AXIC APPLICATION REPORT

Multilayer Film Thickness Measurement 5

The Axic 100-II Wavelength Dispersive Spectrometer (WDS) x-ray fluorescence measurement systems (XRF) can effectively and non-destructively measure the thickness of multilayer films. Typical applications might be measurement of a Ti-Ni-Au backside metalization on semiconductors or a TiW-Au base layer in a hybrid circuit. The Axic 100 series routinely demonstrates multilayer metal measurement accuracies of ±3% or less of the film thickness at three standard deviations (3σ).

The Problem:

Maintaining control over the thickness of the backside metal layer is critical to maintaining the proper electrical conductivity, bonding, back plane conduction and heat sink characteristics of a semiconductor device. Typically these layers consist of several different metals to maximize the bonding and thermal transfer properties of the film. Measurement of the thickness of these layers isn't possible via optical techniques, and resistive techniques will not differentiate the individual layers. Destructive techniques take time to complete and cannot be done on product wafers. Other analytical techniques such as Rutherford Back Scattering (RBS) are expensive and typically cannot be done by most in-house labs. XRF presents an ideal compromise to these limitations as it can quickly and accurately analyze multilayer films in a production environment in a non-destructive fashion.

The Measurement Technique:

XRF uses x-rays generated in a target, typically Rh, Mo, or W, to excite a sample. The sample then produces secondary x-rays upon relaxation from its excited state. The energy of the secondary x-rays relates to the elements found in the sample. Put another way, each element in the periodic table shows an x-ray spectrum unique to that element. By using x-ray dispersive techniques, a specific energy of x-ray can be selected to within ±15 electron volts (eV). This resolution improves by a factor of about 10 the resolution attainable from Energy Dispersive x-ray Spectrometers (EDS). The WDS technique reduces the background levels from other x-ray energies and improves the peak to background ratio of the desired x-rays from the element to be measured.

Thickness Measurement-One Layer:

In the same fashion that elements to be analyzed have characteristic x-rays, the target material used in the tube also has its own x-ray spectrum. Consequently, the majority of the x-rays entering a sample, to a good approximation, are one or two known wavelengths. Absorption cross sections for x-rays of known energy in a known material have been extensively measured. The total absorption of radiation (from the x-ray source) in a material is a function of the thickness of the film. The same is true of the re-emission of the secondary x-rays. Figure one gives a visual idea of the process of a primary beam of x-rays being absorbed into a sample and then being re-emitted into all directions.

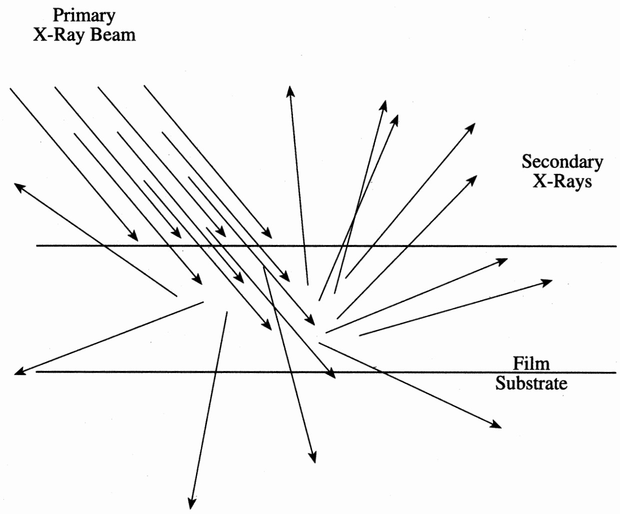

Figure 1

Both of these phenomena follow an exponentially decaying curve. As you move deeper into the sample the primary beam becomes weaker (due to absorbtion in upper layers) and the resulting re-emission from the lower layers lessens. The absorption and re-emission curves can be combined to generate a single curve for emitted intensity of a particular x-ray energy versus the thickness of the film.

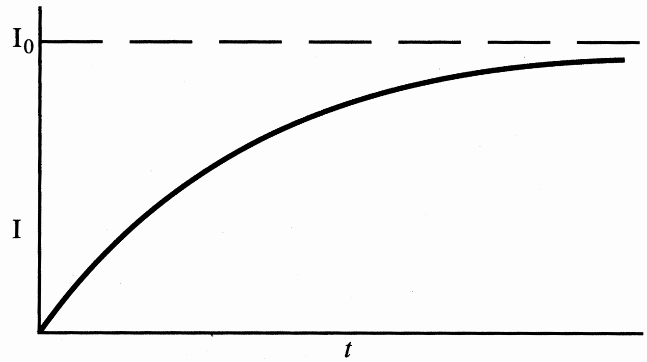

Figure 2

$$I = I_0 (1 - e^{-\mu t})$$

$\mu \equiv$ Collective x-ray absorption cross section.
$t \equiv$ Film thickness.
$I^0 \equiv$ Intensity of the selected x-ray in an infinite film.
$I \equiv$ Measured intensity of selected x-ray.

Figure 2 shows a typical intensity versus thickness curve for a metal film. The maximum seondary x-ray intensity corresponds to the rate emited from an infinitely thick film and is directly proportional to the incident intensity. This technique also can be used to measure alloys, photoresist, and many other films.

Extension to Two or More Layers:

As stated above, the emitted intensity of the x-rays from a film is proportional to the incident intensity. In order to accurately measure a second deeper layer, knowledge of the incident x-ray intensity at the boundary is necessary. This intensity is an exponential function of the thickness and composition of the overlying layer. The emitted secondary x-rays from the lower layer must pass through the upper layer before they can be detected. Again, the absorption of the lower layer x-rays in the upper layer must be considered. These effects are both exponential functions of the wavelengths involved and the materials in the films. By combining these effects, the incident x-ray intensity at the interface between the layers can be determined. This reduces the problem of the thickness of the second layer to the equivalent of a single layer film.

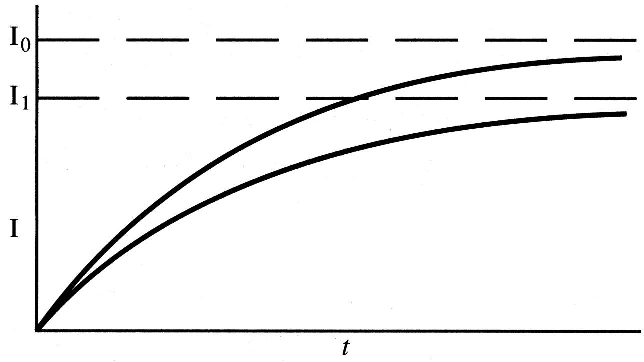

Figure 3

$$I = I_1 (1 - e^{-\mu t})^* e^{-\epsilon t}$$

$\epsilon \equiv$ Absorption effects of the top layer on the second.
$I_1 \equiv$ Intensity of the lower layer x-ray from an infinite film after absorbtion in the upper film.

Measurement Results:

Using the techniques described above, convenient, rapid measurements of films of up to 4 layers can be made with the Axic 100-II with the auto-spectrometer option.

Multilayer measurement applications can include semiconductor, hybrid circuit, or magnetic disk applications. Typical films might be; Cr-Ni-Au or Ti-Ni-Ag on silicon in semiconductor applications, TiW-Au or Cr-Ni-Cu on Al_2O_3 or glass substrates, or Cr-Co in magnetic disk applications. Table 1 lists results and accuracies from just a few of the films measured with the Axic 100-II.

TABLE 1: Multilayer Film Thickness Measurement

Application		Film Stacks	(Å) Thickness Range	1 Sigma Precision of Single Film Measurement	1 Sigma Precision of Stacked Film Measurement
Semiconductor	a)	Cr-Ni-Au			
		Cr	200 to 1000	1.3%	1.6%
		Ni	1000 to 8000	0.8%	1.0%
		Au	200 to 1000	1.0%	1.0%
	b)	Ti-Ni-Ag			
		Ti	400 to 1000	1.0%	1.4%
		Ni	1000 to 8000	0.8%	1.0%
		Ag	200 to 1000	1.0%	1.0%
Hybrid	a)	TiW-Au			
		TiW	500 to 2000	1.0%	1.3%
		Au	500 to 5000	1.0%	1.1%
Magnetic	a)	NiP-Cr-Co			
		Cr	200 to 1000	1.3%	1.6%
		Co	200 to 1000	1.3%	1.3%

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