APPLICATION OF A HIGH-RESOLUTION GRAZING EMISSION X-RAY FLUORESCENCE IN MATERIAL SCIENCES

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In recent experiments [1, 2] performed at the ESRF beamline ID21 we have demonstrated that the grazing emission x-ray fluorescence (GEXRF) technique combined with synchrotron radiation excitation and high-resolution x-ray detection offers new attractive possibilities for application of synchrotron radiation to study the distribution of low-level contamination on the surface of materials. The GEXRF technique benefits from the grazing emission observation angle (*i.e.* below the critical angle) of the x-ray fluorescence excited by a narrow and intense x-ray photons beam and from high-resolution (~1 eV) detection by means of a diffraction von Hamos spectrometer [3]. This technique can be effectively used for detailed surface studies of different materials, including ultra-low concentration ($\sim 10^{10}$ atoms/cm^2) contamination and its depth and lateral distribution in the nanometer and micrometer scale, respectively.

In the GEXRF method [4] the excited x-ray fluorescence is observed at a small, grazing emission angle ($\varphi < \varphi_c$) below a critical angle φ_c , being usually below 1°. The grazing emission geometry results in a relative enhancement of the characteristic fluorescence emission from surface impurities with respect to substantially suppressed x-ray fluorescence from the bulk material, which for grazing emission angles are limited to the evanescent x-ray waves [4] propagating along the surface. In this way the x-ray fluorescence from the substrate is limited to the very shallow surface layer of about few nm. Consequently, the GEXRF is a kind of an "inverse" of the total reflection x-ray fluorescence (TXRF) method [5], both techniques having similar detection limits. In the GEXRF measurements, to fulfill the grazing emission condition $\varphi < \varphi_c$, the samples were tilted close to the direction of observation of x-rays, defined by the Bragg angle. For such geometry the photon beam spot on the target is viewed by the x-ray spectrometer as a very narrow line, allowing its slitless operation mode resulting in an increased detection sensitivity.

The GEXRF method is well suited for elemental 2D mapping with a resolution given by the size of the x-ray photon beam, while the depth distribution of the surface contamination can be extracted from the measured dependence of the x-ray fluorescence intensity on the emission angle with respect of the surface. The high-resolution x-ray detection leads to a drastic improvement of the selectivity of elemental analysis and it allows for a substantial reduction of the x-ray "background" from the Raman scattering process. Furthermore, by using a linearly polarized x-ray photon beam and a polarization sensitive diffraction spectrometer the x-ray background from elastic scattering of primary photons can be substantially reduced.

In this paper the following detailed aspects of the high-resolution GEXRF method will be discussed: measurements of the low-level Al impurities on Si wafers, reduction of the resonant Raman scattering "background" below Si K-edge, 2D-mapping of Cr pattern on Si, and Al depth profiling in Si for film-like and ion-implanted samples. Due to ultra-low detection limits, the 2D mapping and depth profiling capabilities, the GEXRF technique is well suited for future applications in nanotechnology.

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