

6 June 2002

Report on spectroscopic study of thin oxide-nitride samples

These are the same samples that we have studied with our single wavelength Picometer (AP7). There we showed that there was a substantial difference between the “annealed” and the “no anneal” samples, but we were unable using just a single wavelength to assign the difference to differing oxide or nitride thicknesses. We have now completed spectroscopic study of these samples from 196nm to 480nm. With high accuracy measurements we are able to separately determine the oxide and nitride content of the samples.

The samples have weathered a little over the period we have had them. We therefore cleaned them by gentle wiping with ethanol-coated lint-free paper wads before study. The value of y was monitored after each wipe until no further systematic change was found following an additional wipe. We have also controlled the laboratory humidity to around 40%, since we have earlier found that silicon absorbed about 2/3 monolayer (0.2nm) of water at 50% humidity. Diffusion through air slows this process, and little water was absorbed during the measurement time.

Residual interface signals

Most researchers studying oxide layers on silicon find that their data is best modeled by a two layer system, consisting of the oxide layer and an additional small interface layer whose origin is uncertain. One suggestion is that the interface term is due to roughness of the silicon/layer interface, which would be expected to produce a layer with thickness typically 1 to 2 monolayers with an effective layer dielectric constant somewhere between that of silicon and oxide. Or it could be due to roughness of the outer layer surface, when it is likely to have a dielectric constant between that of silicon and air. Or it could be due to residual water. Our own measurements on well-characterised wafers from another manufacturer have suggested that the interface term is best represented by a low (oxide?) dielectric constant layer, with a thickness of $\sim 0.75\text{nm}$. We have made the assumption that the same residue occurs with these samples, and have included in the data analysis the low dielectric constant interface layer.

Oxide and nitride layer thicknesses

We have modelled and curve-fitted the data in three ways (additional to the interface layer):

- (i) A single mixed-layer system optimising the dielectric constant and thickness in the data fit. The dielectric constant has been found to lie between the values for oxide and nitride, with a mixing parameter m where $\epsilon = m \epsilon_o + (1 - m) \epsilon_n$. The mixing parameter gives the

dielectric constant of the mixed layer, from which the refractive index is obtained. It can also be interpreted as a relative thickness of the oxide component $m = t_o / (t_o + t_n)$ and (1-m) the relative thickness of the nitride component.

(ii) A two layer system of oxide and nitride using standard material dielectric constants for these layers, optimising the layer thicknesses in the data fit.

(iii) A third model allowed the interface layer parameters to vary in the data fit. An interface with a larger dielectric constant, the other layer parameters essentially unchanged, produced a better fit. This suggests that the interface term varies from one manufacturer to another.

Figure 2 shows the total thickness (excluding the residual interface term) and the mixing factor m in the mixed model.

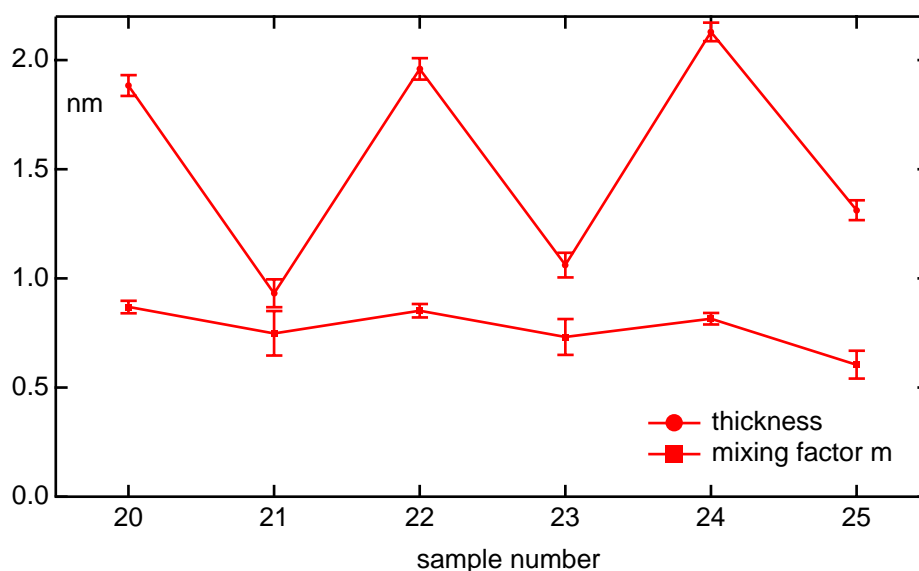


Figure 2 Mixed model variable parameters: mixing factor varies between 0 and 1.

The refractive index (evaluated at 633nm) of the mixed layer is shown in Figure 3 .

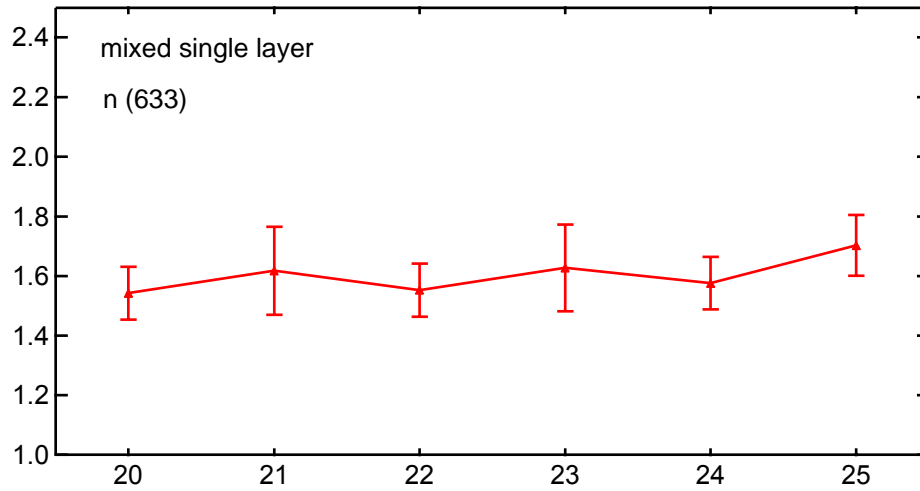


Figure 3: Refractive index of the oxide/nitride layer at 633nm derived from the mixing factor. The thicknesses of the oxide and nitride layers required to give the mixed refractive index are shown in Figure 4, where they are compared with thicknesses deduced using the two layer model. The agreement is good.

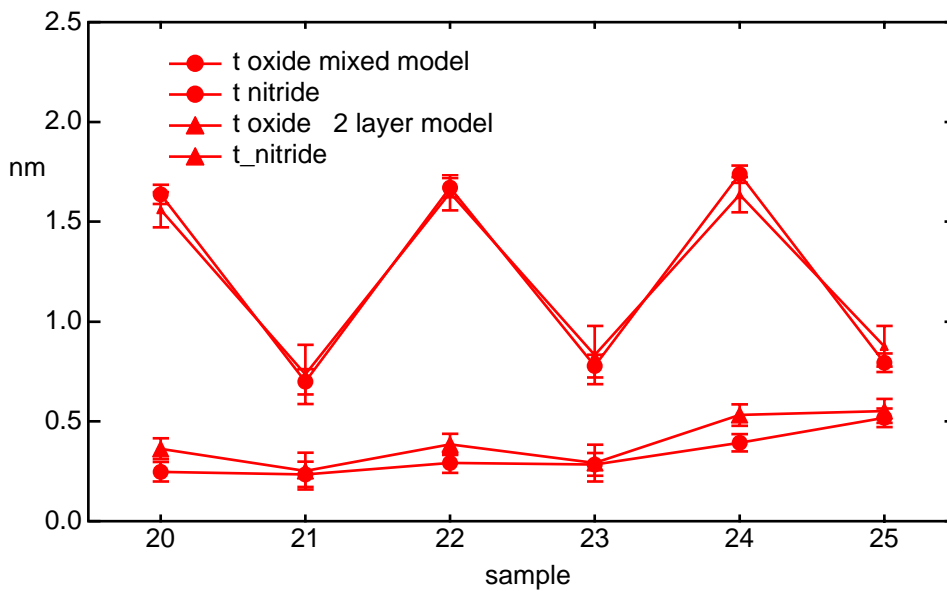


Figure 4 Comparison between thicknesses deduced by the mixed and the 2 layer models

