Novel ultra-sensitive air bearing excitation based resonance contact detection in Heat assisted magnetic recording (HAMR)

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Achieving a stable low head-disk clearance on HAMR HDDs is challenging. During operation, the NFT protrudes and approaches the disk leading to a reliability concern. In-situ detection of the contact between the NFT and the disk has so far remained elusive, presumably due to the small contact area of the NFT protrusion.

In this work, a detailed experimental study to enhance the contact detection sensitivity of the head-disk interface is conducted. A novel resonance based ultra-sensitive contact detection scheme is presented. It is found the signal is significantly enhanced by modulating the NFT protrusion at the air bearing resonance frequency. The thermal fly height control (TFC) along with the acoustic emission (AE) sensor is utilized to measure the contact between the NFT and the disk.

The head-disk interface is comprised of a stationary head flying on top of a rotating disk. A self-pressurized air bearing surface (ABS) on the head maintains a fixed clearance over the disk. The target clearance is typically 10 – 20 nm. The TFC generates a localized protrusion near the trailing end of the head. Contact between such protrusion and disk is detected using AE.

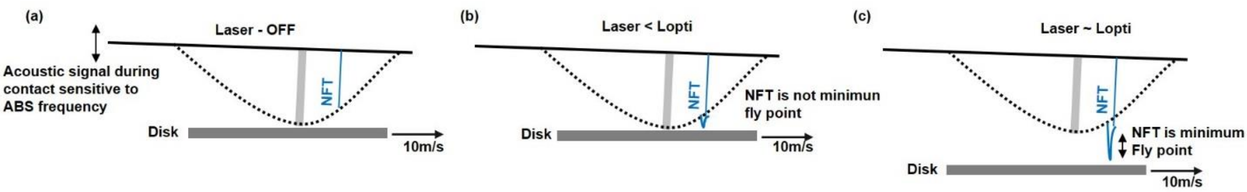

Figure 1: Schematic of protrusion on the head at a constant TFC power and under different laser conditions: (a) Laser is off; (b) Low laser power; and (c) High laser power.

Under HAMR writing conditions, the NFT is energized using an integrated laser diode whose power dissipation in the NFT structure leads to its protrusion. This protrusion increases linearly with the optical power from the laser diode, and the optical power is proportional to the laser current (Figure 1). Due to the small radius of curvature of the NFT protrusion, the contact area of the NFT is much smaller than the TFC's. This smaller contact area is responsible for the poor signal of the contact between the NFT and the disk. The contact signal incorporates contributions of the three ABS modes: roll, pitch P1 and P2. Among these ABS vibration modes, the contact detection signal is dominated by the P2 mode. In order to increase the signal during contact, the head is modulated at the P2 frequency just prior to the contact such that the signal generated during contact is confined to the tapping P2 mode. Exciting the head structure at the air bearing P2 mode frequency (2 – 5 µs) is challenging. The slow protrusion response time of the TFC (0.1-1ms) limits the responsiveness to this excitation, and, consequently, the TFC modulation is mostly used for low frequency applications. In HAMR technology, the NFT structure has a very fast protrusion response time (1-10µs) [1]. In the following, we use modulation of the NFT protrusion amplitude at the ABS frequency to improve the signal during contact [2].

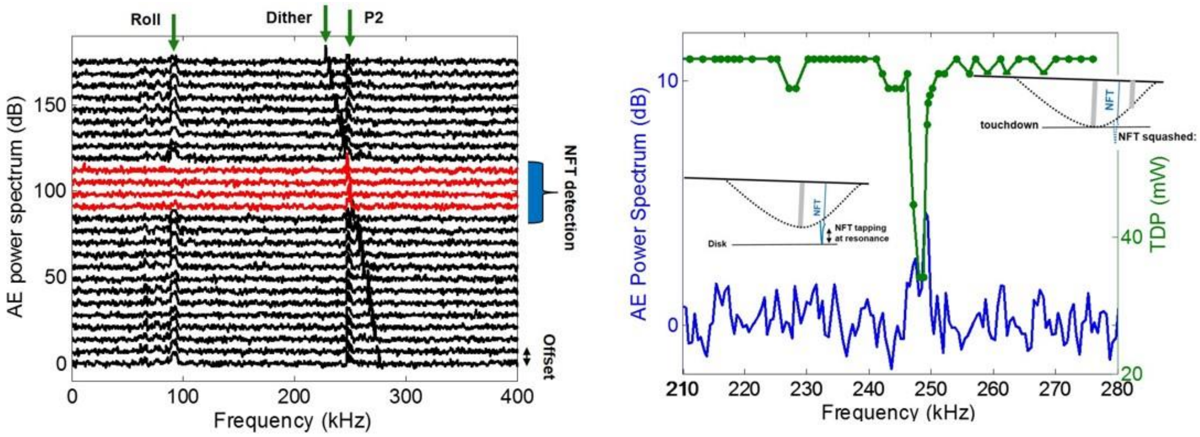

Figure 2: a) left: Acoustic emission power spectrum at different NFT protrusion modulation frequencies. Each curve is manually offset. b) blue line shows the acoustic emission power spectrum. Green dots show the touchdown power with excitation using NFT protrusion modulation during contact with the disk.

Figure 2 Left shows the experimental power spectrum of the AE signal as a function of frequency during contact for different NFT protrusion modulation frequencies. Each curve represents the contact at a particular modulation frequency with a manual vertical offset. For off-resonance modulation, the signal power spectrum at contact has three frequency contributions: Roll, P2 and modulation frequency. For on-resonance (P2 mode) modulation actuation, the signal power spectrum at contact has only one resonant P2 frequency component, indicating the confinement of mechanical vibrational energy generated during contact to a tapping P2 mode of the slider. It clearly demonstrates that this scheme exploits the P2 resonance to significantly improve the contact detection sensitivity of the head-disk interface. The blue trace in Figure 2b shows the AE power spectrum under the laser off condition. The P2 mechanical mode frequency is around 250 kHz. The green dotted line shows the NFT modulating touchdown of the head with the laser turned on to the HAMR writing condition. The touchdown power values for off-resonance air bearing NFT protrusion modulation frequencies are much higher than at the on-resonance NFT protrusion modulation frequency. For off-resonance NFT protrusion modulation leading to a high touchdown power, the contact detection is not sensitive enough to detect the NFT contact with the disk leading to squashing of the structure into the disk. When the modulation frequency matches the resonance P2 frequency, the contact detection sensitivity increases significantly leading to a smaller touchdown power as the NFT contact with the disk is detected.

In conclusion, an air-bearing resonance based novel ultra-sensitive contact detection scheme is discussed. It is found that the contact detection sensitivity of the head disk interface is significantly increased by modulating the head at the resonance P2 mode of the ABS. As an application, we implemented this scheme on the HAMR head-disk interface and demonstrated the capability to detect a non-destructive contact between the pointy NFT tip and the disk. This technique allows for a very accurate determination of the magnitude of the NFT protrusion.

REFERENCES

[1] Schreck, E., Li, D., Canchi, S.V., Huang, L., Singh, G.P., Marchon, B., Richter H.J., Stipe, B. and Staffaroni, M., "Thermal aspects and static/dynamic protrusion behaviors in heat-assisted magnetic recording." IEEE Transactions on Magnetics, **50**, 126-131 (2014).

[2] Rajauria, S. and Schreck, E., Tunable contact detection sensitivity to directly measure clearance of protrusions in magnetic recording heads. US Patent 9595281 filed 11 Aug. 2015, and issued 14 Mar. 2017.