along the track at which the track crossing occurred. The instrumentation required is a fast digital oscilloscope, a spectrum analyzer, and a hard-drive control program with integrated GPIB data acquisition. In a short time, peak amplitude and track crossing times for several thousand seeks can be acquired. Plotting the peak amplitude versus track crossing time provides a profile of the roughness variations in the media over a short 500 μm length of track. The same track profile was obtained crossing the track from inside to outside (ID to OD) and from OD to ID except for a fixed amplitude offset which is caused by and allows measurement of the difference in fly-height between the three cases of ID to OD seek, OD to ID seek and track following. The measurement can reliably resolve 1 nm fly-height changes caused by seeking. Comparison between measured fly-height changes and predictions of air bearing models will be presented.

[1]V. J. Novotny, "Magnetic Recording Drive Dynamics during Seeking and Parking," *Digests of Intermag '97 (35th Intermag Conf.)*, Contributed Paper, Page AR-06.

BQ-16. A DSBTC AMPLITUDE MODULATION METHOD FOR LASER TEXTURE CONTROL AND CHARACTERIZATION. Yufeng Li (Samsung Information Systems America, 75 W. Plumeria Dr., San Jose, CA 95134) and Danzhu Lu (Seagate Recording Media Group, 311 Turquoise St., Milpitas, CA 95035)

Laser texture control and characterization has virtual importance to magnetic head/disk interface. For example, a typical specification requests a tolerance of ± 3 mils to a laser texture OD zone. A few mils of deviation of the laser texture OD zone from the specification will result in either extremely high readback signal error rate or destructive stiction. It is, therefore, desirable to characterize the laser texture of every disk from a manufacturing line. However, disk manufacturers still characterize their laser texture on a sample basis, because there is no accurate and efficient way to carry out this task for each disk, taken account of the volume of millions of disks per month. In this paper we present a novel method for laser texture characterization. This technique is based on double-sideband transmitted carrier (DSBTC) amplitude modulation. The carrier frequency and the bandwidth are determined based on the laser bump circumferential pitch and the disk linear velocity. This method is very fast (a few seconds for a surface), and easy to implement. The method can be used to accurately determine the laser texture zone locations, circumferential and radial pitches, frequency components and magnitudes, and possibly bump shape and height distribution. Its lateral resolution is less than a micron. The laser bump is also characterized with a profilometer, and its Fourier transform is converted from spacing domain into time domain. The frequency response of the DSBTC amplitude modulation can be predicted very well using the profilometer results.

BQ-17. IN-SITU PTR AND PTP MEASUREMENTS OF A MAGNETIC HEAD. Yufeng Li and Geng Wang (Samsung Information Systems America, 75 W. Plumeria Dr., San Jose, CA 95134)

In order to reduce magnetic spacing loss and prevent thermal spike noise of an MR head, the pole tip recession (PTR) and protrusion (PTP) must be tightly controlled. Conventional means to measure PTR and PTP are achieved by using either a stylus or optical profilometer, or an AFM. The interpretation of the results, however, is ambiguous because the reference plane is set up arbitrarily. In addition, these measurements require a time-consuming extra step, and therefore defy 100% head measurements. In this paper we present an in-situ method for PTR and PTP measurement. It is accurate and efficient, eliminates the necessity of reference plane, and can be easily carried out during flying height measurement. Then we apply this method to some in-production heads, and find out that PTR and PTP vary significantly during head manufacturing process. The effect of the PTR and PTP on magnetic performance differs from head to head for the same nominal process, and is a function of the flying characteristics of each individual head as well as the PTR and PTP values. To compare this method with the conventional methods, we also measured the PTR and PTP using a stylus profilometer, an optical profilometer, and an AFM. The results and limitations of each method are discussed in the paper.

BQ-18. CALIBRATING ESCA AND ELLIPSOMETRIC MEASUREMENTS. M. F. Toney, C. Mathew Mate (Almaden Res. Ctr., IBM Res. Div. San Jose, CA 95120), and D. Pocker (IBM Storage System Div., San Jose, CA 95193)

Tribology performance of the head-disk interface in disk drives is sensitive to the amount of lubricant present on disk surfaces. Too little lubricant results in poor durability; too much results in high stiction forces. Consequently, the lubricant thickness on the disk must be precisely controlled to within a few Angstroms, which requires measurement techniques with accuracies much better than an Angstrom for lubricant films typically a few tens of Angstroms in thickness. In this work, X-ray reflectivity (XRR) has been used as an absolute measurement of the thickness of perfluoropolyether (Zdol and Z type) lubricant layers on silicon wafers to check the validity of ESCA and ellipsometry thickness measurements. Excellent agreement is found between the XRR and ESCA measurement if the sum of organic contamination and lubricant thickness determined by ESCA is used and if a 25 Angstrom mean free path is used. ESCA and XRR thickness measurements are about 5 Angstroms thicker than those by ellipsometry, which is attributed to the displacement of contamination on the silicon wafer when the lubricant is deposited. Changes in layer thickness measured by ellipsometry are only about 2(+/−4)% larger than changes in thickness measured by XRR and ESCA, indicating that ellipsometry can be used to measure with good accuracy changes in lubricant thickness at monolayer coverages. Consequently, ESCA and ellipsometry, if contamination displacement is taken into account, can be used to calibrate other techniques, such as Fourier Transform Infrared (FTIR) spectroscopy, for measuring perfluoropolyether lubricants on disk surfaces. The measurements also show that the amount of contamination absorbed on the SiOx surfaces increases over several weeks and that PFPE lubricant layers are not effective at preventing contamination adsorption.

BQ-19. MAGNETIC READBACK MICROSCOPY APPLIED TO LASER-TEXTURE CHARACTERIZATION IN STANDARD DESKTOP DISK DRIVES. E. Schreck, R. Kimball, and R. Sonnenfeld (Adv. Technol. Group, Maxtor Corp., 510 Cottonwood Dr., Milpitas, CA)

In practice, a sealed desktop disk-drive can be a "black-box" even to the engineers that work for the company that manufactured it. Attempts at failure analysis or diagnostics that require physically opening the drive are very likely to damage it (either through the introduction of contaminants or through dinging the disks or damaging the head flexures). Thus "tearing down" the disk drive is always the failure analysis strategy of last resort, and any further functional data obtained thereafter is suspect. We present a variant of the magnetic-readback microscopy technique[1,2,3] that provides an electronic "window" into a sealed hard-drive. The analog read-back signal is probed at the preamplifier testpoints and is demodulated to provide local average amplitude vs time data. This data is captured repeatedly as the head is stepped by the drive servo in fractional track increments. The result looks rather like magnetic force microscopy, except that the head itself is the sensing element. Z-axis sensitivity down to 2 nm and lateral resolution of the order of 1 μm can be achieved. Modified firmware of an existing disk drive allowed full servo-control in the landing zone, necessary to study the laser texture with the MRM (Magnetic Readback Microscope). In a sealed drive, laser-bump shape, pitch and height can be measured. We also observe and explain how the radius of the texture transition zone as seen by the drive has substantially more variation than at the component level. We also include a comparison between MRM and baseline modulation imaging on laser bumps and thermal asperities. Finally, we report variations in M_rt caused by the laser bump and disk manufacturing process itself.

[1]E. Schreck, "Magnetic-readback Mapping and its Application to Slider/Disk Interface Damage due to Shock Impact," *Tribology and Mechanics of Magnetic Storage Systems*, Vol. IX, p. 5 (1994).
[2]K. B. Klaassen, R. E. Eaton, J. C. L. van Peppen "Effect of Thin Film