Very thin (< 10nm) silicon oxynitride (SiO_xN_y) layers formed by PECVD

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In this work, results of PECVD process optimisation aiming in repeatable formation of oxynitride layers below 10 nm, while still providing electro-physical properties, which (in the near future) would allow their application for CMOS ICs production, are presented. Properties of the oxynitride layers were determined by: spectroscopic ellipsometry, XPS and electrical characterisation methods.

The PECVD processing was carried in very low temperature (350°C) in typical parallel plate reactor (Plasmalab 80 Plus).

As a result of performed optimisation procedure it appeared feasible to control the growth of oxynitride layers below 10 nm (see Tab. 1 and Fig. 1).

In the course of this study the overall composition of the layer and its deposition rate, appeared to be relatively weakly dependent on PECVD parameters. As a result of this, the layers formed with very low deposition rates (18 nm/min) contained more silicon-oxide than silicon-nitride bonds in the deposited layers (compare Tab. 1 and Fig. 2), leaving not too much freedom for composition control.

The XPS in-depth composition profiles have shown that depending on the set of PECVD parameters oxynitride layers can have different composition profiles. None of them, however, exhibits characteristic for oxynitride layers formed by high temperature methods nitride few monolayers passivating silicon surface feature, which leads inevitably to poor electro-physical interface properties (very effective charge trapping) and consequently, to high threshold voltages of MOSFETs.

The spectroscopic ellipsometry measurements allowed independent determination of the dielectric layer thickness, evaluation of effective dielectric permittivity of the layer and approximate (preliminary information) composition (mean percentage of silicon oxide bonds in the layer). The composition data obtained in this way are close to the XPS data. The optical properties evaluated from the fitted model of the deposited oxynitride layers are presented in Tab.1.

The properties of the layers (below 10 nm) and systems (silicon-oxynitride) were also characterised by electrical methods using specially designed MOS test structures (MOS capacitors, MOSFETs and gated diodes). Number of electro-physical parameters were determined, e.g.: characteristic charges (fixed and interface traps), critical voltage causing breakdown, defects densities, ... etc. The exemplary results of high frequency C-V analysis are shown in Tab. 2.

The influence of medium temperature annealing (600°C) on the properties of the formed below 10 nm oxynitride layers and systems has also been studied in this work. Some of the results of such post processing are also included in Tabs. 1 and 2 and Fig. 3.

Tab. 1 Parameters of the "as deposited" and annealed in 600°C oxynitride layers determined by spectroscopic ellipsometry

Oxynitride layer	"As deposited" (parameters set A)	"As deposited" (parameters set **B**)	Deposited (parameters set B) + annealed
Temperatures [°C]	350	350	350 + 600
Deposition time [s]	20	20	20
Thickness [A]	83	69	59
Refractive index @630nm	1.702	1.783	1.748
Ratio SiO_2/(SiO_2+Si_3N_4) [%]	55	41	47

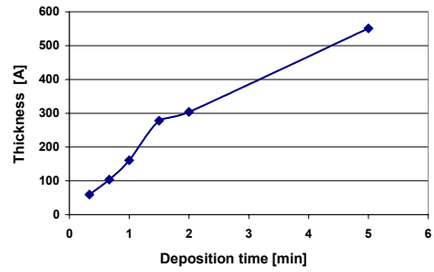

Fig. 1 Kinetics of PECVD deposition for optimised set of PECVD parameters set B

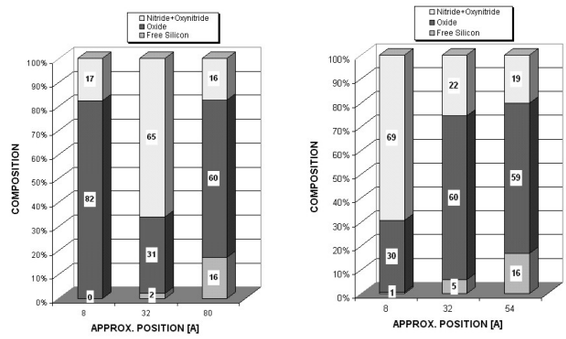

Fig. 2 Comparison of XPS determined compositions at few chosen positions within the layer for two different sets of PECVD parameters: a) 83Ă thick layer (parameters set A) and b) 60Ă thick layer (parameters set B).

Tab. 2 Parameters evaluated from the analysis of electrical characteristics of test structures (PECVD parameters set B)

Oxynitride layer	As deposited	Deposited and annealed
Temperature [C]	350	350 + 600
Final thickness [A] by ellipsometry	59.7	59.4
Effective dielectric permittivity	2.59	1.78
Ditmb(*Terman) [1/Vcm2]	4.39E+12	2.41E+12
Qeff/q [1/cm2]	7.86E+12	1.54E+12

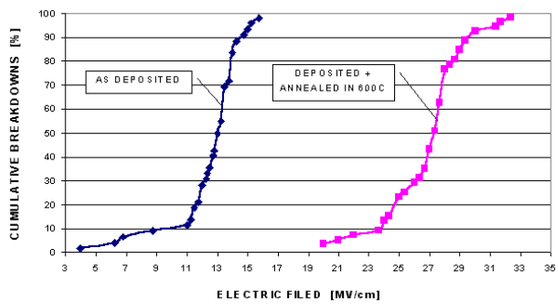

Fig. 3 Weibull plots for breakdowns measured under ramping voltage conditions on MOS structures with "as deposited" and annealed oxynitride layers (PECVD parameters set B in both cases)