Simulation of BF_3 Plasma Immersion Ion Implantation into Silicon

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Plasma immersion ion implantation (PIII) has several advantageous features which make this method of semiconductor doping important for leading-edge semiconductor technology. In this work, the PULSION plasma doping tool developed by Ion Beam Services was applied to investigate PIII. Positively charged ions are extracted from the plasma by negative voltage pulses. To efficiently apply the PIII boron doping in silicon technology, simulation methods are needed to describe the boron implantation profiles in silicon after PIII. Conventional software tools for process simulation have only a limited applicability for this purpose, because the physical effects and parameters that determine the final doping profiles after plasma implantation are not well characterized. In this work, we performed PIII of boron into crystalline (100) silicon from BF_3 plasma using different values of the extraction voltages between 1 and 4 kV. The energetic distribution of different molecular and atomic single charged ions after extraction from the plasma is known to cover the range from zero to the maximum energy E_{max} which is equal to the product of elementary charge times the extraction voltage. In this work, we use an analytical model for the energy distribution of Tian et al. [1] based on the analysis of the plasma behavior at the onset of the extraction pulses. Assuming a universal energy distribution for the extracted ions of different masses, the implantation velocity of boron species is the lower the higher the mass of a molecular ion is. Therefore, different boron implantation profiles result for different ions. This is shown in Fig. 1, where boron profiles simulated separately for single charged ions of BF_3^+, BF_2^+, BF^+ and B^+ are presented. These profiles were calculated for each ion type using the Monte-Carlo ion implantation module of the Sentaurus Process [2] simulator for an implantation dose of 1×10^{15} cm^{-2} and the energy distribution mentioned. The profiles exhibit a maximum near the surface and channeling tails with different penetration depths. In the simulation of the final boron implantation profiles from PIII shown in Figs. 2 and 3 in comparison with experimental results for a boron implantation dose of 1×10^{15} cm^{-2}, a fixed relative abundance of BF_3^+, BF_2^+, BF^+, and B^+ was assumed and a finite depth of amophization during the implantation was accounted for. A good agreement of the simulation results with the measurements supports the physical assumptions of the simulation model. The suggested model allows a prediction of the implantation profiles after PIII doping for different extraction voltages. The full paper will also present the results of the simulation of PIII doping into two-dimensional and three-dimensional structures.

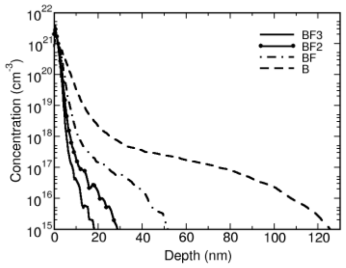

Fig. 1: Boron implantation profiles from single ionized ions of BF_3^+, BF_2^+, BF^+ and B^+ for extraction voltage of 1 keV

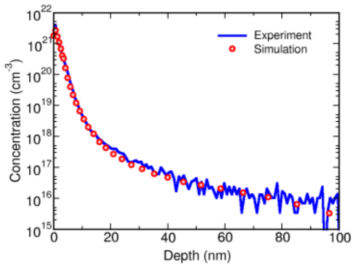

Fig. 2: Boron implantation profile from BF3 plasma immersion ion implantation for extraction voltage of 1 keV

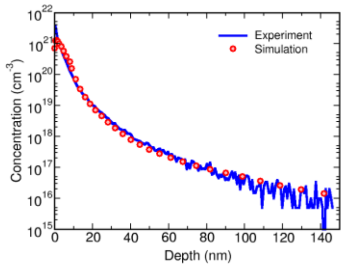

Fig. 3 Boron implantation profile from BF3 plasma immersion ion implantation for extraction voltage of 4 keV

References

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