calculate the thickness of an SiO$_2$ layer that would give rise to this Si 2p (bonded) feature using the standard expression and the parameters derived for SiO$_2$ by Lu et al.\textsuperscript{1} The sample deposited at ambient without O$_2$ (----) had a peak area corresponding to a nominal thickness of 0.08 nm of SiO$_2$. The films deposited in O$_2$ at 20 °C (-----) and 500 °C (-----) had a thickness of 0.4 and 0.6 nm, respectively. Also shown (-----) in Fig. 1 is the spectrum for a bare silicon substrate annealed for 42 min in 1.3 mPa.

The film deposited without O$_2$ at 20 °C was brought out of the system for several hours and reintroduced for subsequent XPS analysis. The spectrum shown in Fig. 1 (-----) indicated that the interfacial layer had grown to a thickness of 0.8 nm. Since a layer this thick would not be formed by oxidizing silicon in ambient O$_2$ or H$_2$O, it can be deduced that the film was formed by a catalytic process, most likely through the diffusion of atomic oxygen liberated through reaction with the Sc$_2$O$_3$ film. The HRTEM analysis of the cross-section of this film revealed it to be amorphous with an amorphous interfacial layer ~0.8 nm thick, in agreement with the XPS result.

The result of ex-situ annealing of these films in O$_2$ and N$_2$ will be discussed. Further analysis was done to determine the amount of Sc present in the interfacial layers.

Advanced techniques used for the characterization of these thin dielectric films will be presented and compared with results obtained on ultrathin Si oxynitride films. These include energy filtered transmission electron microscopy, near edge structures analysis, electron nanodiffraction and high angle annular dark field scanning transmission electron microscopy with near nanometer to 0.2 nm spatial resolution.

Acknowledgements

We are grateful to X. Tong, A. Duft, F. Pearson, and T. Quance for their expert technical support.

References


![Figure 1. Si 2p XPS peak for Sc$_2$O$_3$ films: (-----) deposited at 20 °C without O$_2$, (----) at 500 °C without O$_2$, (-----) at 500 °C with 1.3 mPa O$_2$, (-----) wafer deposited at 20 °C without O$_2$ exposed to air, (-----) bare Si(100) heated in 1.3 mPa O$_2$ for 42 min.](image-url)