HL 38.40 Frühjahrstagung der Deutschen Physikalischen Gesellschaft, Regensburg, March 27. - 31. 2000

Production and characterization of oxides and oxynitrides on highpure silicon for radiation detectors*

MPI Halbleiterlabor

Andreas Pahlke[1,2], Josef Kemmer[1], Heike Soltau[1], Lothar Strüder[1], Henning von Philipsborn[2]

[1]MPI-Semiconductor Laboratory, Otto-Hahn-Ring 6, 81739 Munich

[2]University of Regensburg, Universitätsstraße 31, 93053 Regensburg

The radiation hardness of silicon detectors is very important for the future use in highenergy physics, extraterrestrial science and analytics. With oxide-passivated devices radiation damage mainly occurs at the oxide-silicon interface. The process that is believed to produce these damages is the release of hydrogen from saturated silicon-valences at the interface (see figure 1).

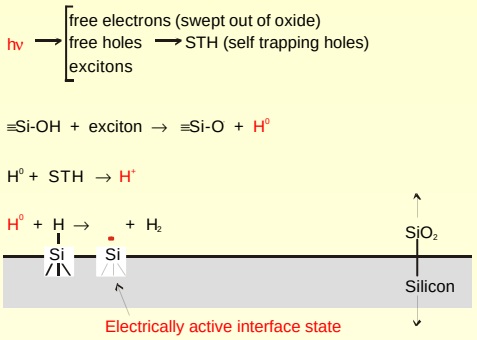

Figure 1: The hydrogen-model for radiation induced interface states: atomic hydrogen is formed by the reaction of excitons with OH-groups. Atomic hydrogen near the interface reacts with Si-H-bonds and forms an interface state. Atomic hydrogen formed in the oxide itself reacts with self trapped holes (STH) and forms a proton. The proton drifts to the interface and also forms interface states.

OH-groups in the oxide are mainly formed by moistness in the oxidation tube. Watermolecules diffuse through the oxide and break Si-O-Si-bonds. Thereby a Si-OH-group is formed.
Before irradiation the silicon valences at the interfaces are saturated with hydrogen. This desired saturation is done by an annealing of the wafers in a hydrogen atmosphere at 400°C. The hydrogen annealing is the last process step.

Options for the production of radiation-hard oxides

- **Reducing the density of OH-groups in the oxide by preventing of moistness in the oxidation tube => vacuum-process: the oxidation tube is evacuated before oxidation and filled with high purity oxygen (99,9995% purity).**
- **Passivating the silicon valences at the interface by strong bonded nitrogen instead of weak bonded hydrogen.**

1. Evacuating the oxidation tube

Before oxidation the oxidation tube is evacuated to $6 \cdot 10^{-5}$ bar and subsequently filled with oxygen. Moistness in the tube is therefore removed and gas composition is reproducible. By this vacuum process the density of interface states (determined by HF-LF-CV-measurement) of <111>-orientated wafers could be reduced by a factor of two to three compared to standard process.

Evacuating the oxidation tube before the oxidation reduces the density of interface states.

2. Production of oxynitrides

Oxynitrides are produced by incorporation of nitrogen. Several methods exist for the production of oxynitrides (see figure 2):

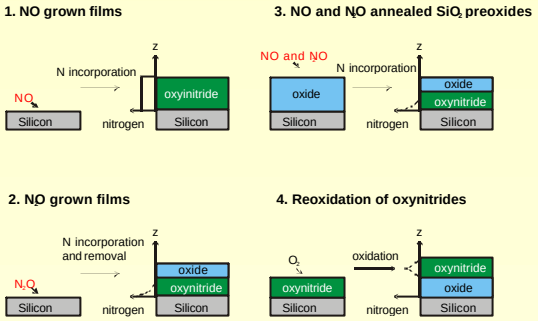

Figure 2: Production methods for oxynitrides: 1. Growth in pure NO, 2. Growth in pure N_2O, 3. Annealing of oxides in NO or N_2O , 4. Reoxidation of oxynitrides.

For the creation of thick oxynitrides (200 nm or more) one can only use method 3, the annealing of oxides in NO or N_2O. With the other methods the thickness of the produced oynitride obtains a maximum of 10 nm. NO was used as annealing gas because higher nitrogen concentrations at the interface can be achieved compared to N_2O.

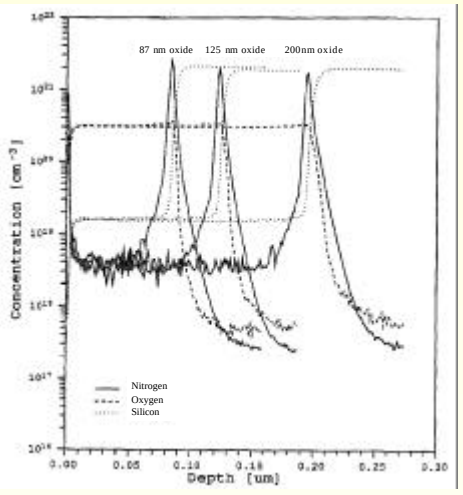

Figure 3: SIMS-measurements with oxynitrides of different thicknesses. The samples were produced by a two hour annealing of oxides in NO at 1050°C after oxidation at the same temperature. Noticeable is the sharp peak of nitrogen at the interface silicon-oxide.

By annealing of oxides at 1050°C in pure NO nitrogen concentrations of 3-5% at the interface could be achieved. An annealing time of 30 minutes was sufficient
By reoxidation of the produced oxynitrides the stability of the incorporated nitrogen could be approved. After a NO-annealing the further oxide growth is completely suppressed.

The incorporation of nitrogen at the interface is possible by annealing of oxides in a NO-atmosphere.

* Diploma thesis, University of Regensburg, October 1999