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Electron probe microanalysis of thin films and multilayers using the X-FILM computer code

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Electron probe microanalysis (EPMA) is an analytical technique widely used for determining the composition of solid samples that are homogeneous at the micrometer scale. The technique is also suitable for determining the thickness and composition of thin films deposited on substrates and multilayers, with thicknesses less than one micrometer. To do that, conventional k-ratio measurements are performed at varying incident electron energy and they are processed with the help of a thin-film analysis program. The latter determines the composition and thickness of the film or multilayer by fitting the predictions of an x-ray emission model to the measured k-ratios.

The reliability of thin-film programs is usually assessed by comparing measured and calculated k-ratios from well characterized thin films. In recent years, extensive experimental databases have become available for this purpose [1,2]. In this communication, we investigate the reliability of X-FILM, one of the thin-film codes available at present. X-FILM has been developed by one of us (C. Merlet) and since its release in 1995 it has been improved and refined in the light of new experimental data. The validity of X-FILM is assessed by comparing its predictions with the recent experimental measurements of Bastin and Heijligers [1,2], which constitute the most extensive database of k-ratios from thin films, as well as with other experimental data available in the literature. The predictions of X-FILM are also compared with the results of Monte Carlo (MC) simulation using the code PENEPMA, a dedicated tool for the simulation of x-ray spectra based on PENELOPE [5]. Finally, we give examples of applications of X-FILM which illustrate the capabilities of the code that, in turn, are useful to assess its consistency.

Figure 1a compares experimental Al k-ratios emitted from Al films deposited on 20 different substrates, as functions of substrate atomic number, with the predictions of X-FILM and PENEPMA. The thickness of the Al films is 13.8 $\mu g/cm^2$. The measurements were performed by Bastin and Heijligers [2,3], at an accelerating voltage of 20 kV. The k-ratios resulting from the calculations with X-FILM and PENEPMA are found to be in good agreement with the experimental data, although MC simulation results seem to match slightly better the measurements. Figure 2 shows comparisons of measured k-ratios and the best fit obtained with X-FILM for a C coated, P-doped SiO_2 glass film deposited on Si, as a function of beam energy. The fit gave the following result: C 30 nm/P-SiO_2 1 μm/Si, with a P concentration of 4 at.%. The measurements were performed on a CAMECA SX-100 electron microprobe, using the $K\alpha$ lines of O, C, Si and P. The agreement between measured k-ratios and the predictions of X-FILM is satisfactory for all analyzed elements and electron incident energies. Our results show that X-FILM is a valuable tool for quantitative analysis of thin films and multilayers with EPMA.

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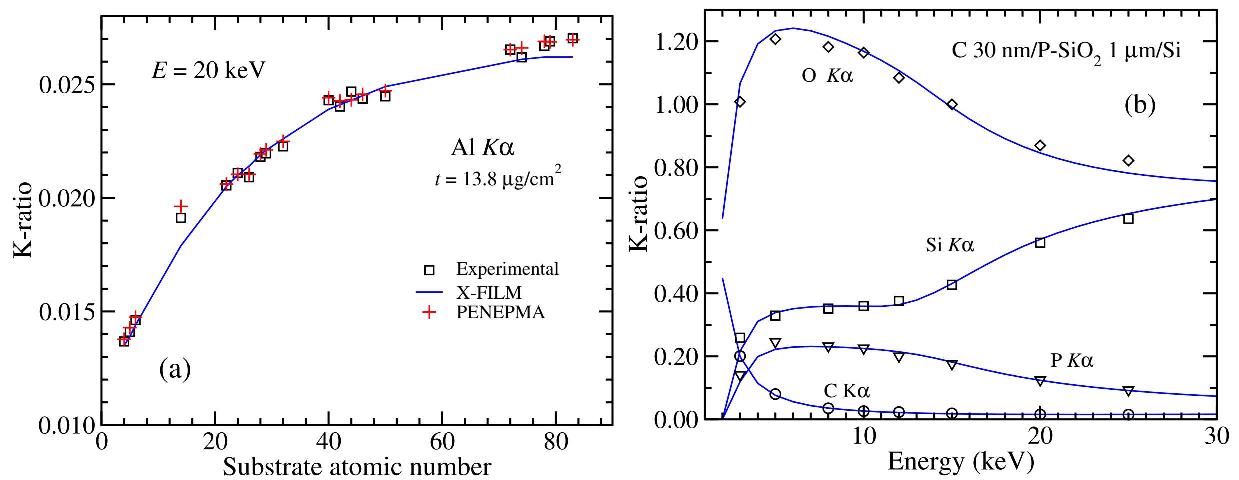

Figure 1: K-ratios for Al films deposited on different substrates, versus substrate atomic number (a) and for a C 30 nm/P-SiO_2 1 μm/Si multilayer, as a function of electron incident energy (b). Open symbols represent experimental data. Continuous lines are the results from X-FILM. Crosses are MC simulation results using PENEPMA.

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