APPLICATION NOTE

XPS Analysis of a Hard Disk Platter by Rapid Depth Profiling

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The award-winning* Thermo Scientific™ K-Alpha™ X-ray Photoelectron Spectrometer (XPS) System features outstanding spectroscopic performance, delivering fast analysis times and excellent chemical detectability. The instrument was used to investigate the changes in elemental composition of a hard disk platter from the surface down to the substrate. Principal component analysis was used to identify the elements present at each level of the depth profile.

Introduction

A hard disk platter is a component of a hard disk drive. All hard drives contain one or more hard disk platters, which are used to store the data. They consist of complex layer structures, which can be broken into three distinct levels. The base of the structure is a substrate material which forms the bulk of the platter and gives it structure and rigidity and is typically made from aluminum or glass. On top of the substrate is the magnetic media coating, where the magnetic impulses that represent the data are written.

The magnetic layers are created by vapor deposition of various metallic alloys. The surface of each platter is usually covered with a thin, protective layer made of carbon and, a super-thin lubricating layer.

The quality of the platters and their media coating is critical. A problem with the composition of any of the layers in the platter could lead to a malfunction in the hard disk resulting in data loss. This drives the need to characterize the platter for both elemental and chemical information from the surface to the substrate to check layer integrity and conformity.

XPS depth profiling offers a simple way of characterizing multilayer samples such as these.

Thermo Scientific K-Alpha XPS

Experimental

There are two different methods of depth profile analysis. The first, which uses a rapid snapshot acquisition technique to capture region data for each element, would be used if the elements in the sample were already known. In the case of the hard disk platter, the elements that would be present were unknown, so a second method was used. This procedure involves recording a wide scan or survey spectrum at each depth profile level. By using a wide scan across the entire spectral range, all elements, with the exception of hydrogen and helium, can be detected.

A fragment of a hard disk platter was depth profiled by rastering a beam of 500 eV argon ions over a 2 mm by 4 mm area. Each etch cycle was 10 seconds, and after every etch level a survey spectrum was collected to detect all possible elements at every sample depth. To obtain the best quality depth profile, the sample was rotated azimuthally during each etch cycle, giving rise to an etch crater of diameter 2 mm. Figure 1 shows an optical image of the etch crater recorded immediately after completion of the depth profile.

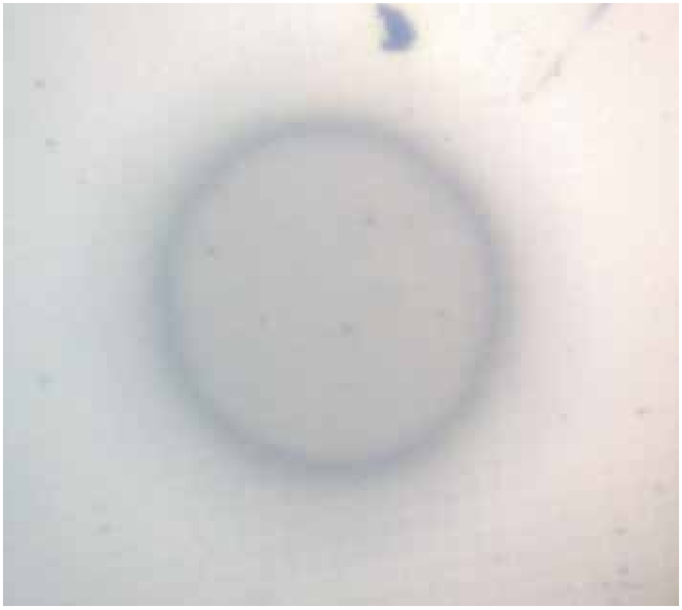


Figure 1: Optical image of the circular etch crater obtained by azimuthal rotation during depth profile sample analysis

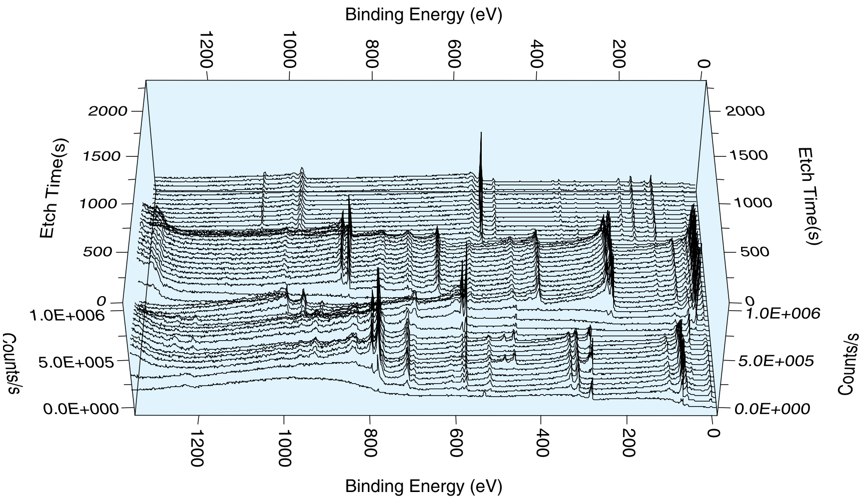
The outstanding XPS sensitivity offered by the K-Alpha system allows for the data to be collected in a very short timeframe without compromising spectral quality. In this case, each survey spectrum took just nine seconds to acquire.

The Thermo Scientific™ Avantage™ Surface Analysis Software supplied with all Thermo Scientific surface analysis systems features principal component analysis (PCA) for reviewing large multi-level data sets such as depth profiles and images. This was used to pick out the major components of the complete set of 230 survey scans from the depth profile data set. Other tools in the software were used to identify the elements present in the identified PCA components, and generate the final atomic concentration profile.

Results

The results of the analysis are shown in figures 2-4. Figure 2 features a montage of survey spectra at each level of the depth profile. Survey spectra are typically used to provide elemental information from the surface and can be useful in identifying contaminants or unknown sample compositions.

Figure 2: Montage of depth profile survey spectra



The integrated PCA tool in the Avantage data system picked out the seven major components of the complete set of 230 survey scans, represented as a set of seven discrete survey scans reconstructed from the data. Figure 3 shows the depth profile expressed in terms of the relative intensities of the seven PCA components.

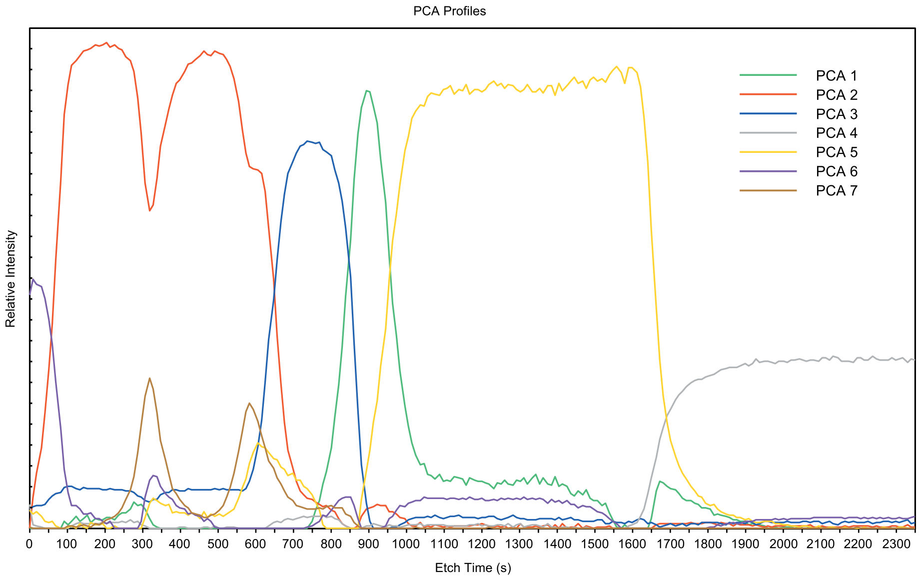


Figure 3: Depth Profile of hard disk platter expressed in terms of principal components

An automated "Survey ID" routine was then used to identify the elements present in each of the seven component PCA survey spectra. A total of 14 different elements were identified across the seven PCA components. The survey spectra from the original data set of 230 scans were then peak fitted at each etch level to give a full atomic percent quantification throughout the sample depth.

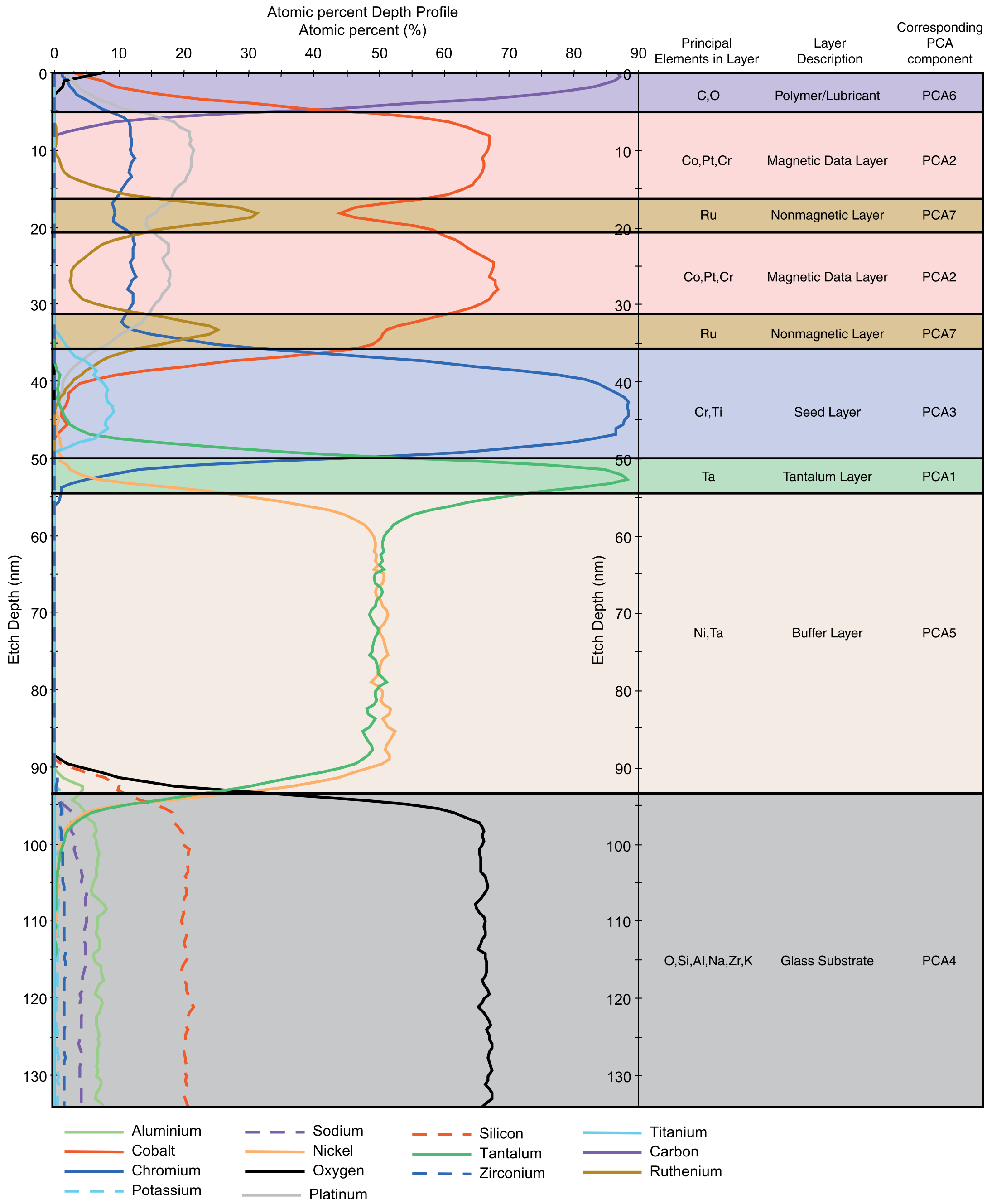
Finally, the etch time (s) was converted to an etch depth (nm) using etch rate measured on a 30 nm Ta_2O_5/Ta standard. Figure 4 shows the atomic percent depth profile and indicates the layers present.

The depth profile in Figure 4 shows that the platter substrate is glass. Above this is a buffer layer of nickel and tantalum to prevent the crystallographic structure and orientation of the glass from affecting the orientation of any of the other thin film layers. Directly above this is a thin tantalum interlayer. On top of the tantalum layer is a seed layer of chromium and titanium to improve the growth and orientation of the subsequently deposited layers. Next there are two pairs of nonmagnetic (ruthenium) and magnetic (cobalt, platinum and chromium) layers. The magnetic layers are used to store the data, and the thin nonmagnetic layers allow the magnetic layers to be magnetized in opposite directions, which reinforces the magnetic state and removes the danger that the magnetic state might be lost because of thermal effects. Finally, a thin top layer of carbon is added to provide corrosion resistance and improve its mechanical reliability.

Summary

The excellent XPS sensitivity offered by the K-Alpha system allows for rapid depth profiling of both known and unknown samples without compromising data quality.

Tools in the Avantage data system, such as PCA, allow for fast and easy data processing of large data sets. In this example, by expressing the data in terms of its principal components, only seven spectra had to be analyzed to find all the different elements present over all 230 scans. This enabled a high quality elemental depth profile of the hard disk platter sample to be generated very quickly.



Principal Elements in Layer	Layer Description	Corresponding PCA component
C,O	Polymer/Lubricant	PCA6
Co,Pt,Cr	Magnetic Data Layer	PCA2
Ru	Nonmagnetic Layer	PCA7
Co,Pt,Cr	Magnetic Data Layer	PCA2
Ru	Nonmagnetic Layer	PCA7
Cr,Ti	Seed Layer	PCA3
Ta	Tantalum Layer	PCA1
Ni,Ta	Buffer Layer	PCA5
O,Si,Al,Na,Zr,K	Glass Substrate	PCA4

Figure 4: Depth profile of hard disk platter expressed in terms of elemental atomic percentages

* R&D 100 award 2007; AVS New Product award 2006.

Keywords
K-Alpha, Depth Profile, Hard Disk Platter, Principal Component Analysis (PCA), Surface Analysis, XPS

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