In the optical drive system adopting optical flying-type head (OFH), flying stability of small OFH interfaced with a removable plastic disk is investigated as basic functions of reliable optical pickup head for first surface recording. Additional micro actuators for focus servo are studied for better interface of OFH on the thin cover layered plastic disk to eliminate focus error due to the non-uniformity in cover layer thickness and the tolerance of lens assembly.

Key words: Optical pickup, Plastic disk, Optical flying head (OFH), Slider, Air bearing surface (ABS), Small form factor (SFF), Optical disk drive (ODD), Flying stability, Focus actuator

1. Introduction

The use of optical flying head (OFH) with a high numerical aperture (NA) objective lens is an effective solution when building a small form factor (SFF) optical disk drive (ODD) for first surface recording. Generally the usual optical pickup adopting OFH requires both precise assembly of the optical components with each other during the manufacturing process and reliable motions during the operation.

![Fig. 1 Various focusing errors in the optical flying head system interfaced with plastic disk](image)

However, in high NA pickup head system interfaced with cover layered plastic disk, floating gap between the OFH and the recording layer of rotating disk media varies as shown in Fig. 1 because of the non-uniformities in the disk surface, disk waviness, and flutters. Furthermore, the accumulated focus errors in the assembly of the optical components severely degrade the laser beam spot focused on the recording media. Therefore, in the SFF ODD, the OFH technology on thin cover layered plastic disk requires not only uniformity of the cover layer thickness of the disk media but also flying stability of OFH on the plastic disk surface with low flying variation, as well as precise tolerance management in the OFH assembly.

Moreover, besides of tribological performance as flying slider in the HDD, an additional focus actuator should be equipped to eliminate focusing error due to the non-uniformity of cover layer thickness, which is adopted for surface protection from environmental dust.

Therefore, in order to develop proper OFH interfaced with plastic disk in mobile SFF ODD system, first we evaluate the characteristics of flying stability related with various disk parameters, such as disk waviness and flutters. Then referring to dynamic characteristics of flying head on plastic disk, we study different types of focus actuator which can be adopted in optical pickup head in the SFF ODD system.

2. Flying stability variation under various disk parameters

For mobile devices application of a SFF ODD, the OFH system with a high NA objective lens is an effective solution when building for first surface recording type ODD[1]. However, the application of the OFH to thin cover layered plastic disk strongly calls for the advanced technologies to keep the stable flying of the OFH on a flexible and various plastic disks as well as a non-uniform cover layer thickness of the disk.

The OFHs have been proposed by several advanced studies. Especially, Kim et al.[2][3][4] suggested a new OFH for application of a small form factor plastic disk, where the target flying height at the lens is $2\mu m \pm 0.1$ with the nominal flying height of 200 nm. However, this design can...
not meet the required flying stability on the load/unload (L/UL) and the plastic disk systems because this basically relies on parametric study in a limited fashion using designer’s experience.

For the introduction of the L/UL mechanism, a reliable design way of the slider is to pitch the slider up and maintain a positive pitch throughout the dynamic load process[4]. Large pitch angle is also required to reduce the probability of the contact between the head and disk. On the other hand, since a plastic disk for a small form factor has the vertical run-out or flutter of several 10μm order, this vibration leads to increase the flying height variation as shown in Fig. 2.

![Fig. 2 Flying height (FH) variation due to disk waviness and flutters](image)

To obtain high stability on flying height, it is important to achieve a high air-bearing stiffness and to reduce the flying height fluctuation during the slider motion over the disk surface[4]. Hence, the air-bearing stiffness should be enhanced to keep the small variation of the flying height from the external disturbance, if possible.

In this study, an optimum design of the OFH is carried out beginning from this design point [2] in order to achieve more stable flying characteristics on the plastic disk. Design variables are set to five dimensional indexes defining the air bearing surface of the OFH. The objective is to minimize the variation of the flying height at lens from the target one, 2μm. The constraints are to keep the pitch angle higher than the target value, 180μrad for the application of the L/UL system and, simultaneously, to make the air-bearing stiffness of flying height, pitch, and roll angles to increase by 30%, respectively, for the application of the plastic disk.

The optimal solution of the OFH was automatically obtained. The optimized configuration, pressure distribution, and mass flow are shown in Fig. 3. Here, the scale displayed in the pressure profile is normalized to ambient pressure. The bright color refers to a high positive pressure resulting in lift force of the slider, and the dark one does a negative pressure resulting in suction force. The mass flow is plotted as the stream lines to estimate the path of inlet air flow. Here, the stream lines are drawn based on the average flux in the interface.

Their flying characteristics and air-bearing stiffness are also listed in Table 1. The results show that the pitch angle and all of the air-bearing stiffness are optimally increased without change of the target flying height at lens. That is because the proposed approach is able to effectively control the pitching moment of the OFH and to increase the surface area for negative pressure while increasing that for positive pressure.

![Fig. 3 Optimum ABS & pressure and mass flow distribution](image)

<table>
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<th>Table 1 Flying attitude and air-bearing stiffness</th>
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<td>FH@lens [μm]</td>
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In addition, to evaluate the real flying stabilities, the dynamic characteristics about disk waviness and flutter are simulated in Fig. 4 and 5. First, to explain the variation in the flying height of the OFH, Fig. 4(a) shows a variation gain, which means a ratio of the flying height modulation (FHM) over the amplitude of disk waviness, with respect to disk wavelength. Here, the amplitude of the waviness is set to ±100nm and the wavelength varies from 0.1 times the slider length to 10 times.

The optimal design looks more stable than the initial one over all disk wavelengths. However, the simulation result is present with a variation gain rapidly increasing as the wavelength approaches the slider length. Their FHMs could be larger than the amplitude of the disk waviness.
when the wavelength is less than the slider length.

![Graph](image)

(a) Variation gains with respect to wavelength

![Graph](image)

(b) 2 times the slider length

![Graph](image)

(c) 0.4 times the slider length

Fig. 4 Flying stability on disk waviness

For example, Fig. 4(b) indicates that the large wavelength allows the OFH to easily follow the wavy disk with a bit of time delay. However, Fig. 4(c) implies that the OFH is not able to follow the waviness of the plastic disk anymore. The peak-to-peak amplitude of the FHM increases into 0.23\(\mu\)m which is larger than the target value of the FHM's tolerance, \(\pm0.1\mu\)m, as mentioned above. Therefore, the slider length should be smaller than the wavelength or the wavelength should be larger than the slider length to keep the flying stability from the disk waviness.

![Graph](image)

Fig. 5 Flying stability on disk flutter

To investigate the flying instability occurred by the vibration of a flexible plastic disk, Fig. 5 shows the FHM on disk run-out or flutter. Here, the flutter amplitude is set to \(\pm25\mu\)m considering the flexibility of a small form factor plastic disk and its frequency is two times the rotational frequency of the disk. The results show that the optimal design flies with smaller FHM than the initial one. Even though the rotating flexible disk generates large amplitude of the disk flutter, the relatively small flutter frequencies releases sliders to easily follow the disk flutter. However, notice that higher rotation speed of the disk can result in a risk in flying stability.

3. Actuator design for optical flying heads

In order to focus a laser beam exactly onto the recording layer, in case of the OFH with high NA objective lens interfaced with cover layered plastic disk, additional focusing actuator is needed. Generally the types and locations of actuators depend on design requirement of servo frequency bandwidth considering driving power and geometrical layout within total drive height limitation.

In the Fig. 6, there are three possible designs of actuators “A”, “B” and “C”. First design “A” is an integrated vertical actuator inside the slider for actuating objective lens, which is generally...
fabricated by micromachining technology. Second design “B” is an additional actuator to drive collimator instead of objective lens.

For design “A”, it is necessary to reduce the size of actuator within the volume of the slider. Small and robust actuator should be precisely equipped inside the slider for actuating objective lens. For design “B”, small actuator can actuate small collimator instead of objective lens. The case of “B” has more flexible room for designing the shape and size of actuator. For design “C”, relatively large actuator can be easily installed in the swing arm and can actuate the collimator assembly. However, in this case, servo bandwidth for tracking is limited by increased inertia of the actuator mass.

For practical applicability into the SFF ODD, reliability and focusing performance of individual actuators interfaced with common plastic disk should be guaranteed under the environmental shock and temperature change under mobile use.

4. Summary and conclusions

In this paper, we studied the flying characteristics of a small optical pickup adopting the flying-type head for the future small form factor optical drive. To obtain more stable flying characteristics on the flexible plastic disk and L/UL mechanism, the shape optimization of the slider was implemented. The slider with optimized ABS was used to develop the new OFH interfaced with flexible plastic disk system. Those flying variations and gains were investigated to evaluate the flying stability of the optimized OFH with respect to the critical disk parameters such as disk waviness and flutters.

On the other hand, in order to focus a laser beam effectively on the recording layer, a couple of additional micro actuators with high NA objective lens interfaced with cover layered plastic disk were proposed. Their design characteristics were also compared each other. It is necessary that a micro actuator for focus servo should be designed and fabricated for better interface of optical flying head on thin cover layered plastic disk. Therefore, the results of flying stability of the OFH on plastic disk will be effectively used to develop optimized optical pickup heads for better performance and practical use in small form factor optical drives.

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References


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