SIMS
Application Note 278

SNMS
Sputtered Neutral Mass Spectrometry

Magnetic Layers

Summary

Sputtered Neutral Mass Spectrometry is ideally suited to the analysis of thin metal films where composition, thickness and interface condition can be determined. In this example we show a magnetic film stack containing Cr, Ni, Cu and Fe.

Introduction

Of the many methods of data storage magnetic hard discs still provide the most cost effective means for high density rapid access. The continued move towards ever smaller read/write heads and more closely spaced data tracks has lead to a dramatic development of magnetic materials and structures for this demanding application.

Analysis of the metallic layer structures used in magnetic data storage is vital for both development and quality management with Secondary Ion Mass Spectrometry (SIMS) and Sputtered Neutral Mass Spectrometry (SNMS) providing information on minor and major element composition repectively.

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SIMS and SNMS

Both SIMS and SNMS use a focused, mono-energetic, chemically pure ion beam of typically 1-10 keV to sputter erode the surface under analysis. A small fraction of the sputtered material becomes ionized due to the sputtering process itself and, in SIMS, it is these ions that provide the sensitive information for which the technique is known. Being a mass spectrometry technique all elements and isotopes may be detected, and in favorable conditions the detection limit can be in the low ppb region.

However, because the ionization mechanism for SIMS occurs at the sample surface, it is highly dependent upon the local chemistry and the ionized fraction can vary by many orders of magnitude. This makes SIMS ideal for trace analysis in materials of known matrix but quantification in materials of changing matrix can be complex.

SNMS overcomes the “matrix effect” by separating the sputtering and ionization events. Even in high ion yielding situations the fraction of ions rarely exceeds 1% of the sputtered material, so the neutral flux is much more representative of the sample composition. Ionization for SNMS occurs in an electron bombardment cell at the front of the analyzer which means that the ionization probability is a constant and does not depend upon the sample chemistry.

To quantify SIMS it is important that the reference material be as similar to the unknown as possible and should certainly be of the same matrix material.

For SNMS this matrix matching of reference materials is unnecessary, as calibration factors do not change with matrix, therefore, the required sensitivity factors can be determined from easily available metal and ceramic samples of published composition.

In addition, SNMS is ideal for the analysis of insulators, as the neutral species are unaffected by sample charging, however, charge compensation is still advisable in order to maintain consistent primary beam conditions.

The ionized secondary particles are analysed and detected in the mass spectrometer. At very low ion beam currents analysis is confined to the top few monolayers – excellent for detection of surface contamination. As the ion beam dose is increased and sputtering becomes more aggressive, subsequently deeper layers are exposed and concentration as function of depth can be determined.

Using a focused ion beam, both SIMS and SNMS become spatially resolving and elemental images can be recorded.

The analysis presented here was made using the Hiden SIMS workstation, a complete and highly flexible quadrupole SIMS/SNMS instrument equipped with the IG20 gas ion gun and MAXIM SIMS/SNMS analyzer.

Layer Analysis

The depth profile below was measured using 5 keV Ar^+ ions whilst detecting the sputtered neutrals. Secondary ions were rejected by using a high target potential in order to give them energy in excess of that required to pass the analyzer.

The detection limit of SNMS is frequently better than one part per thousand. Quantification was provided using readily available stainless steel and copper based alloy materials.

The depth profile shows the alloy composition of the uppermost 30nm thick NiCr layer and indicates that there is no diffusion into the lower Cu layer. The Cu layer also shows no contamination with the underlying Fe, either through diffusion or early exposure due to pin-holing in the film. The Cr signal can be seen rising towards the end of the analysis as the substrate adhesion layer is reached.

Inherent in SNMS is the ability to accurately determine interface quality in regions of changing chemistry.

SNMS depth profile through magnetic layer stack