ESRF	**Experiment title:** Influence of the top metal contact on the high-k oxide layer and the interface to the InAs substrate in MOS structures studied by hard x-ray photoelectron spectroscopy	**Experiment number**: 25-02 734
Beamline: BM25B	**Date of experiment**: from: 05 April to: 12 April 2011	**Date of report**: 01 March 2012
Shifts: 18	**Local contact(s)**: Juan Rubio-Zuazo, Gérman R. Castro	*Received at ESRF:*

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Report:

Metal-Oxide-Semiconductor (MOS) devices are challenged by the ongoing demand for higher speeds and less power consumption. One strategy for improving MOS field-effect-transistors is to use small band-gap III-V semiconductors with high electron mobility, like InAs [1]. A high-k dielectric material is used as substitute for the native oxide to further increase the performance. Thereby the interface between the semiconductor and the high-k layer is crucial for the device performance.

This interface has widely been studied using X-ray photoelectron spectroscopy (XPS) [2-4]. However, such investigations are limited to very thin high-k layers due to the small probing depth of conventional XPS, neglecting the influence of a thicker dielectric layer and the impact of the top gate metal. Only the use of Hard X-ray PhotoEmission Spectroscopy (HAXPES) allows the investigation of realistic MOS stacks.

We have investigated InAs-HfO_2-W and InAs-HfO_2-Pd structures with HAXPES at BM25 at the ESRF, using photon energies varied between 11 and 20 keV. HfO_2 layers of either 6 or 12 nm thickness were formed by atomic layer deposition, while the 5 nm thick metal films were evaporated. Film thicknesses were confirmed by X-ray reflectivity measurements, which also indicate rather abrupt interfaces, with a fitted interface roughness of less than 0.5 nm for the InAs-HfO_2 interface and less than 0.2 nm for the HfO_2-metal interfaces. InAs-HfO_2 samples without any metal on top served as reference.

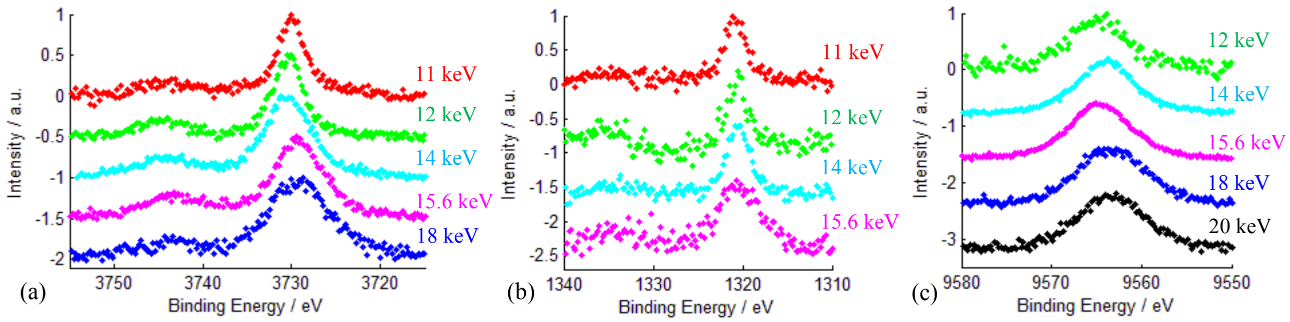

Figure 1: (a) In *2p* spectra of a sample with 6 nm HfO_2 and 5 nm W. (b) As *2p* spectra of the same sample. (c) Hf *2p* spectra of a sample with 12 nm HfO_2 and 5 nm W. All spectra are normalized and shifted vertically for better visibility. Note that the instrumental peak broadening increases with increasing beam energy.

The In *2p* [Fig. 1 (a)] and As *2p* [Fig. 1 (b)] core-level spectra demonstrate the ability of HAXPES to investigate an interface buried more than 15 nm below the surface. The peak shapes show no dependence on the imaging depth except of the varying instrumental broadening, indicating an abrupt interface between the InAs and the HfO_2, in agreement with conventional XPS studies [2-4]. From the As *2p* peaks any significant amount of interfacial As-oxide can be excluded [Fig. 1 (b)]. The energy-dependent Hf *2p* spectra [Fig. 1(c)] reveal a homogeneous depth profile of both the 6 nm (not shown here) and 12 nm thick HfO_2 layers.

A manuscript discussing these data is currently being prepared and will be submitted soon.

As external users, we want to gratefully thank the whole team of the SpLine beamline, especially Gérman Castro for giving us the possibility to perform experiments at this exceptionally versatile instrument, and Juan Rubio-Zuazo for his very friendly and competent support at the beamline. Further, we want to acknowledge the Swedish Research Council (VR), the Crafoord Foundation, and the European Commission for financial support. This work was performed within the Nanometer Structure Consortium at Lund University (*nmC@LU*).

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