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High–energy–resolution grazing emission x–ray fluorescence applied to the characterization of thin Al films on Si

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Abstract

The grazing emission x–ray fluorescence (GEXRF) technique was applied to the analysis of different Al films, with nominal thicknesses in the range of 1 nm to 150 nm, e on Si wafers. In GEXRF the sample volume from which the fluorescence intensity is detected is restricted to a near–surface region whose thickness can be tuned by varying the observation angle. This is possible because of the refraction of the fluorescence x–rays and the quite long emission paths within the probed sample. By recording the x–ray fluorescence signal for different shallow emission angles, defined relatively to the flat, smooth sample surface, the deposited Al surface layers of the different samples could be well characterized in terms of layer thickness, layer density, oxidation and surface roughness. The advantages offered by synchrotron radiation and the employed wavelength–dispersive detection setup were profited from. The GEXRF results retrieved were confirmed by complementary measurements. The experimental setup, the principles and advantages of GEXRF and the analysis of the recorded angular intensity profiles will be discussed in details.

Key words: grazing emission x-ray fluorescence (GEXRF), thin film characterization, synchrotron radiation, high–resolution x–ray spectroscopy
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1. Introduction

Thin film depositions or coatings can be prepared by different methods like atomic layer deposition (ALD) [1], chemical vapor deposition (CVD) [2], molecular beam epitaxy (MBE) [3], magnetron sputtering [4], pulsed laser deposition (PLD) [5], spin coating [6] or electrospraying [7]. They are important for both technological and scientific applications. The aim of the layer deposition is to modify the thermal, mechanical, optical, chemical or electrical properties of a system. Examples of applications are organic surface modification, chemical sensors, photoelectrochemical cells, photocatalysis, structured semiconductor applications, mass storage and microelectronic devices (metal-oxide-semiconductors, dynamic random access memory), laser and x-ray optics (lenses, mirrors and multilayers). Technological progresses in the microelectronic and the solar cell industries with the inherent device size downscaling result in more demanding requirements for the thin film production and analysis. A better characterization is also asked for novel materials with high dielectric constants and oxynitride layers, which are both foreseen to replace silicon dioxide because of diffusion problems and defect density, polymer films and very thin films in the nanometer range.

As a specific example of thin–film applications, Al depositions on Si were used during some decades in the microelectronic industry, for example in the production of integrated circuits. However, the advances in the performance of semiconductor devices and their increased complexity revealed some limitations in the use of Al so that alternatives were looked for (Ag and Cu mainly) [8] although applications with Al are still realized [9]. The better adhesion of Al to the Si surface and the low intermiscibility of Al (resp. aluminates of a metal) and Si, are reasons why Al depositions on Si are still used, e.g., as a buffer layer, a diffusion

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