# Thin Films and Coatings by XRF and XRD: An Overview

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I spoke recently with a senior engineer from one of the world's largest semiconductor companies. He told me "If I was allowed to have only one analytical tool in my lab, my first choice would be X-ray. It can do everything. But if another technique can do the job, no matter how indirectly, X-ray is my last choice". And, until recently, that summed up the position of X-ray techniques in the thin-film industry. XRD, XRF and XRR are universally acknowledged to be more direct and less model-dependant than optical methods but, with several notable exceptions, their practical difficulties have limited their application to a laboratory role and prevented their widespread use as metrology tools in the manufacturing line. What are those practical difficulties? In short, it's the trade off between angular, spectral and spatial resolution on the one hand and, on the other, accuracy, precision and measurement time. For an Industry used to micron-scale spatial resolution and MAM times in seconds, the typical x-ray spot is too big and the measurement is too slow.

But X-ray metrology in the thin-film industry appears to be approaching a tipping point driven by the confluence of a set of needs and an emerging set of solutions. The drivers in the semiconductor industry are multiple and include the use of ultra-thin layers for new gate dielectrics, the use of localized stress to enhance channel mobility, the use of novel low-k dielectric materials and the emergence of engineered substrates such as SOI, and GOI. All of these present new metrology problems that are poorly served by the classical optical methods in current use.

At the same time, the last decade has seen slow but steady improvement in the performance and availability of x-ray optical devices for focusing an x-ray beam – combined with some remarkable advances in detector technologies for parallel data acquisition. The diameter of the XRR, XRF or XRD probe beam has dropped from a few mm to a few hundreds of microns – or perhaps even less than 100 microns.

In this talk, I'll try to present an overview of the information content of XRD, XRF and XRR in the context of contemporary thin-film problems and then attempt to position the three X-ray techniques with respect to the more established metrologies.