Thermal Fly-height Control (TFC) Technology in HGST Hard Disk Drives

Introduction

The ever increasing demand for higher capacity storage devices continues to challenge hard disk drive (HDD) companies to find innovative solutions for fundamental magnetic recording technology issues. One such issue is how to effectively read data and write new data over a wide range of operating temperatures and read/write duty cycle conditions. An important parameter affecting error rate performance is the spacing between the read/write head and the recording disk, commonly referred to as fly-height. A key variable of fly-height is the read/write element protrusion towards the recording disk. This protrusion changes with temperature and read/write duty cycle affecting the spacing to the recording disk. Controlling the spacing of the head read/write elements relative to the recording media becomes more and more critical for each successive generation of higher areal density product. HGST introduced Thermal Fly-height Control (TFC) technology in 2007.

Background

Two key factors contributing to the spacing of the read/write elements to recording disk are the mechanical fly-height of the read/write head over the recording media, and any protrusion of the read/write element due to environmental temperature changes or from the read/write operations. The mechanical fly-height of the read/write head is well understood for different positions on the disk and different operating temperatures. For many product generations, HGST has incorporated an on-board thermal sensor so the operating temperature can be monitored, and in turn the write current can be adjusted accordingly to compensate for changes to the head mechanical fly-height. Now with the introduction of Thermal Fly-height Control the effects of changes to the read/write element protrusion can also be compensated.

Protrusion refers to the physical distance that the read/write elements extend towards the disk surface relative to their initial position at some reference or nominal temperature. These elements are composed of materials different from the rest of the flying slider on which the read/write sensors reside. These materials expand and contract at a more rapid rate than the body of the slider. When data is written to the disk, a high frequency electrical current is applied to the head's write coil. A side effect of the applied write current is that the write element heats up causing it to expand, generating additional protrusion of the read/write element region of the head towards the disk. Both these thermally-driven protrusion phenomena reduce the effective spacing between the read/write elements on the head and the media and needs to be allowed for in the design in order to avoid destructive head/disk interactions. Finding a method to compensate for both these thermal effects automatically and thus maintaining a consistent spacing between the head and the magnetic disk, independent of temperature and writing conditions, is what drove the efforts to develop TFC.

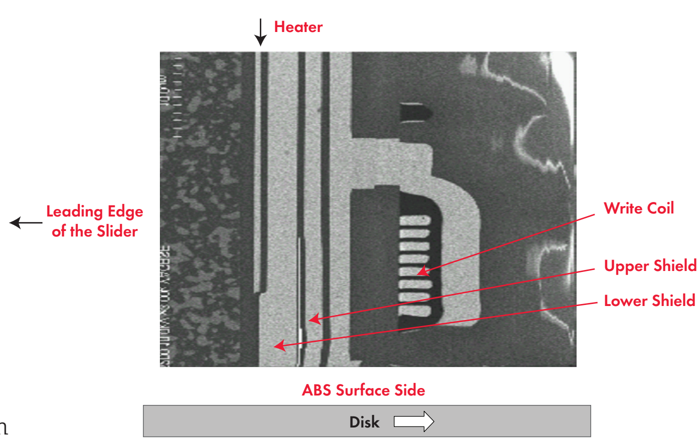

Figure 1: Cross-section of head structure

Thermal Fly-height Control Implementation

The TFC concept involves imbedding a separate heating element into the head structure. See Figure 1 for a cross-section of the head identifying the heater location relative to the read/write elements. This separate heater structure enables the control of the read/write element protrusion independently from the effect generated by the read/write elements during read or write operations. To supply the necessary current to the separate heating element, additional circuitry was added to the arm electronics (AE) pre-amplifier and two additional traces were added to the head wiring. The heater current is controlled by a separate control function. Figure 2 shows a thermal distribution map of the head when current is applied to the heater element. Applying heat to the head results in an increased protrusion of the read/write elements thus reducing the spacing to the disk. Figures 3 and 4 show the change in the spacing of the read/write elements to the disk with and without the heater current applied. Since there is some time constant before the head reaches a steady state temperature, the heater is turned on a certain time before the read or write operation is to be executed. Once the spacing has reached the stable

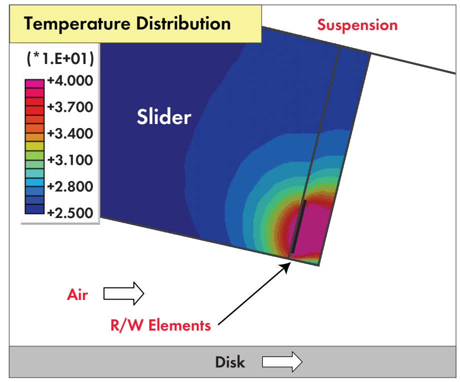

Figure 2: Temperature distribution with thermal heater activated

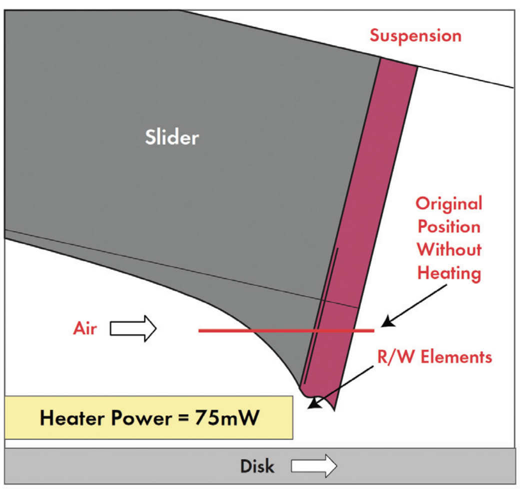

Figure 3: Nominal read/write protrusion before TFC adjustment

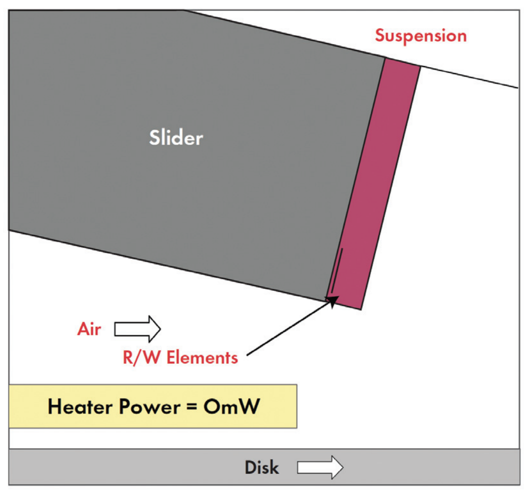

Figure 4: Read/write element protrusion with TFC adjustment

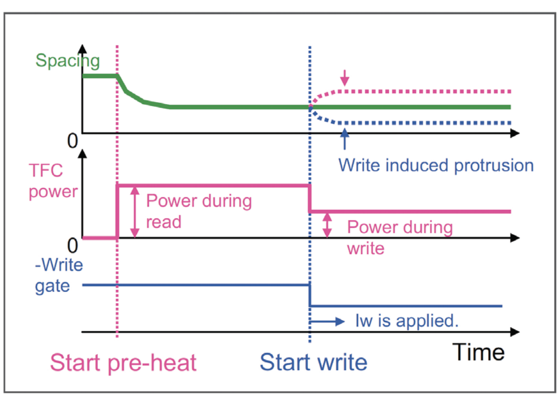

Figure 5: Write operation with TFC

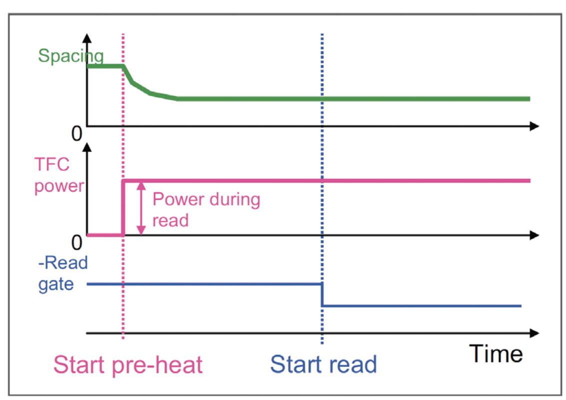

Figure 6: Read operation with TFC

target value, the read or write operation can be executed. Figures 5 and 6 depict the timing of applying current to the heater element relative to when the read or write operation is started. Note that during the write operation, the current to the heater is reduced when the write current is applied. This is done because the application of current to the write element causes additional localized heating which produces additional protrusion; this effect is compensated by reducing the current to the heating element. The end result is a consistent spacing of the read/write elements to the disk throughout the write operation.

Conclusion

Testing of read/write performance indicates that with the addition of TFC the raw Soft Error Rate (SER) can be improved by several orders of magnitude (depending on the level of application and the aggressiveness of design). This represents a powerful new means of advancing the overall drive performance and reliability. With TFC, the written data is more consistent because the write element to disk spacing is maintained more precisely throughout the write operation and the read-back process can be controlled to achieve consistently low SER. In addition, the ability to write more consistent data over a wider temperature range enabled HGST engineers to more accurately optimize the write currents for different operating temperatures. The end result is that the Adjacent Track Interference (ATI) performance with TFC has also shown significant improvement in comparison to previous generations of hard drives. Ultimately, this more precise control of the spacing between the read/write elements and the magnetic disk yields a more reliable and better performing hard drive for HGST customers.

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