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An advanced X-ray spectromicroscopy of Bi2Se3 ultrathin films on SiO2/Si substrates

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Here, our aim is to study through an advanced X-ray spectromicroscopy (SPEM) analysis the first stages of growth of ultrathin Bi2Se3 films on the same substrate with particular attention to the film stoichiometry and interaction with the substrate underneath. To this end, Bi2Se3 films have been grown on n-doped silicon (001) wafers with native oxide. The X-ray photoelectron spectromicroscopy (SPEM) was conducted at ESCA microscopy beamline of Elettra Sincrotrone Trieste research center. Two samples (obtained by positioning the two substrates in two different locations along the bottom of the furnace quartz tube) were been analyzed through SPEM. Using the data obtained, the ability of this two-step PVD growth technique to produce stoichiometric Bi2Se3 films is confirmed. Moreover, SPEM images taken at Bi4f, Se3d, Si2p XPS peaks show for the two samples a completely different behavior. While in one of the samples, Bi and Se are almost homogeneously distributed on the Si oxide substrate; for the other one, Bi atoms are present only in certain areas corresponding to the protruding regions in the optical micrograph, while Se atoms are distributed quite homogeneously on the Si oxide surface. This means that at the first stages of this PVD growth, Se atoms are the first sticking on the Si oxide surface. Interestingly, the Bi4f and the Se3d binding energies are found to be comparable with those reported in literature for the Bi2Se3 films, suggesting that no charge transfer occurs at the interface with Si oxide surface, which should have been clearly detected for such an ultrathin Bi2Se3 film. In addition, the analysis of the high resolved XPS O1s peaks confirms the presence of Bi-O bindings. All these findings confirm the SPEM images results, indicating that in the first stages of PVD growth, Se atoms are the first to distribute on the Si oxide substrate and followed by the formation of a stoichiometric Bi2Se3 film. Furthermore, no charge transfer has been detected between the substrate surface and the Bi or Se atoms, which we detect after about more than a month from the growth, a small fraction of the bismuth oxide formation due to the interaction of the Bi2Se3 film with environment.

Summary

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