WRITE PROTRUSION MODULATION FOR SUB–NANOMETER CONTACT INTERFERENCE

Bernhard Knigge

Barry Stipe
Robert Payne
Peter Baumgart

Hitachi San Jose Research Center, Hitachi Global Storage Technology, San Jose, CA 95120

ABSTRACT

With the continual reduction in slider to disk clearance in hard disk drives, new methods to measure this clearance with high accuracy are needed. Understanding the contact dynamics when touching the disk at sub-nanometer interference levels is an important aspect of the problem. We have developed a new methodology to gradually bring the slider into contact with the disk, based on controlled and localized thermal expansion of the slider as it occurs during the regular write process (write induced protrusion). By applying short pulses to produce time controlled thermal protrusion, the duration of contact can be limited to a few milliseconds, by which short contacts and their contact hysteresis can be investigated.

INTRODUCTION

Active control of slider-disk spacing by using a thermal heating device at the trailing end of the slider has been proposed before by Meyer et al. [1]. Nikitin et. al. investigated write protrusion profiles and rise times of various sliders [2] using the Wallace spacing loss formula. Since write protrusion is linear with write power, a very accurate interference level can be dialed in. However, calibration of the write protrusion (or write power) needs to be performed to accurately translate write power into spacing change. This can be done using the magnetic read-back signal (Wallace spacing loss).

The proposed technique to investigate the transition from flying to contact is based on pulsed thermal write protrusion. The duration of the induced nano-contacts can be controlled with high precision down to ~ 1 msec. This technique offers a novel approach to high precision investigations of head/disk interface dynamics on much shorter time scales (~1000x shorter) than was previously possible.

To induce nano-contacts we apply to the write coil square pulses, half-sine pulses and square pulses combined with sinusoids (ie DC + AC modulation).

Slider to disk contact is monitored with an acoustic emission (AE) sensor and with a laser heterodyne interferometer. With increased power to the write head, increased protrusion occurs. At sufficiently low flying heights this eventually leads to head-disk contact. Interestingly, the slider has the ability to stay in smooth sliding contact for a few milliseconds before AE and slider bounce rapidly increase.

Due to the short contact time and the small contact area/interference, the method is an ideal tool for investigating repeatable slider-disk interactions with minimum interface disturbance. Previously applied techniques such as spin-down/spin-up or pump-down based measurements are usually non-repeatable due to unavoidable lube and debris pickup on the slider when contact is maintained for many seconds or longer.

EXPERIMENTS AND RESULTS

A computer with simultaneous signal generation and data acquisition was programmed in Matlab. The signal output waveforms to the head write coil were sampled at 250kHz at 16bit. The AE and interferometer input signal was simultaneously acquired at sampling rates up to 2.5MHz with a 12 bit resolution. The output signal was triggered with the air bearing spindle index, hence, the slider protrusion experiments could be repeated at the same disk location and compared with other circumferential locations.

In Figure 1, the simulation of the slider write response to a square voltage pulse is shown. If a 1V square pulse is send to the write element (dotted line) it translates to a power of 47.3mW. Since the calibration constant for this slider is 6mW/nm (estimated from Wallace spacing loss), the write protrusion is 7.88nm (solid line). However, due to the slow thermal expansion rise time of the write coil, the actual protrusion needs to be convolved with the transfer function of the head (see dashed line). The total time per revolution is 6ms (at 10,000rpm). We choose a pulse length here of 290 degrees.
In Figure 2, the AE response to the square waveform is shown at an interference level of 0.33 nm at 42 mW power to the write coil. No contact was observed at a power of 40 mW (2 mW = 0.33 nm clearance change).

From Figure 2 we observe that the AE signal rapidly increases about 2 ms after the pulse is turned on. The delay can be explained by both, the thermal expansion rise time (which is in this case ~1.5 ms to fully bridge the clearance) and smooth sliding without AE activity. Depending on the slider air bearing design, this delay can be prolonged or shortened.

Certainly no or very small AE activity is desired when in contact. Simultaneously with the AE signal the slider vertical displacement was measured with an interferometer at the slider trailing end. This is shown in Figure 3. Overlaid in Figure 3 is the transfer function convolved write protrusion (in nanometers) with the slider bounce response. Similarly to the AE response, we observe a delayed onset of slider bounce. The bounce becomes gradually worse with prolonged contact, possibly due to a change in friction caused by lube depletion/pickup.

In Figure 4, the slider bouncing response to a much longer applied signal (24 ms = 4 revolutions) is shown. Interestingly, the slider does not become unstable at the first contact at t=4 ms, however, it does become unstable for consecutive contacts at t=10 ms and t=16 ms.

It is possible that the first contact at t=4 ms caused a small HDI instability such as lube ripples [3]. Since the contact time is very short, no slider bounce is yet observed. However, consecutive contacts at the same location could further increase the ripple amplitude and eventually lead to slider bounce.

**SUMMARY AND CONCLUSION**

A novel method using pulsed calibrated write protrusion has been introduced. This method can be used to monitor contact dynamics for interference levels at angstrom level. It is extremely repeatable and accurate due to its short contact times and small contact area.

**REFERENCES**


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