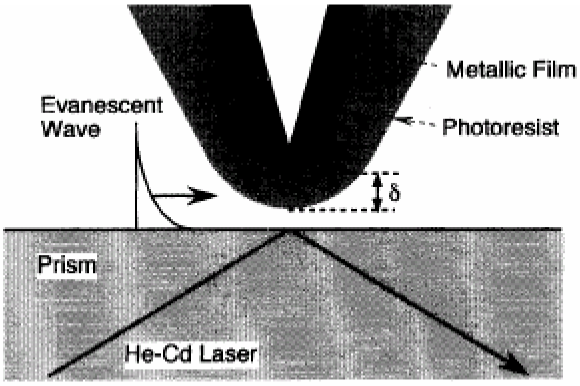


Fig.1-6 Exposure by using the Evanescent Wave (Takuya et al., 1996)

As shown in Fig.1-7, another way to make a tiny aperture from a metal-coated tip was the Focus Ion Beam (FIB) technique (Saeed et al. 1999). In this technique, an ion beam was focused precisely to cut away the material at the apex of the tip, make an opening of the metallic film. Generally the opening hole could have a diameter smaller than 100nm.

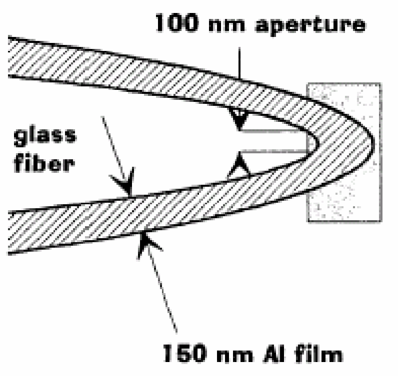


Fig.1-7 Fabrication of a metallic aperture by using FIB milling (Saeed et al., 1999)

Although the methods above are effective, unfortunately, they are not suitable for batch production. The following will describe some fabrication of aperture by a batch process. Furthermore, the fabrication of a integrated structure combining microlens and aperture becomes easier.

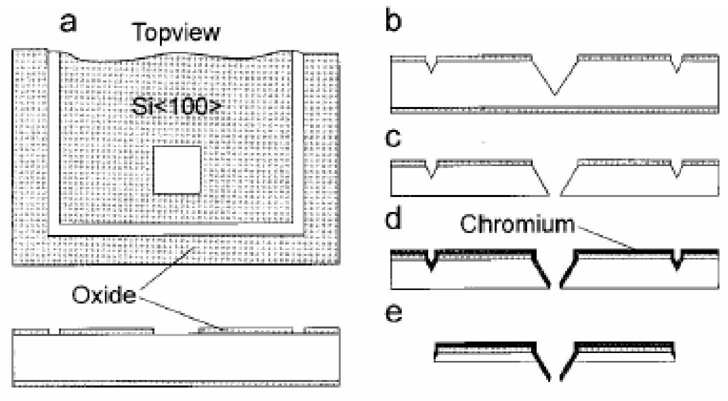


Fig.1-8 Scheme of the fabrication process of a aperture (Mihalcea et al., 1996)

In 1996, Mihalcea et al. reported the fabrication of an aperture by anisotropic wet etching and deposition techniques. The process was shown in Fig.1-8. First, the oxide film was grown on silicon substrate for mask material. Then, the oxide film was defined to make the cantilever and aperture pattern. Next, an anisotropic etchant (30wt% KOH at 80°C) was used to produce the pyramidal groove for aperture and the desired cantilever. After removing the backside oxide film, the silicon membrane was etched anisotropically until the pyramidal groove was opened. So a small aperture could be formed. Then, the chromium layer was deposited on the top surface and pyramidal groove to shrink aperture. Finally, the structure combined cantilever and aperture together was released by RIE etching. The optima size of the aperture about 50nm could be obtained.

In 2001, Lane proposed a method to form a tiny aperture by over-electroplating. As shown in Fig.1-9, an initial aperture size was defined by lithography process. Then, the electroplating step was adopted to shrink the initial aperture size. The final diameter of the aperture was determined by electroplating parameter, such as: electroplating time and current density etc.. Besides, the cost could be decreased in this technology.

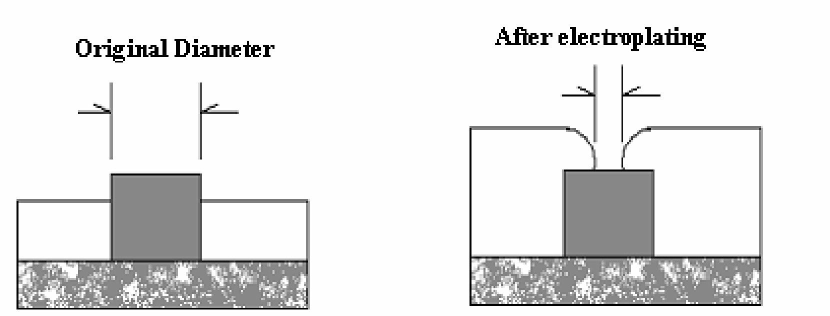


Fig.1-9 Making a sub-micro aperture by over-electroplating (Lane, 2001)

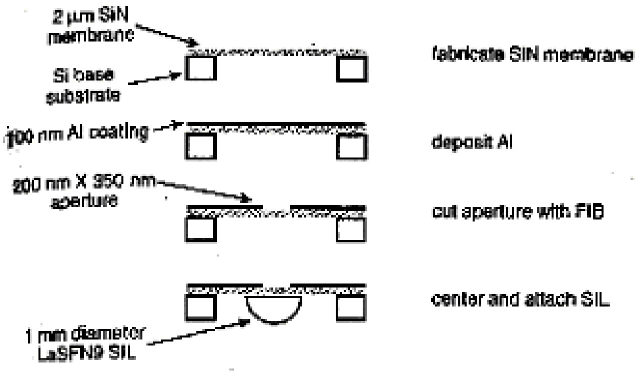


Fig.1-10 Fabrication process for aperture array combined with the SIL (Milster et al., 2001)

In 2001, Milster et al. reported a structure combining a SIL and an aperture by the assembling process shown in Fig.1-10. By combining the SIL and aperture, a better resolution was achieved. First, a 2μm thick SiN membrane was fabricated, then, 100nm aluminum (Al) was deposited on the membrane. After, the Focus Ion Beam (FIB) was employed to cut the Al film to form the aperture. Then, the fabricated SIL was attached to the backside of the membrane. However, this is not a batch process to combine the SIL and the aperture in a pick-up head. Furthermore, the SIL and aperture is not easy to align precisely in assembly process.

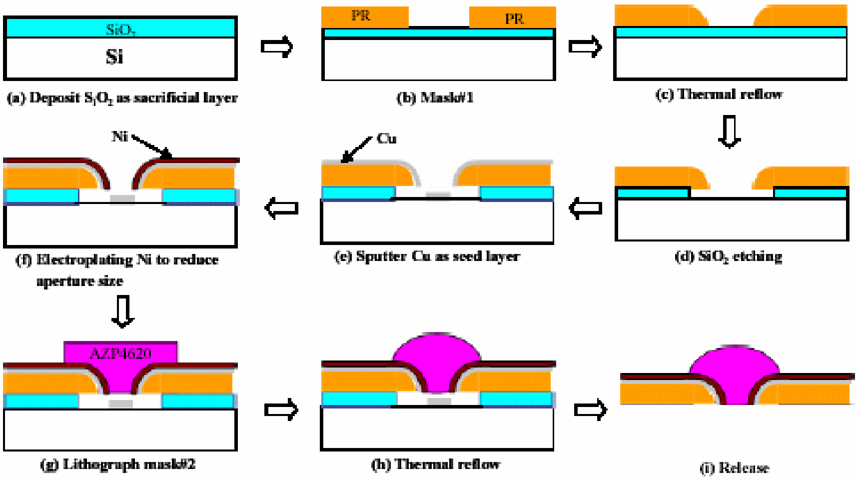


Fig.1-11 Batch fabrication process to combine the SIL and aperture (Chou, 2002)

In 2002, Chou proposed a new process to combine the SIL and aperture by a batch process. First, a silicon-oxide layer was deposited on the substrate as a sacrificial layer. Initial aperture was patterned by the photoresist lithography process. Then a thermal reflow at 150°C was adopted to make the sidewall of the aperture smooth, which could allow more incident light. After that, the substrate was put into the etchant to remove the sacrificial layer under the aperture properly to prevent the aperture sealing in following sputtering process. Then the aperture could be shrunk to a sub-micro size by electroplating. Then, the lithography and the thermal reflowing process were employed to fabricate the SIL lens again. Finally, the total structure was released. The process is shown in Fig.1-11. Although this process is a batch process for the pick-up head fabrication, but the alignment between the SIL and aperture in a batch process is still a problem. The misalignment between the SIL and aperture will cause the optical performance lose in near-field recording.

1.2.3 Integrated MO Structure

In 1998, TeraStor Corporation brought up the integral MO structure that combined the SIL and microcoil together, as shown in Fig.1-12. This structure was positioned at a close distance above the surface of the spinning disk. If the distance between the SIL and the recording disk was less than the wavelength, the diffraction limit could be overcome. When a laser beam passed through the objective lens, and was focused again by the SIL component. The resolution of the spot could be shrunk by the SIL. The recording mechanism was induced by Evanescent Coupling for data storage.

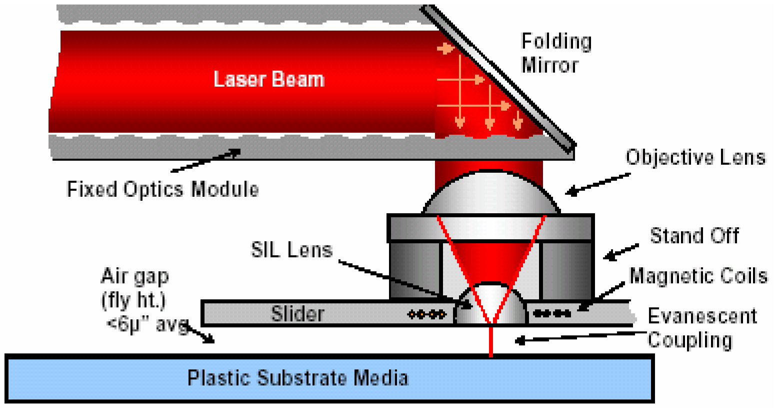


Fig.1-12 MO pick-up head combined the SIL, microcoil (Terastor, 1998)

In 2000, Kato et al. presented another structure for near-field recording. This device combined the SIL and aperture components, as shown in Fig.1-13. The spot size could be shrunk by the SIL and aperture for higher recording density. In the case, the individual parts were fabricated separately, so that every part must be aligned and bonded precisely.

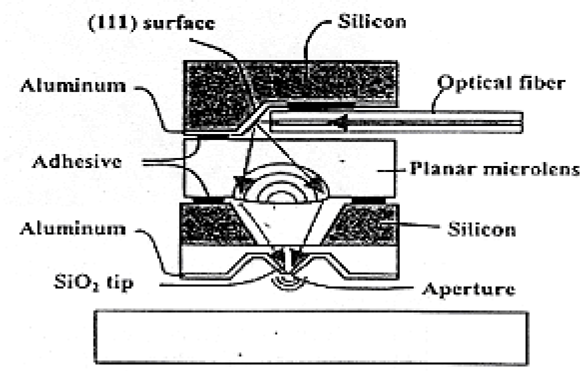
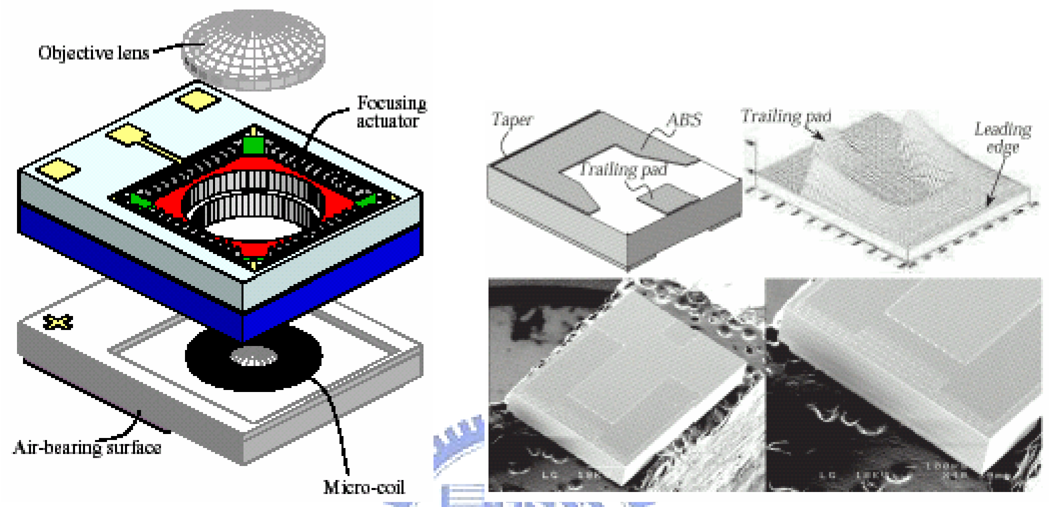


Fig.1-13 Cross section of the near-field optical pick-up head (Kato et al, 2000)

In 2003, LG Company demonstrated a micro optical pick-up head for MO recording. This structure combined microcoils, microlens, and air-bearing slider, as shown in Fig.1-14(a). The laser beam passes through objective lens, and was focused by the microlens. The focusing length of the objective lens was controlled by a vertical comb-drive actuator. By using air-bearing slider, the flying height between the bottom of the pick-up head and media surface was controlled very well. The air-bearing structure is shown in Fig.1-14(b). However, this structure have to own a very precisely alignment technique in individual parts bonding process.



(a) (b)

Fig.1-14 (a) Schematic drawing of a micro optical pick-up head composed of the objective lens, focusing actuator, microcoil, and air-bearing (b) the air-bearing structure (LG Company, 2003)

From the above structure, it is found that a precise alignment technique is needed to fabricate pick-up head. Besides, a batch process is needed too. In 2003, Shieh et al. brought up a new method to fabricate MO pick-up head by surface micromachining (MEMS technology), as shown in Fig.1-15. The optical head module was composed of a well defined V-groove with a 45° mirror, a front-end optical fiberlens, the SSIL, and an aperture. The laser beam was guided by the fiber, collimated by the front-end fiberlens, and reflected by the 45° mirror into SIL lens. The spot size was reduced by the SIL and aperture components to obtain higher recording density. In this case, the

MO pick-up head was made by a batch process. But the misalignment between the SIL and aperture is still a problem.

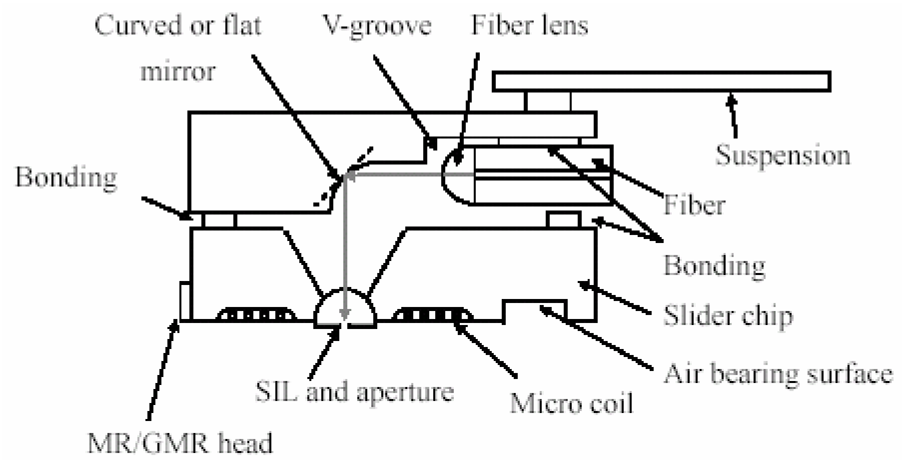


Fig.1-15 Near-field optical pick-up head structure (Shieh et al., 2003)

1.3 Current Approach

From the previous researches, it is found that the SIL/SSIL and aperture act as the key components to reduce the spot size in near-field recording pick-up head. By using the SIL/SSIL or aperture component, the recording density could be increased. By combining the SIL/SSIL and aperture together, a better performance can be obtained. But the alignment between the SIL/SSIL and aperture is very critical. Hence a precise alignment process between the SIL/SSIL and aperture must be needed. Furthermore, a batch process is also needed to fabricate near-field pick-up head.

Here, in order to overcome the misalignment problem, a self-alignment process is proposed to align precisely between the SIL/SSIL and sub-micro aperture for the MO pick-up head. Also, a new design of the integrated MO pick-up head is proposed for near-field recording. This MO pick-up head combines the SIL, sub-micro aperture, microcoil, and contact pad. The microcoil is taken as the magnetic field generator to provide an extra magnetic field for data reading and writing. The current density is inputted into microcoil by the contact pad. The SIL/SSIL and sub-micro aperture components are used to reduce the spot size. Hence the high density recording will be realized in this MO pick-up head.

The MO pick-up head will be fabricated by a batch process without bonding or assembling. The fabrication processes are based on surface micromachining (MEMS technology) and electroplating technologies. Furthermore, this MO pick-up head can be further combined with an optical fiberlens (Tien et al. 2001). Therefore, a smaller device area and high performance MO pick-up head are expected to be achieved by this fabrication process.