Study of Buried Interfaces in Fe/Si Multilayer by Hard X-ray Emission Spectroscopy

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Abstract — The study of periodic multilayers is a topic of interest due to their applicability as optical components for numerous applications in x-ray mirrors, x-ray spectroscopy, space telescopes, and quantum well lasers. The optical performance of these multilayers dramatically depends on the interfaces formed between different layers of the multilayer stack. Hence, it is essential to characterize them and obtain necessary information regarding the multilayer structure.

X-ray emission spectroscopy (XES) has been proved to be a studied tool for analyzing buried layers and interfaces non-destructively. The emission spectra allow us to study the interactions between elements in the buried layers from the analysis of their valence states, thereby providing sensitive information about the physical-chemical environment of the emitting element in multilayers. Until now, XES has been applied in the soft x-ray region (photon energy $\leq$ 2 keV) to study the buried layers and interfaces, but now we extend the methodology to study the buried interfaces in the hard x-ray region (i.e., $\geq$ 5 keV). We choose Fe/Si multilayer system owing to its potential applications in microelectronics and magnetism. We exploit the chemical sensitivity of XES to study the interfaces between Fe and Si layers in the Fe/Si multilayer from the Fe $K\beta_{2,5}$ emission spectra obtained in the hard x-ray region.

The Fe $K\beta_5$ emission line results from the electronic transition from occupied 3d to 1s levels (i.e., valence to core transition) and is hence sensitive to the chemical state of emitting Fe atoms. The characterization of the physicochemical state of the iron atoms within the Fe/Si multilayer as obtained by XES shows the formation of iron silicide, i.e., $FeSi_2$ at the interface and enabled the determination of its thickness of 1.2 nm. The formation of $FeSi_2$ at the interface was further confirmed by the x-ray diffraction and X-ray photoelectron spectroscopy done on the Fe/Si multilayer.

Keywords **—** Buried Interfaces, Hard X-ray emission spectroscopy, X-ray diffraction, X-ray photoelectron spectroscopy

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Characterization of Mg/Sc system for X-ray Spectroscopy in the Water Window Range

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Abstract — Periodic multilayer mirrors have potential application as optical components in X-ray microscopy, particularly, working in the water window region. The water window range, located between the absorption edges of carbon (285 eV) and oxygen (530eV), along with the presence of nitrogen K absorption edge (395 eV), makes it a powerful method for imaging biological samples due to the natural optical contrast between water and carbon. We characterized bilayer, trilayer, quadrilayer and multilayer systems of Mg/Sc with ZrC thin layers introduced as a barrier layer and capping layer prepared by ion beam sputtering.

The structural analysis of the Mg/Sc systems was carried out by using grazing incidence X-ray reflectivity (GIXRR) to obtain non-destructively a first description of the structural parameters, thickness, roughness, and density of the layers. Resonant soft x-ray reflectivity measurements in the vicinity of Sc L-absorption edge were performed to investigate and to quantify the atomic distribution of deposited layers. Near absorption edge, the atomic scattering factor of an element changes sharply depending on its chemical environment inside the structure.

Mg/Sc systems were also characterised using grazing incidence X-ray fluorescence (GIXRF) that enabled us to obtain element specific composition and depth concentration profiles inside the material. First results show that a strong intermixing occurs between Sc and Mg layers without the presence of ZrC barrier layer. However, the introduction of barrier layer shows better reflectivity in the multilayer. The ZrC capping layer also prevents the stack from oxidation. Additional information about elemental distribution in buried layers and interfaces will be obtained with secondary ion mass spectrometry (SIMS).

Keywords — Buried Interfaces, Grazing Incidence X-ray Fluorescence, Resonant soft X-ray reflectivity, X-ray reflectivity

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