MBE growth monitoring of thin Oxides/Si

LayTec is expanding the application of its sensors to new materials such as ultra-thin oxides on silicon. In collaboration with Dr. Lutz Geelhaar of Namlab in Dresden (Germany) – a joint venture of Qimonda and TU Dresden – first promising in-situ measurement results were gained recently [1].

Reflectivity is a well known and established method for relatively thick layers (> approx. 20 nm). However, for thin films it is often assumed that ellipsometry is the only suitable optical technique, but ellipsometry usually requires very accurate sample positioning and strain free view ports. Since reflectivity measurements are less demanding regarding the alignment and therefore better suited for in-situ applications, the intention of the joint project was to pave the way for Å-scale oxide thickness monitoring by optimizing reflectance tools.

This document shows how reflectivity measurements at optimized UV wavelength can be used to monitor the deposition of extremely thin ZrO_2 and Al_2O_3 layers (less than 30 Å) on silicon wafers in MBE. Furthermore, reflectivity was used as a means for temperature measurements as well. It is suited in particular for low temperatures when NIR pyrometry is not applicable or lacks accuracy, as it is the case for oxide deposition.

For layer thickness monitoring, LayTec's diode array based UV reflectometer **EpiR DA UV** was applied to VG-V80H MBE system. Fig. 1 shows the measurement set-up. Fig. 2 shows simulated reflectance signals for deposition of various 100 Å thin oxide layers: it is clear that the sensitivity is mainly influenced by the index of reflection n: materials with high n tend to more significant changes in the reflectance signal.

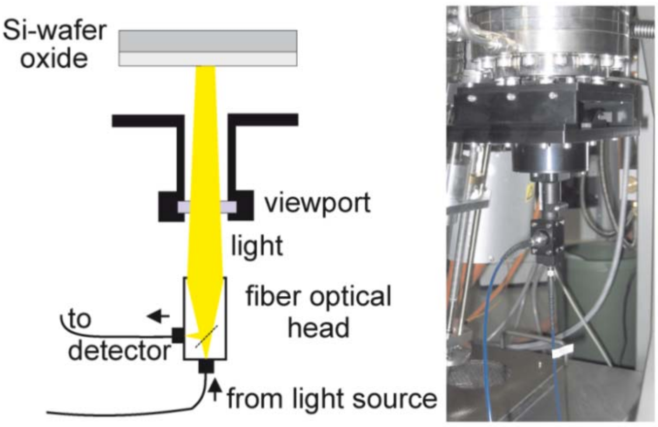

Fig. 1: Measurement setup installed at an oxide MBE chamber.

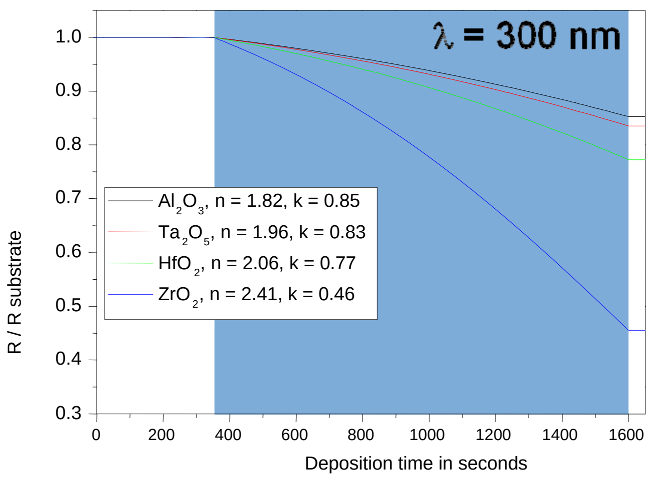

Fig. 2: Simulated in-situ reflectance signals for typical oxides.

Fig. 3 shows the measured reflectance at wavelengths of 300 and 405 nm during the deposition of 115 Å ZrO_2 on a TiN (46 Å) coated silicon wafer. The reflectance decreases with increasing thickness of the oxide layer. For ultra-thin layers, the 300 nm signal is most sensitive to changes in layer thickness.

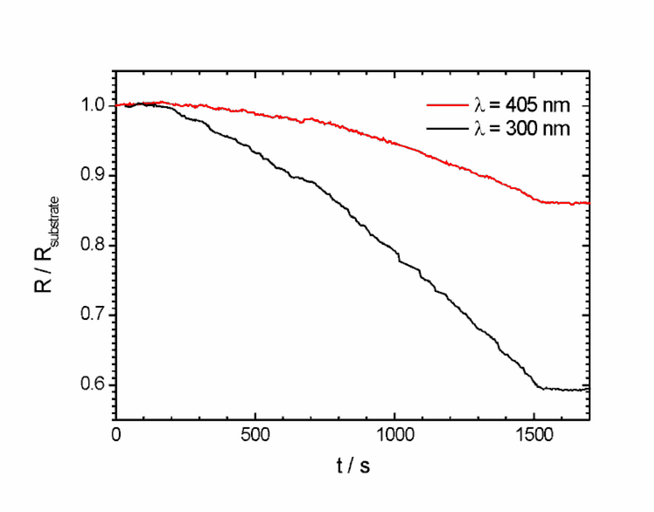

Fig. 3: Deposition of 115 Å ZrO_2 on TiN coated Si, monitored by reflectance measurements at wavelengths of 300 and 405 nm.

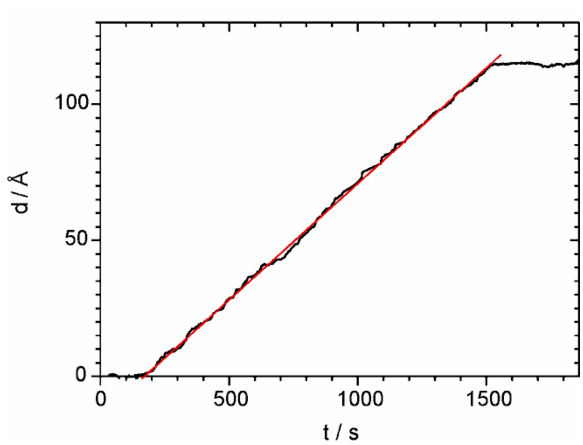

Fig. 4: Thickness of the ZrO_2 layer on TiN coated Si as determined by in-situ reflectance measurement at 300 nm (black curve).

However, when thicker layers are grown, the 300 nm signal passes a Fabry-Perot minimum. In this case a second wavelength can close the gap: a combination of 300 nm and 405 nm reflectance allows expanding the effective range of measurements to all typical thicknesses between 30 Å and 500 Å.

If the refractive index and the absorption coefficient of the oxide layer are well known, the layer thickness can be calculated directly from the measured reflectance. Fig. 4 shows the change of the thickness of a 115 Å layer of ZrO_2 as obtained from the 300 nm reflectance measurement, revealing a fairly linear growth with a growth rate of 0.085 Å/s, as indicated by the straight red line in Fig. 4. The accuracy of this method was shown to be better than ±1 Å for 50 Å ZrO_2 layers.

Beyond growth rate studies, reflectance measurements at longer wavelengths were used in [1] to determine the wafer temperature based on a double wavelength band-edge approach. For temperature measurements a VIS-IR reflectometer was applied. The measurements showed that during oxide growth the wafers experience a temperature offset of 17°C between process temperature and the wafer surface temperature, which was attributed to heating effects from the hot MBE sources.

This work opens a new field of application for LayTec tools not only in oxide MBE but also in sputter and other thin-film techniques. Please feel free to contact us for a copy of the publication [1].

[1] S. Uredat et. al.: Deposition of ultra-thin oxides on silicon: real-time film thickness and wafer temperature measurement. To be published in SVC 2008 conference proceedings.