Spatially-resolved EELS study of dielectric properties of high-\(\kappa\) HfO\(_2\) thin layers stacked between Si(001) and poly-Si.

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Improvements in energy resolution and deconvolution algorithms allow to explore smaller features closer to the zero loss peak (ZLP) in EELS. Of particular interest is the extraction of energy for direct or indirect bandgaps [1]. For thin layers included in a stack, the proximity of interfaces result in spatially-localised interface plasmons (IP) with peaks in the low-loss region [2]. The IP energy can be less than the bandgap, which can affect the interpretation of the band structure. Here, we compare energy-loss spectra of bulk HfO\(_2\) with spectra taken on Si/HfO\(_2\)/poly-Si stack. The effects related to interfaces are explored with spatially-resolved EELS in STEM. Low-loss spectra were acquired with a cold-FEG STEM and a TEM equipped with a monochromator. Two approaches for the removal of the ZLP tail were tested: (1) direct subtraction and (2) pre-deconvolution of ZLP. The bandgap of HfO\(_2\) (\(\approx\) 4.5 eV) appears clearly for bulk specimen (fig. 1a) but not for thin (\(\approx\) 5 nm) layers in a stack. Contrary to the bulk specimen, the hafnium oxide layers (fig. 1b) are polycrystalline and contain significant amount of nitrogen. Moreover, additional layers (\(\approx\) 1 nm) of SiO\(_x\)N\(_y\), as identified by core-loss analysis, are present at both interfaces with the high-\(\kappa\) layer. Multivariate statistical analysis (MSA) of low-loss spectra also highlights the presence of these additional layers (fig. 1c). However, the spectra taken at the centre of the HfO\(_x\)N\(_y\) film differs from the bulk spectra. In this study, we analyse the contribution of the different interfaces to the energy-loss signal. The effect of delocalisation on low-loss measurements will be discussed.

![Spectra and images](image)

FIG. 1. (a) Low-loss EELS of bulk HfO\(_2\), (b) HRTEM image of gate stack, and (c) profile of the 3 principal components extracted from MSA of low-loss spectra.

References
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