Interface electronic and magnetic states and band dispersion of insulator/ferromagnet heterostructures studied by hard x-ray angle-integrated and angle-resolved photoemission

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Hard x-ray photoelectron spectroscopy (HAXPES) combined with x-ray total reflection (TR) allows us to depth-dependent electronic structures of solids [1]. Surface band bending of GaN was successfully observed in TR-HAXPES [1]. To further explore the application of TR-HAXPES, we applied this method to probe insulator/ferromagnet heterojunctions, which are of importance in the performance of magnetoresistance devices. For a $AlO_x/Co_2MnSi(001)$ structure, we found that the near-interface Co and Mn magnetizations underneath the AlO_x layer obtained by TR-HAXPES are reduced to ~77% compared to the bulk region obtained by non-TR-HAXPES for Co_2MnSi at room temperature, revealed by magnetic circular dichroism (MCD) in core-level HAXPES with the photon energy of 5.95 keV. In addition, the valence band structure of the near-interface Co_2MnSi was different from that of the bulk Co_2MnSi due to the enhanced spin-wave excitation near the interface [2]. The changes in the valence band structure in Co_2MnSi for both near-interface and bulk regions were also observed in the temperature-dependent valence band HAXPES [3], suggesting the importance of thermally induced spin fluctuations in Co_2MnSi at finite temperature [4]. Furthermore, we adapted the TR technique to band dispersion measurement for a MgO/Fe(001) heterojunctions by means of hard x-ray angle-resolved photoemission spectroscopy (HARPES) [5]. HARPES with the photon energy of 3.29 keV at 20 K clearly exhibited band dispersion of Fe(001) underneath the MgO layer. The subtraction of bulk band dispersion of Fe obtained by non-TR-HARPES from the near-interface band dispersion obtained by TR-HARPES revealed the hidden band folding at the MgO/Fe interface, which did not occur in the ideal MgO/Fe(001) interface. Thus, HAXPES and HARPES combined with TR are useful for detecting buried interface electronic and magnetic states of heterojunctions.

Keywords: HAXPES, HARPES, insulator/ferromagnet interface, x-ray total reflection, buried interface, electronic and magnetic states, band dispersion.

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