Integration of High Dose Boron Implants - Modification of Device Parametrics through Implant Temperature Control

Matthias Schmeide, Michael S. Ameen*, Serguei Kondratenko*, Bernhard Krimbacher*, Ronald N. Reece*

Infineon Technologies Dresden GmbH, Königsbrücker Str. 180, D-01099 Dresden, Germany
Matthias.Schmeide@Infineon.com
**Axcelis Technologies, Inc., 108 Cherry Hill Dr., Beverly, MA, 01915, USA*

Abstract.

In the present study, we have extended a previously reported 250 nm logic p-S/D implant (7 keV B 4.5×10^{15} cm^{-2}) process matching exercise [5] to include wafer temperature, and demonstrate that matching can be obtained by increasing the temperature of the wafer during implant. We found that the high dose rate delivered by the single wafer implanter caused the formation of a clear amorphous layer, which upon subsequent annealing altered the diffusion, activation, and clustering properties of the boron. Furthermore, increasing the temperature of the wafer during the implant was sufficient to suppress amorphization, allowing profiles and device parameters to become matched. Figure 1 shows a representative set of curves indicating the cluster phenomena observed for the lower temperature, high flux single wafer implanter, and the influence of wafer temperature on the profiles. The results indicate the strong primary effect of dose rate in determining final electrical properties of devices, and successful implementation of damage engineering using wafer temperature control.

The Axcelis Optima-HDx [2] is a single wafer ion implanter utilizing spot beam technology. The most important difference between high current single wafer and high current batch implanters is the significantly higher dose rate due to the different scanning and therefore, the higher damage rate for the single wafer tool architecture [3]. For example, the instantaneous dose rate of the single wafer platform is over an order of magnitude higher than the batch system.

The integration of an Axcelis Optima HDx single wafer high current spot beam implanter into an existing 200 mm production line with Axcelis GSD ULTRA batch implanters has shown that matching of different technologies with and without pre-amorphization implantation is possible. However, the integration of different processes is more complicated compared to a simple dose matching showing the importance of the implant parameters such as implant dose rate and wafer temperature in addition to the energy and the dose [4]. These parameters play an important role in defect accumulation during implantation and following dopant redistribution and activation during Rapid Thermal Processing (RTP). The influence of these effects is more pronounced for BF_2 ions, which may require other implantation process optimizations in addition. The role of the wafer temperature for BF_2 S/D implants was already studied on batch implanter and during the matching of the batch implanter to the VIISta80, a single wafer ribbon beam implanter, using DRAM technology [5-6].

) [4]. The process is used for p-S/D formation and also for doping of the poly-Si structures to build resistors for oscillators, so that the poly-Si resistance directly correlates to the yield. Device differences, observed between the single wafer ion implanter and the batch ion implanter, were attributed to the large variance in effective dose-rate between the tools. Specifically, the boron profile implanted on the single wafer implanter was shallower after RTP and the accumulated boron peak position was deeper (cf. Fig. 1).

For an implanted dose of 5×10^{15} ions/cm^2 at different wafer cooling temperatures the amorphization layer and damage region below was measured using TEM. A summary of the TEM results is shown in Table 1. The thickness of the amorphization layer of the cooler wafer (16°C) is more than twice as that of the wafer implanted at 48°C (cf. Fig. 3). The thickness of the damage layer below the amorphization layer is changed by 3 nm (cf. Fig. 4). Since the region directly beneath the a/c interface is heavily damaged, even a small change in the thickness of the amorphous layer will consume an appreciable amount of the EOR damage.

TABLE 1. TEM results on n-type bare wafers implanted with 7 keV boron 5×10^{15} cm^{-2}.

Implant tool	**Temp. [°C]**	**Amorph. layer thickness [nm]**	**Damage layer thickness [nm]**
ULTRA	18	14	20
Optima HDx	16	18	20
Optima HDx	32	12	22
Optima HDx	48	8	23

Fig. 3. TEM profile of the amorphization layer for 7 keV boron 5×10^{15} cm^{-2} implanted on Optima HDx at a wafer cooling temperature of 16°C or 48°C.

Fig. 4. TEM profile of the damage layer below the amorphization layer for 7 keV boron 5×10^{15} cm^{-2} implanted on Optima HDx at a wafer cooling temperature of 16°C or 48°C.

The SIMS measurement results (cf. Figs. 1 and 5) show nearly comparable profiles after RTP for the ULTRA and the Optima HDx when a wafer temperature of about 32°C is applied. The accumulated boron peak concentration in the EOR damage region is comparable between all Optima HDx samples; however, the profile of the 16°C sample ends more abruptly due to the thicker amorphization layer. This also effects the junction depth which is around 10 nm lower for the wafer implanted at 16°C.