System Integration Challenges for a Slider with an Integrated Microactuator

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The system integration process for a slider with an integrated microactuator incloses different challenges during the fabrication sequence. These challenges are related to the system stacking, the double rowbar thinning and slicing, the chiplet bonding, the slider separation, and the cross crown fabrication. In addition to these challenges, this paper presents the developed solutions, tools and concepts for solving these challenges.

***Index Terms*— Hard disk drive, second stage track following, flying height adjustment, electromagnetic microactuator**

I. Introduction

A slider with an integrated microactuator (SLIM) allows second stage actuation, which includes the adjustment of the flying height and the track following in hard disk drives, respectively [1]. A SLIM is built up of four parts: first, the micromagnetics, which is fabricated on a standard Si wafer and consists of two electromagnetic microactuators. Any of these microactuators can be excited independently. The second part of SLIM is the micromechanics, which is fabricated on a two-device-layer Silicon On Insulator (SOI) wafer and features two leaf springs suspending a mounting platform. The other two parts are a Si spacer located between the micromagnetics and the micromechanics part, and a chiplet, residing on the moving mounting platform of the micromechanics part and carrying the read-write (R/W) element (Fig. 1). The SLIM dimensions are 1.240 µm x 990 µm x 300 µm and thus corresponding to the dimensions of a standard pico-slider. For SLIM system to be functional, all these four components must be assembled and very tight tolerances must be obtained.

FIG. 1 HERE

The active micromagnetics part with two separate coil systems enables the lowering of the chiplet by simultaneously exciting both micro electromagnets (flying height adjustment). A minute rotation of the chiplet can be generated by an uneven excitation, which results in different actuator forces left vs. right (track following).

In the following the challenges of the system integration process and its solutions are presented. The challenges are described following the fabrication process sequence. It starts with the system stacking of the micromagnetics, spacer, and micromechanics. Furthermore there is the thinning of the double rowbar and the fabrication of the Air Bearing Surface (ABS). Afterwards the chiplet bonding is done, then the slider separation, and at last the fabrication of a cross crown.

II. System Integration Process

A. System Stacking

Before the system stacking, the micromagnetics and micromechanics wafers are separated by dicing into double rowbars, which are containing 2x10 devices. Fig. 2 shows the double rowbar with twenty SLIM devices on an one Euro Cent coin.

FIG. 2 HERE

Achieving the dimensions of a pico-slider means that a stack of micromagnetics and the micromechanics part, and the spacer can not exhaust 300 µm thicknesses. Under this limitation the both, micromagnetics and the micromechanics parts, must feature a 100 µm nominal thickness. Stacking of such a system is very challenging, in the first line due to the handling issues. Therefore, the stacking process is done with thicker micromagnetics components. The thickness of the micromagnetics wafer of 520 µm is kept to provide a sufficient stability during the wafer fabrication steps, resulting in height aspect ratio thin film structures featuring a certain amount of stress in layers. The micromechanics part is fabricated with the nominal thickness, because this part feature very sensible Si parts (leaf springs and mounting platform) and no post machining can be executed.

The spacer placed between the actuator parts is fabricated using a SOI-wafer conducting standard Micro-Electrical-Mechanical-System (MEMS) processes. Fig. 3 illustrates a view of the assembling of the SLIM components.

FIG. 3 HERE

The spacer establishes the length of the air gap between the top of the micromagnets pole faces, which are located on the micromagnetics device, and the bottom of the flux guide, which are located on the micromechanics device. The thickness of the spacer, one of a key parameter to obtain the required air gap, is defined by the device layer thickness of the SOI-wafer. The length of the air gap is crucial for an appropriate function of the completed SLIM device. The main challenge is to accomplish an air gap between 24.5 µm and 29.5 µm. This air gap is needed to enable the micromagnetics to generate the necessary force for the rotation and translation of the mounting platform. A spacer thickness of 80 µm is used to adjust the gap between the micromechanics and the micromagnetics. The design of the spacer is adapted to the design of the SLIM devices. Adhesive bonding is employed to stack the SLIM components. The spacer is performed with an adhesive hole of 300 µm x 300 µm with recesses, where excessive applied adhesive can go to during the curing process. The result after bonding is a stack with a thickness of 720 µm.

B. Double Rowbar Thinning and Slicing

The SLIM thickness must be 300 µm, which is causing the need to thin this stack. This is accomplished using a “thinning-by-dicing” process, followed by nanogrinding and Chemical-mechanical Polishing (CMP) [2]. The stack is bonded on a special prepared thermo-release dicing tape. By using a dicing wheel as a profiling tool, a “thinning-by-dicing” process is executed on a DAC551 dicing machine. Using the special prepared thermo-release dicing tape as a transfer tool, the stack is mounted on the nanogrinding tool. Nanogrinding on a Sn plate conditioned with a 0.5 µm-1 µm diamond grain, a rough machining of the stack ABS is executed. Afterwards, CMP using the same tool is executed generating the end ABS. The application of the thermo-release dicing tape enables the releasing of the parts after the processing without damage.

After the CMP process, the ABS fabrication is carried out similar to the ABS fabrication used for standard hard disk drive sliders. For handling the 300 µm thin Si stack during the ABS fabrication process, the double rowbars are placed into a special tool made of a Si-wafer, which is bonded onto a glass substrate. The ABS is fabricated in two etching steps. After coating with photoresist, the first etching mask is patterned by photolithography. The levels of the ABS are generated by Ion Beam Etching (IBE). To pattern the second level another coating and photolithography is done. The overall height of the ABS is 1.24 µm, whereas the first etching step is 1 µm and the second 240 nm (Fig. 4).

FIG. 4 HERE

The ABS fabrication is followed by the deposition of a 30 nm Diamond-like Carbon (DLC) layer [3]. Initially, the test devices were fabricated without an ABS and without a DLC layer. Experimental investigations were carried out with these devices, which were not capable of flying [4].

In the next step, a profiling cut uncovered the contact pads at the slider’s leading edge, allowing static electrical tests to find out the electrical functional microactuators. Then, the double rowbars were sliced into two single rowbars, each of them containing ten devices.

C. Chiplet Bonding

The process for the chiplet bonding must assure a lateral as well as a vertical tolerance of ±1 µm for the position of the chiplet, which is in the middle of the mounting plateform’s front (Fig. 1). To achieve this within the given tolerance is the main challenge in this step. The dimensions of the chiplet are 280 µm x 300 µm x 150 µm (h x ℓ x w). On the top of the chiplet, there is a recess for an adhesive. The tool for chiplet mounting consists of several parts, which are placed on an Al ground plate. In the center of the ground plate, a ceramic mounting plate is mounted. Around the mounting plate, there are four positioners with spring pins for moving and adjusting devices on the mounting plate (Fig. 5).

FIG. 5 HERE

The planar surface of the mounting plate is also used as a reference tool one for the mounting process. During the mounting process, the rowbar is laying on this surface. The side of the mounting platform of the rowbar is slightly pressed against a second reference tool, which is made of a 300 µm thick Si wafer and consists of two parts. The first part of this reference tool two has a rectangular edge fabricated by dicing and the second part has recesses for mounted chiplets (Fig. 6).

FIG. 6 HERE

Both parts of the reference tool two are bonded on the mounting plate. Between the two parts of the reference tool two, there is a gap for arranging the chiplet. The gap is above a slot, which is diced in the mounting plate for fixing the rowbar and the chiplet during the bonding process with vacuum. For the adjustment of the chiplet and the rowbar, a micrometer screw is used and the exact position of the chiplet is controlled by an optical microscope. To bond the chiplet to the mounting platform of the rowbar, an adhesive droplet is placed on the top of the chiplet in the recess. After glue drying, the rowbar is moved for bonding the next chiplet.

D. Slider Separation

The next step is the single slider separation. This is a very critical step, because after the separation; the mounting platform with the chiplet is only suspended on the 5 µm thick leaf springs, which can easily be damaged. To fix the mounting platform during the separation process and prohibit damaging the leaf springs, a single row bar is attached to a thermal release tape with the micromechanics side down. This means, that the mounting platform is attached to the thermal release tape, too. This proceeding is necessary, otherwise with the slider ABS attached to the thermal release tape, the mounting platform side will be cut free (separated) and hold only by the leaf springs. The stress during this dicing process would destroy all leaf springs.

The tape has a release temperature of 140°C. After dicing, the thermal release tape is heated up to this temperature and the sliders can be released from the tape.

E. Fabrication of a Cross Crown

The two features of flying height adjustment and track following require a cross crown on the chiplet. More than 500 nm from the chiplet edges has to be removed for cross crown concept to be functional. Thus, a minimal damage of ABS is necessary. There are three fabrication alternatives for the cross crown. A Cross crown fabrication on Head Gimbal Assembly (HGA) level can be executed by applying the “kiss lap“-process of the assembled HGA and microactuators facilitating the rotation. This will achieve an optimal cross crown shape, but facing the insufficient machining force by the microactuator as well as the time consuming process. Cross crown fabrication on slider level requires a nanogrinding process on SLIM with pressure applying on two sides of the mounting platform. This way a nearly optimal cross crown shape is achievable by unlimited machining force and time efficient process. This task is connected with guiding and fixing challenges. Cross crown fabrication on chiplet level respectively cross crown fabrication before chiplet bonding, is relatively simple and time efficient, but a practical cross crown contour is difficult to achieve. The approach chosen was a slider level cross crown fabrication [5]. The main challenge by cross crown machining on slider level is contacting between mounting platform / chiplet and slider body (by a pair of 5 µm thick leaf springs). Therefore, the force is only transferring at the chiplet or mounting platform. Contact areas alternatives are at the chiplet and at the mounting platform. To use this concept successfully, all relative movements must be minimized. SLIM is guided with a nanogrinding plate (self adjusting). For fixing and guiding of SLIM on the nanogrinding plate, a height precise AlTiC cage is fabricated. Coupling in contact between AlTiC cage and the nanogrinding machine is by tracks (self adjusting). A few concept optimizations are executed: application of supporting block instead of pin (for minimizing the twisting forces on the chiplet), loading with a wire loop (100 µm wire) instead of loading by a pin, and reduction of the AlTiC cage length and its center adjusted tangential to the plate rotation (Fig. 7).

FIG. 7 HERE

By applying a load force on the left (right) side of the mounting platform, a left (right) cross crown incline is machined, and vice versa. This way, the cross crown radius is created by alternating force application. SLIM slides in an AlTiC cage and follow the nanogrinding plate surface. This results in a small, eccentric up and down motion of a SLIM. Load application is off center due to the separate fixture of the wire loop system on a machine. This leads to a reduction of the force impact time as well as a reduction of the chiplet exposure. Using this system, no fracturing is observed.

III. Conclusion and Outlook

There are several system integration challenges for fabricating a slider with an integrated microactuator. A concept for system stacking the micromagnetics, the spacer, and the micromechanics to fabricate an air gap between 24.5 µm and 29.5 µm is carried out. A process for thinning by dicing and nanogrinding the micromagnetics part to a thickness of 100 µm was established. To prepare the double rowbar for ABS fabrication, the nanogrinded surface is processed by CMP. An ABS with a height of 1.24 µm can be successfully fabricated by IBE. For bonding the chiplet with an accuracy of ±1 µm, a mounting set-up was developed, which assure this tolerance. To separate the rowbars into sliders, a thermal release tape is used for fixing the moving part of SLIM during the dicing process. It could be demonstrated, that a required cross crown may be created by a nanogrinding process on a Sn plate with a special tooling enabling self adjustment and minimal relative movement of the system components involved. For further cross crown fabrication, DLC studs will be added to the ABS of the SLIM to avoid its wear during the nanogrinding process, as will be DLC stripes on the center pad at the later location of the R/W element. An approach to generate loading force using thermo elements will be investigated.

While the initial fabrication tests proved the feasibility of the described approaches, the processes have to be further evaluated and improved. Additional tests will focus on the standardization of the approaches.

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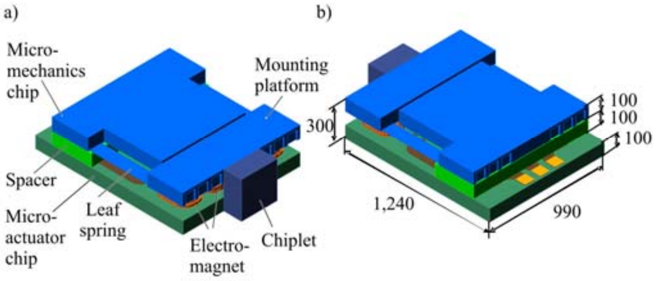

Fig. 1. Schematic representation of a Slider with an Integrated Microactuator (SLIM); a) diagonal rear view; b) diagonal front view [1].

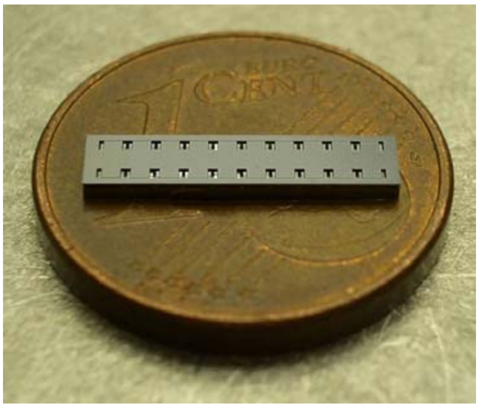

Fig. 2. Double row bar with twenty SLIM devices on a one Euro Cent coin.

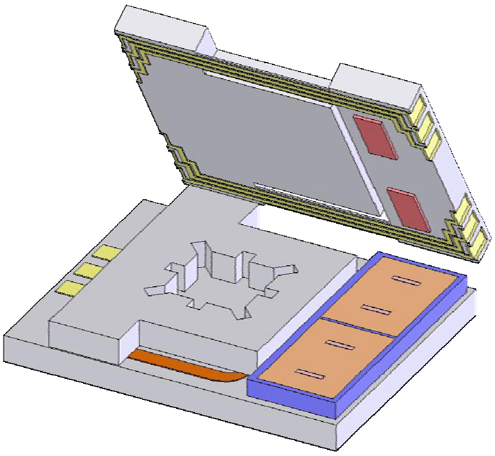

Fig. 3. Alignment and adhesive bonding of SLIM components.

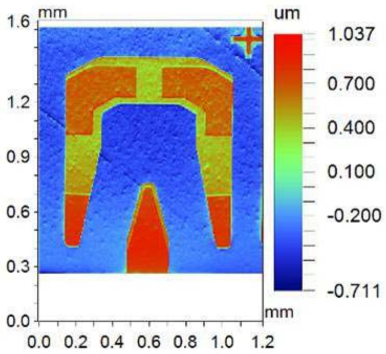

Fig. 4. Fabricated ABS-structure, measured with a white light interferometer.

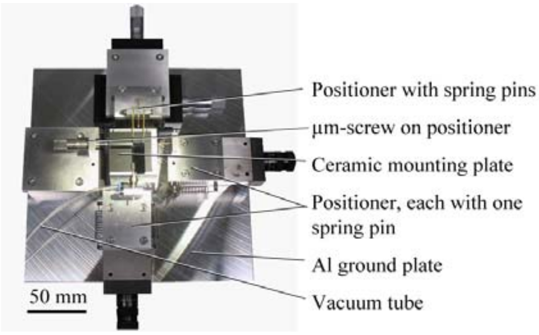

Fig. 5. Mounting set-up for chiplet bonding.

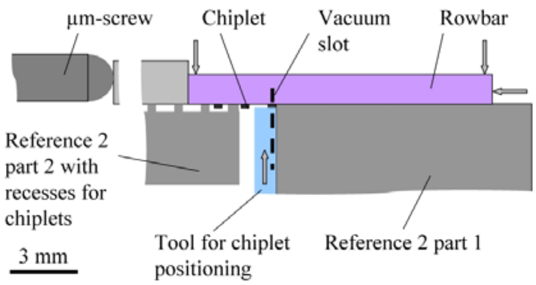

Fig. 6. Schematic detail view of mounting plate for chiplet bonding.

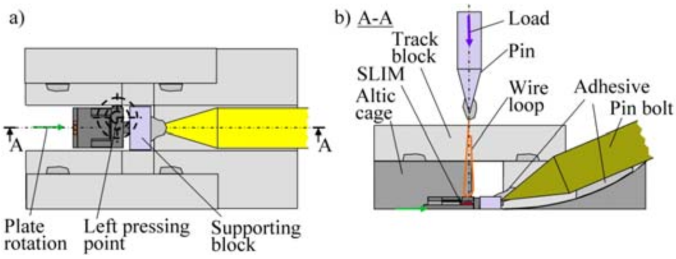

Fig. 7. Schematic representation of the cross crown fabrication tool; a) top view; b) cross section [5].