THE DIFFUSION, ACTIVATION AND MICROSTRUCTURE EVOLUTION OF PHOSPHORUS IMPLANTED INTO POLYSILICON

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As device scaling continues, rapid thermal annealing (RTA) has been used to minimize thermal budgets. However, these thermal budgets need to be optimized so as to control poly depletion effects. However, to date, a detailed physical understanding of how phosphorus diffuses in polysilicon is lacking. A physical understanding of how phosphorus activates in polysilicon is also lacking. While capacitance measurements can give us a measure of the poly depletion effect, the estimation of the electrically active profile in polysilicon is important for modeling purposes. This paper will discuss both experimental and modeling work pertaining to the diffusion and activation of phosphorus implanted into polysilicon thereby enhancing our understanding of the behavior of phosphorus in polysilicon.

Proprietary gate oxide of 18 A was grown on Czochralski silicon substrates. Subsequently, 1200 A of polysilicon was deposited at 625 deg C. Then Phosphorus was implanted into 1200 A of poly for doses between 1.5e15 and 5e15 at 8 keV and annealed for times between 800 deg C and 1050 deg C RTA.

As can be inferred from Fig 1, phosphorus diffuses very rapidly towards the poly/oxide interface. This is quite interesting as even a 800°C, 20 min anneal is sufficient to drive a substantial portion of the profile to the poly/oxide interface. The diffusion has been modeled in the industry standard simulator TSUPREM-4 [1] and the fits are also shown in Fig 1. In order to model this behavior correctly, a 2-stream diffusion model was used for the grain interior and the grain boundaries. The diffusivity of the phosphorus in the grain interior and the boundaries and the segregation of the phosphorus between the interior and the boundaries were varied to achieve the fits in Fig. 1. The critical parameters for the diffusion process of phosphorus in polysilicon have thus been identified. Some samples were also sent for profiling with the SSRM [2] (Scanning Spreading Resistance Microscopy) technique. The relative fractions of the electrically active profile for the 5E15, 8 keV case is indicated in Fig 2. Comparing Figs. 1 and 2, we see that while the phosphorus chemically accumulates at the poly/oxide interface, the electrically active fraction reduces close to the interface thereby increasing poly depletion. Possible mechanisms will be discussed. The study of the microstructure evolution using plan view and cross sectional TEM and investigation of the Phosphorus close to the poly/oxide interface are currently under progress.

References:

1. copyright Synopsys Inc.
2. P.De Wolf, et. al, J. Vac. Sci. Soc.A, 13(3),1995

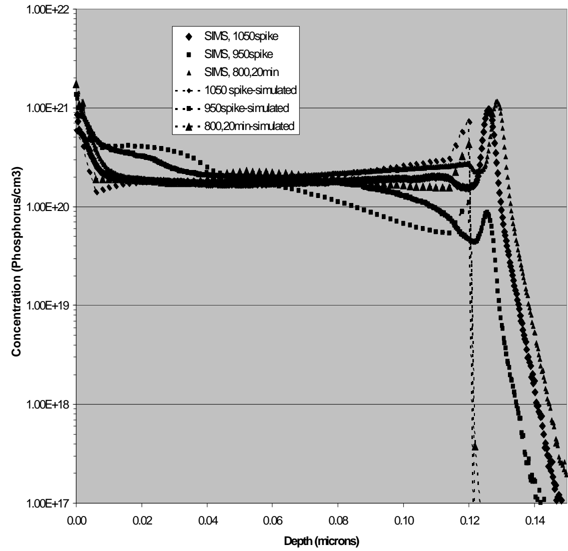

Fig 1: SIMS and simulated profiles of 3E15, 8 keV Phosphorus implanted into 1200 A of polysilicon. The solid lines are the SIMS and the dashed lines are the simulation. The SIMS profiles at 1200 A and beyond are indicative and not numerically accurate due to matrix mixing effects (~3%error) and variations (~3% error) on poly thickness

Fig 2: Results of SSRM (Scanning Spreading Resistance Microscopy) for 5E15, 8 keV Phosphorus. The origin “0” of the X-axis corresponds to the poly/oxide interface. Two 1050 spikes show larger activation than a single 1050 spike. This data also shows that the electrical activation decreases towards the poly/oxide interface while Fig 1 indicates that the chemical concentration increases towards the poly/oxide interface.