Analysis of Very High Energy Implantation Profiles at Channeling and Non-Channeling Conditions

Serguei I. Kondratenko
Axcelis Technologies, Inc.
108 Cherry Hill Drive, MA, USA
Serguei.Kondratenko@axcelis.com

Leonard M. Rubin
Axcelis Technologies, Inc.
108 Cherry Hill Drive, MA, USA
Leonard.Rubin@axcelis.com

Eric A. G. Webster
OmniVision Technologies, Inc.
4275 Burton Dr. Santa Clara, CA, USA
Eric.Webster@ovt.com

Abstract—This paper presents SIMS data for very high energy ion implantations of arsenic (1.9-8.0 MeV), boron (2.0-5.0 MeV), and phosphorus (4.0-8.0 MeV) from Axcelis' Purionm Axonioæ[(VX)8 (cE (o)-6 (Ax9tatio)7 (d)- (e)e0)-13 r w0lcnd Ax9tataslto-0.0082 Tc 0.53 Tw [(8.963 -1016 Td [(Om)24 s(o)-6 (A

with a 2nd order polynomial as shown in Fig. 1(b). Assuming the curve minimum position corresponds to true zero implantation angle, an offset of 0.02º was estimated for the tilt angles relative to the (100) plane. The arsenic SIMS profiles are shown in Fig. 2. Significant channeling reduction was observed at tilt angles of 0.25° and higher. Accordingly, the profile peak position (Rp) is getting shallower for the higher implantation tilt angles. As expected, very high energy profiles are found to be highly sensitive to the ion beam incident angle. At tilt angles 0.25º the SIMS profiles show some difference in channeling tails even for tilt angle variations as low as 0.04º. This drives higher requirements for the angle alignment and control during implantation relative to the wafer cryrs tation anTw anananp.4124 Tw ET Agk (p)6 ()-2 (t Agk (p)3i71iv)6 (e2Si8-8 (n1t)13 ([(w)17 (-4Tw ar

simulated profile. The only way found to make the TCAD channeled peak higher than non-channeled peak was to increase the Debye temperature. With a higher Debye temperature, the TCAD profile fits better for both the channeled and un-channeled peak of 2.0 MeV boron, but the validity of this method is questionable. Further work on model improvement for 2.0 MeV boron is needed.

Fig. 6. Experimental and simulated profiles for B, 2.0 and 3.6 MeV ($1x10^{14}$at/cm^2), and 5.0 MeV ($1x10^{13}$at/cm^2). Tilt/twist angle 5º/27º.

Fig. 7. Experimental and simulated profiles for B, 2.0, 3.6, and 5.0 MeV. Tilt/twist angle 0º/0º. For 2MeV simulated profiles are shown for two Debye temperatures 519K (default) and 1100K.

C. Phosphorus SIMS Profiles and TCAD Modeling

SIMS profiles and TCAD simulation for phosphorus at a non-channeling implant angle are shown in Fig. 8 for energies 4.0, 6.0, and 8.0 MeV. Similar to As and B, the model overestimates the channeling tails. In the phosphorus case this difference is higher, especially for 8.0 MeV and lower dose $1x10^{13}$at/cm^2. Doubling the implantation damage

tilt=0° has the best agreement at TCAD tilt=0.3°. Either this is the (unexpected) actual implant angle or the TCAD model needs improvement. Further investigation is required.

default LSS.pre [4] parameter of 1.25. This unusual result suggests the TCAD model needs further improvement.

For the maximum P energy of 8.0 MeV, increasing the TCAD damage de-channeling 4X slightly improves fitting in places (Fig. 12), but does not provide satisfactory agreement with the SIMS profile.

P and As profiles comparison at 8.0 MeV is presented in Fig.13. The channeling profile shapes are significantly different between P and As (blue and green curves). The projected ranges are very close despite the large mass difference between P and As. It is thought possible that the relatively higher and complex influence of damage on phosphorus could contribute to the difficulty of modeling the profile. Further model adjustments are needed to wd1 (t(e)12 on)6 ((s)18 x)6 (c (a)12(f)22 ’)]TJ Pe(rv)8 (io)8 (

Fig. 11.Experimental and simulated profiles for phosphorus, 6.0 MeV. Tilt/twist angle 0º/0º. TCAD modeling with different electronic stopping power (LSS.pre).

Fig. 12.Experimental and simulated profiles for phosphorus, 8.0 MeV. Tilt/twist angle 0º/0º; TCAD modeling with different implantation damage.

Fig. 13.P and As 8.0 MeV SIMS and TCAD profiles comparison. Tilt/twist angle 0º/0º. Default TCAD parameters.

For P 6.0 MeV implants (Fig. 11), the profile peak position cannot be fit with the default TCAD parameters. The electronic stopping power in TCAD has to be reduced by ~8% to fit the SIMS peak position. This was not observed for other energies; all other phosphorus profiles fit with the