Thermal Hard Disk Drive Micro Actuator for Improved Tracking Performance

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Abstract

This paper presents the design, fabrication and characterization of a Hard Disk Drive (HDD) thermal micro actuator. The goal of the fine-stage actuator is to increase the storage capacity of future drives by improving the tracking accuracy. Our thermal fine-stage actuator occupies less area than an electrostatic or electromagnetic actuator (e.g. [1, 2]) with the same driving force while still reaching over 3 kHz bandwidth which enables a positioning accuracy better than 5 nm. Our actuator does not require a high driving voltage or special materials, unlike piezoelectric actuators (e.g. [3]).

1 Design

The micro actuator, depicted in Figure 1, is to be mounted between the arm of the coarse positioning system and the slider with the read / write head. The slider is mounted on a rotating platform, which is connected to the fixed part of the actuator by means of a flexible suspension. The platform is rotated by the thermal expansion of two Thermal Linear Motors (TLMs). The concept and principle of operation of these motors was presented in [4]. They are made of aluminum to achieve a relatively large thermal expansion at a modest temperature (< 200 ºC). To prevent large parasitic losses in for instance lead wires, the TLMs have thin, embedded heaters with high resistance, which keeps the actuation current below 50 mA.

The micro actuator is designed for a stroke of 1 μm, but it can move the head by more than 5 μm at low frequencies (<< 100 Hz). The thermal time constant of the motors is 0.06 ms, which is crucial to meet the 3 kHz bandwidth requirement. The rotating platform in this demonstrator is about 500 μm instead of 100 μm thick to emulate the moment of inertia of the slider in a real HDD.

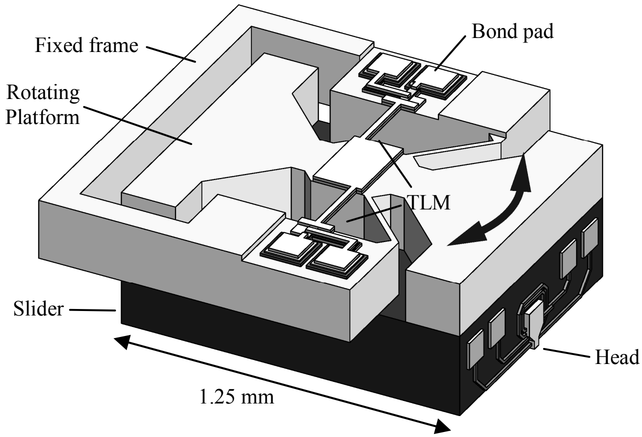

Figure 1: Concept of the thermal HDD micro actuator. The eccentric position of the two thermal linear motors (TLM) in combination with the elastic hinges converts the small thermal expansion in rotation of the platform. This rotation translates into a displacement of the head, which is at the edge of the slider.

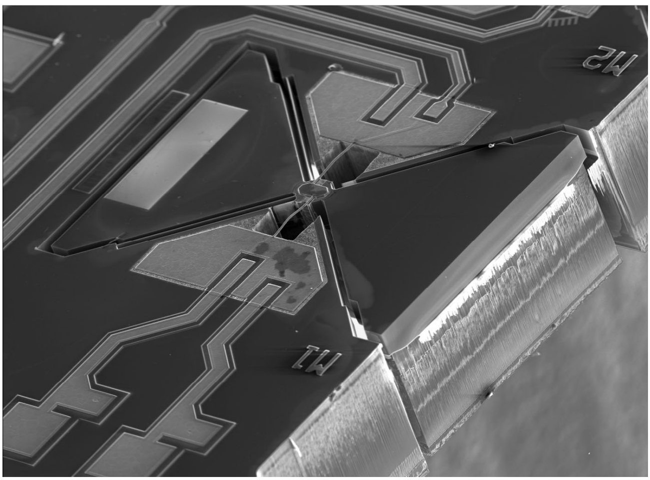

Figure 2: SEM photograph of a realized thermal HDD micro actuator

2 Fabrication

The proposed micro actuators were fabricated by combining bulk micromachining of the silicon wafer with the process used to fabricate the TLMs. A total of 11 masks were used. The TLMs were first fabricated on the wafer with a process similar to the one described in [2], were only the fabrication of the bond pad was altered to make them more robust for wire bonding. Next the 100 µm high, 500 µm long and 3 µm wide springs of the flexible suspension and the outline of the rotating platform were etched from the front side with a Deep Reactive Ion Etch (DRIE). After this the wafer was processed from the backside and the actuator was released in two DRIE steps; one of 100 µm and one of about 400 µm depending on the wafer thickness. The release was done in two steps because underneath the TLMs all the silicon had to be removed (~500 µm) without etching the springs. After the DRIE steps the silicon oxide which was used as mask is removed from the wafer by a wet etch in a highly concentrated (73%) solution of hydro-fluoric acid.

3 Results and discussion

Figure 2 shows a photograph of the realized thermal fine-stage actuator. An experimental setup to characterize the micro actuator was realized as well. The setup uses an optical angle measurement technique to measure the rotation of the demonstrator's platform. The measured transfer function from heat input, i.e. electrical power, to rotation angle is plotted in Figure 3. The frequency of the actuator's first rigid body was predicted to be 1.3 kHz, but is found at 475 Hz. This mismatch is caused by the motors which were buckled during the wafer drying after the final release (stiction). In the future, the problem can be avoided by freeze-drying after the release or by adding end-stops to the design. Despite the lower resonance frequency, the device is functioning and there were no other resonances found up till 100 kHz.

4 Conclusion and future work

Because the phase lag of the actuator is about 200º and no resonances were found up till 100 kHz, the actuator, with a PID controller and a phase lead filter, can support at least a 3 kHz bandwidth to improve the tracking accuracy of a hard disk head by at least a factor 20. In future work, the fabrication process or the design has to be improved to avoid buckling of the motors. Also, different control strategies should be tested to investigate the maximum bandwidth and maximum tracking accuracy of the thermal HDD actuator.

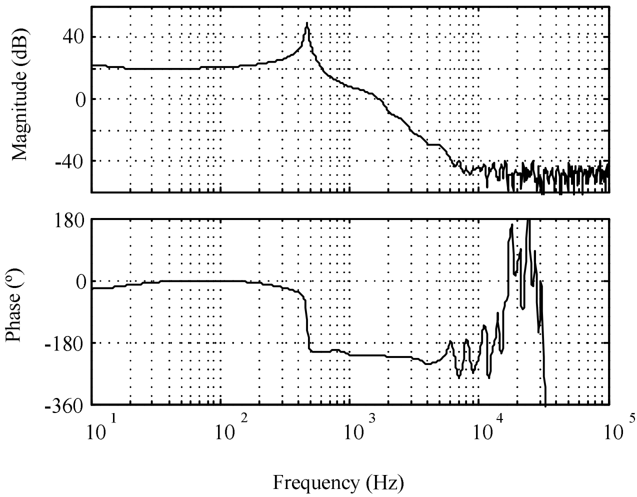

Figure 3: Transfer function of the thermal HDD actuator from heat input [mW] (electrical power) to rotation [degrees].

Acknowledgements

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