Spectroscopic ellipsometry in the VUV range applied to the characterization of ALD HfO_2, Al_2O_3 and $HfAlO_x$ thin layers for high k dielectrics

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New high k dielectric materials are intensively investigated to replace the silicon dioxide as gate dielectric in the next generations of electronic devices. The layer thickness which will be used in the future devices is of the order of some nanometers and a precise control of this critical stage of the process will be mandatory.

In this respect, spectroscopic ellipsometry has long been recognized as a powerful technique for thin film characterization and is now used routinely to control thin films and multilayers at different stages of the device fabrication process. For very thin layers like high k dielectrics, the interface properties play a key role in the device. A precise physical model is then needed to extract accurate information from ellipsometry. In addition, since these layers are completely transparent in the visible and UV range, the correlation between thickness and refractive index is very high and so, structural and thickness information cannot be extracted independently.

In this paper, we use vacuum UV (VUV) spectroscopic ellipsometry to characterize such layers. Indeed, all the candidates for high k dielectrics become absorbent when the wavelength is reduced down to 190nm. So, the correlation between thickness and refractive index is reduced in the VUV range and more precise structural information can be deduced. HfO_2, Al_2O_3 and mixed $HfAlO_x$ layers have been deposited by Atomic Layer Deposition (ALD) on a 1 nm oxide grown in-situ by rapid thermal oxidation (RTO) on 200 mm (100) silicon wafers. The thickness and the composition of the layers has been changed and some wafers have been annealed in a nitrogen ambient at 700ºC after the deposition. X-ray reflectometry (XRR) has been used to measure precisely the layer thickness and transmission electron microscopy (TEM) was used to get information on the crystallinity and on the interface properties.

VUV spectroscopic ellipsometry can detect the crystalline character of the HfO_2 layers (cf. Fig.1) thanks to the absorption peaks detected in the VUV range. The composition of $HfAlO_x$ layers can also be deduced in addition to the layer thickness from the optical absorption (Fig. 2). More results will be discussed in the paper.

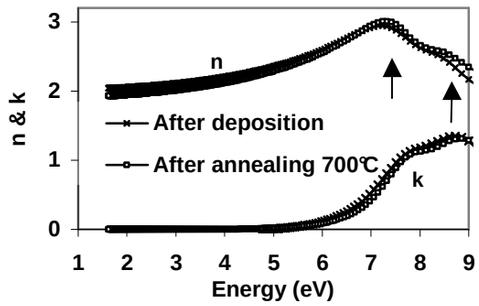

Fig. 1 : HfO_2 optical indices with and without thermal annealing at 700°C.

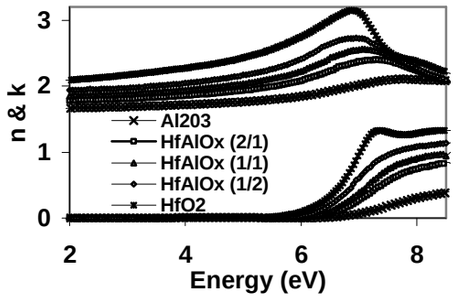

Fig. 2 : Optical indices of different high k dielectrics deposited by ALD.