

OSEE Determination of Fluorocarbon Lubricant Film Thickness on Magnetic Disk Media

Khalid T. Mahmud*

Nashua Computer Products, Santa Clara, California

Mantosh K. Chawla

Photo Acoustic Technology, Inc., Westlake Village, California

To reduce stiction/friction, increase disk life, and to minimize interaction of the read/write head on the magnetic disk surface, manufacturers of magnetic media frequently add a thin layer (5 to 50 Å) of some commercially available fluorocarbon lubricant.

Optically Stimulated Electron Emission (OSEE) is particularly well suited to measuring lubricant thickness because of its speed. It offers, for the first time, simultaneous measurement of lubricant thickness on both sides of the disk. Data from both sides can be archived into a computer in < 30 sec. A graphics software package can display a color map or 3D graphics image of the lubricant thickness variation across the surface of the rigid disk media.

Theory of OSEE

Metals and other surfaces emit electrons when illuminated with ultraviolet (uv) light of the proper wavelength. The scattered electrons cross an air gap and are detected by a biased collector as a current converted into a voltage. Any thin film coating on the surface, depending on its own photoemission characteristics, can either enhance or attenuate the inherent emission from the substrate.

An unlubricated rigid disk media has high photoemission characteristics. A coating of lubricant film on the media attenuates the photoemission. Attenuation of electron flow follows an exponential law (1):

$$I_p = I_o \exp(-d/L) \quad (1)$$

Where I_p is the attenuated OSEE signal due to film thickness, d . I_o is the OSEE signal at $d = 0$ and depends on the work function

of the substrate. L is an attenuation index representing the resistance to electron transport through the film. It is a constant for a given lubricant.

Equation 1 can be simplified into:

$$d = L \ln(I_o) - L \ln(I_p) \quad (2)$$

Experiment #1

Winchester-type media with lube thicknesses of 14 to 36 Å were measured at Photo Acoustic Technologies on a P.A.T. OP1030 Disk Analyzer, an OSEE system particularly suited to measuring lube thickness on rigid disk media. The system is fully automatic, except for the disk loading/unloading operation. About 300 readings per side were taken on each disk spinning at 500 rpm. There were 5 disks for each of 4 different thicknesses.

OSEE readings on the 5-1/4 in. dia. rigid disks were taken every 12 degrees around the circumference at 10 different radial positions between the outer and inner diameter. The OSEE readings and corresponding angular and radial positions were stored in the computer, available for printout in matrix format.

On at least 2 disks of each thickness, Electron Spectroscopy for Chemical Analysis (ESCA) was used to determine lube thickness, d . The lube thickness also was measured on each disk using FTIR (Fourier Transform Infrared) spectroscopy

(Table 1). Correlations were made between OSEE and these two alternative lube thickness measurement techniques (Tables II and III).

Correlation with ESCA. A relationship was established between OSEE (OSEE units) and ESCA (Å) measurements. Good correlation between the two methods was obtained within the range of film thicknesses examined. The parameters, L and $L \cdot \ln(I_o)$, in eq. 2 as derived from least-squares-fit lines (slope and intercept, Fig. 1), are listed in Table II. "Upper side" refers to the side of the disk media that was facing up when spinning during measurement. The coefficient of correlation, r , between the two methods is good within the range of lube thicknesses measured.

Correlation with FTIR. A relationship was established between OSEE (OSEE units) and FTIR (MABS; Mili-Absorbant units) measurements. Once again, good correlation between the two methods was found within the range of thicknesses examined. The relationship between FTIR and OSEE is also of the type shown in eq. 2 with the thickness measured with FTIR spectroscopy. Table III lists the values of the slope and intercept parameters in eq. 2 from the least-squares-fit lines for the FTIR measurements (Fig 2).

Table I – ESCA, OSEE, and FTIR Results

ESCA (Å)	OSEE (OSEE units)		FTIR (MABS)	
	Upper Side	Lower Side	Upper Side	Lower Side
14	399	384	4.91	5.26
25	179	167	11.15	10.64
31	117	103	17.70	14.85
36	82	70	17.99	17.41

*K.T. Mahmud is now at Akashic Memories, Santa Clara, California.

Table II – ESCA/OSEE Regression Results

	Upper Side	Lower Side
L	13.84	12.84
$\ln(I_0)$	96.86	90.54
r	-0.999	-0.999

Table II – ESCA/OSEE Regression Results

	Upper Side	Lower Side
L	8.18	67.14
$\ln(I_0)$	53.76	47.90
r	-0.999	-0.999

Experiment #2

Lubricant thickness can be measured using a variety of techniques, including ESCA, FTIR, and ellipsometry, and each is very accurate ($\pm 1 \text{ \AA}$). However, large capital costs for analytical equipment (\$60,000) combined and slow measurement times have prompted Nashua Computer Products, a supplier of thin film media technology, to search for a new technique for reducing the measurement time. This search led to an OSEE instrument which can measure the lube thickness in < 10 sec and at a cost of < \$35,000.

The unit consists of a disk fixture with spin stand (3600 rpm), a P.A.T. surface quality monitor Model OP1010-2 based on OSEE principle, and dual-sided uv probe emitter/detector. Repeatability was evaluated first and, then after establishing a lube correlation curve with ESCA and FTIR (Fig 3), sensitivity to the disks' chemical status and surface roughness was examined.

A production calibration curve between an FTIR instrument and an OSEE instrument was established for a total of 54 disks with upper and lower surface readings combined onto the same plot. Each point marked in Fig. 3 represents one individual OSEE/FTIR data point. The relationship between the lubricant thickness and OSEE reading is as described in eq. 2. The regression analysis yielded the following values: $L = 14.29$; $L \cdot \ln(I_0) = 95.43$; $r = -0.975$.

The results of Experiment #2 compare well with the correlation of OSEE with ESCA readings in Experiment #1. The coefficient of correlation is lower because the upper and lower side readings were combined; it is therefore suggested that the sides be monitored separately to measure true correlation. This quick measurement

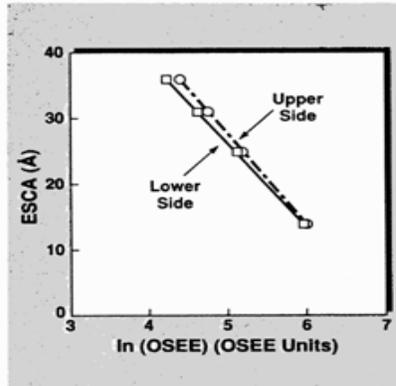


Fig. 1—Relationship between ESCA and OSEE.

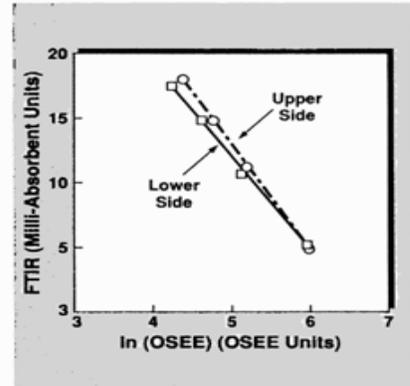


Fig. 2—Relationship between FTIR and OSEE.

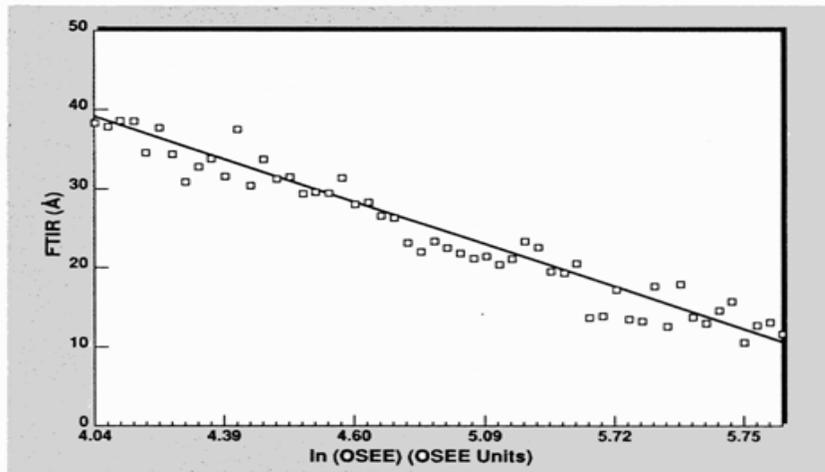


Fig. 3—Production calibration curve relating FTIR and OSEE measurements. The correlation coefficient (r) was -0.975 for the straight line shown here as determined by least-squares method.

technique has been most effective in controlling the application of fluorocarbon lube when combined with statistical quality control techniques.

One reason Nashua Computer Products has been able to ship high quality products is that they monitor and control lube thickness with $\pm 3 \text{ \AA}$ on a real-time basis in manufacturing. The OSEE has paved the way for using process control charts, increasing sampling plans, charting population distributions, and identifying unusual trends.

Summary

As an alternative to ESCA, FTIR, and ellipsometry, for measuring fluorocarbon lube thickness on magnetic media, Optically Stimulated Electron Emission has the following advantages:

1. Results in < 10 sec.
2. Large throughput of disks for sampling.
3. Readings within $\pm 3 \text{ \AA}$ of FTIR.
4. Minimum operator training.
5. Compact, rugged equipment, well suited for a production environment.
6. Process variations can be identified and corrected immediately.

7. Easily used as a go/no go test for detecting lube on any coated surface.

As disk drive designs call for a decrease in the flying height of read/write heads, the lubricant overcoat becomes more and more critical; it must be precisely controlled to avoid stiction/friction and increase durability. To attain better control, continued research must be aimed at understanding 3 interacting factors, namely, *lube*, *texture*, and *magnetic overcoat*. OSEE offers the capability, speed, and cost-effectiveness needed to further our understanding these 3 fundamental factors.

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