

Surface and Thin Film Analysis Methods

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It is very important to realize the many different and complementary techniques currently used in the field of surface and thin film analysis. All of these methods involve bombarding the sample with an incoming (incident) particle and monitoring an ejected particle. The precise method being employed is differentiated from the others according to the identity of the respective particles. Figure 1 illustrates the basic principles and Table 1 lists the most common techniques and their acronyms.

It is very important to note that these methods all require that the analysis be performed in an ultra-high vacuum apparatus and that each of the methods wherein the incident particle is either an electron or an ion measures must be taken to insure that the sample surface is electrically conductive. Thus, for insulating materials and films such as oxides, glasses, and polymers, the experiments are not straight forward. The fact that the instrument is maintained at high vacuums and has very sophisticated components, virtually requires that the operator has a Ph.D. degree. Other than XRF, these instruments cost a lot.

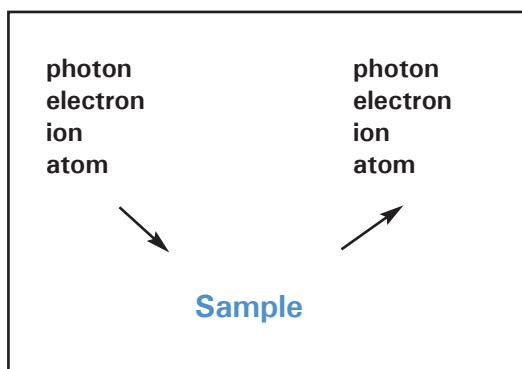


Figure 1: Incident and monitored particles in surface analysis methods.

Table 1: Surface and thin film analysis methods and their acronyms

Incident Particle	Ejected Particle	Technique name	Acronym
X-ray	Electron	X-ray photoelectron spectroscopy or electron spectroscopy for chemical analysis	XPS or ESCA
X-ray	X-ray	X-ray fluorescence spectrometry	XRF
Electron	Electron	Auger electron spectroscopy	AES
Electron	X-ray	Electron probe microanalysis	EPMA (EDAX)
Ion (Ar, Xe, Cs,O)	Sample ion	Secondary ion mass spectrometry	SIMS
Ion (Ar, Xe, Cs,O)	Sample atom	Sputtered neutral mass spectrometry	SNMS
He ion	He ion	Rutherford backscattering spectrometry	RBS
Laser photon	Sample ion	Laser mass spectrometry	LAMMA

The use of the above methods in depth profiling applications, rather than surface analysis is dependent on the sampling depth of the incident and ejected particles. For XPS and AES, this value is approximately 3 monolayers (10 angstroms), SIMS and SNMS 10 monolayers, and RBS and XRF on the order of 100 monolayers. Subsurface information can only be obtained beyond these levels through the removal of sample material, usually through sputtering with a high energy ion beam. This step is implicit in the SIMS/SNMS experiments, but is usually included as an auxiliary feature in the other instruments. In XPS for example, one would alternate between bombardment of the sample with ions and X-rays to generate a depth profile. In fact, most surface science instruments come with a multiplicity of these methods (SIMS + AES + XPS) as the actual vacuum chamber is one of the more costly components. The sputtering rates in these instances, on the order of 10 nm/min, place a major limitation on these methods as films of >5 m thickness require prohibitive amounts of time for analysis. On the other hand, depth profiles generated in this manner can achieve depth resolution of better than 10 nm without much difficulty.

One of the most compelling reasons for using these surface analysis methods is the ability to generate elemental maps of the sample surface. These images are effectively similar to scanning electron micrographs, but with element-specific information. In the cases where electrons are the incident particles, spatial resolution on the order of 5 nm can be achieved. Ion microprobe (SIMS) experiments can generate elemental images having 20 nm resolution over regions of 10s of square micrometers. Due to the inability to focus x-ray beams to such fine levels, the spatial resolution of those methods is only on the order of 50 m. It is the ability to generate element-specific images of surface species that is the strong point of these techniques. There are limitations for most of the methods

regarding range of elemental coverage and sensitivity. This is particularly true for the electron/x-ray based methods as they are applied to non-metals such as H, C, N, and O. In practice, SIMS provides the largest range of coverage and best sensitivity, down to the ppm level while the others are generally limited to >0.1 %.

The vendors of the various surface science instruments can be found in widely distributed 'buyer's guides', such as published by Analytical Chemistry or R&D Magazine. Many of the conferences where surface science is discussed have instrument exhibits. These include the Materials Research Society, the American Vacuum Society, and SemiCon. Different countries and regions of the world will have similar conferences.



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