Nissin's New Cluster Implanter: CLARIS

S. Umisedo[1*], N. Hamamoto[1], Y. Koga[1], H. Une[1], N. Maehara[1], T. Nagayama[1], M. Tanjyo[1], N. Nagai[1], T. N. Horsky[2], R. D. Goldberg[2], S. K. Hahto[2], D. G. Bilbrough[2], D. C. Jacobson[2], H. F. Glavish[2]

[1] Nissin Ion Equipment Co., Ltd, 575 Kuze Tonoshiro-cho, Minami-ku, Kyoto, Japan, 601-8205
[2] SemEquip Inc., 34 Sullivan Road, Suite 18, Billerica, MA 01862, USA
**e-mail: Umisedo_Sei@nissin.co.jp*

Abstract. A new implanter for cluster ion implantation has been developed for production use. Some key performances will be described to show that equivalent beam current enhancement by using cluster implantation supported by high precision beam and dose control together with good tool stability enables a production worthy high throughput implantation for advanced device fabrication.

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INTRODUCTION

Cluster ion implantation technology has been revealed to have many advantages for fabrication of advanced semiconductor devices [1,2]. Ultra low energy implantation, self amorphization, and low leakage current are the typical characteristics of boron cluster implants such as $B_{10}H_{14}$ and $B_{18}H_{22}$. Also, carbon cluster implants such as $C_{14}H_{14}$ or C_7H_7 are being studied for the use in diffusion control or for Si stress engineering [3].

For a sufficient utilization of such an advantageous technology, a new cluster implanter has been developed as a production machine through a joint development program between Nissin Ion Equipment Co., Ltd. and SemEquip, Inc [4,5].

In this paper, many of its tool performance features are described to understand how the tool serves the cluster implant technology with production quality and reliability.

BEAM PERFORMANCE

Beam Current

First of all, the triggering feature of the cluster ion implantation, i.e., enhancement of ultra low energy beam current is shown in Figure 1. Cluster ion beam is extracted from SemEquip's 350 ClusterIon® source [6,7]. The beam is then mass analyzed, drifted or decelerated, X-Y focus adjusted, scanned in the horizontal plane and then collimated before being implanted into a wafer [4]. The beam current at the target at equivalent energies of 2 to 3 keV exceed 20 pmA in drift mode operation which is free of energy contamination. Since the punch through of energy contaminant for poly gate implant causes damage on the device, a high current but energy contaminant free beam serves as a strong tool for poly gate implantation.

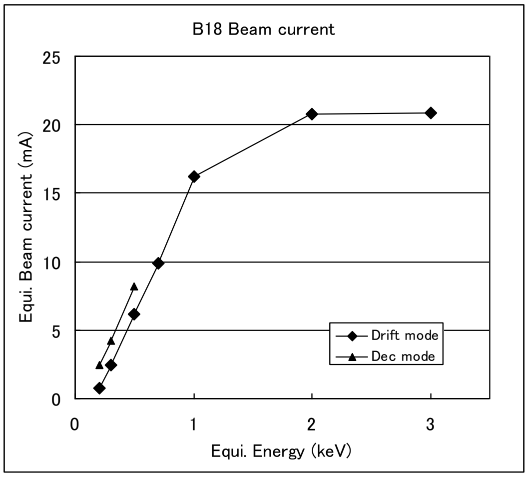

FIGURE 1. B_{18} beam current with drift mode operation plotted as equivalent particle mA vs equivalent B energy.

It should also be noted that even for the energies as low as 500 eV, the equivalent beam current with drift mode is more than 6 mA, which clearly shows the

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advantage for USJ formation such as SDE, while deceleration mode is also available when even higher beam currents are needed for lower energies.

Beam Angles

Figure 2 shows the beam parallelism and divergence angle for FWHM beam size in the horizontal plane of B_{18} beam plotted against equivalent B energy. It is noted that beam parallelism is controlled to less than 0.3 degree for all the available energy range while the divergence angle is also suppressed mostly below 0.5 degree.

It should be noted that these data are obtained for large beam currents at low energies with drift mode, i.e. not using deceleration just prior to the wafer, and also for the beams that contain 15 mass peaks, which shows the success of this beam line design for cluster ion beam transportation.

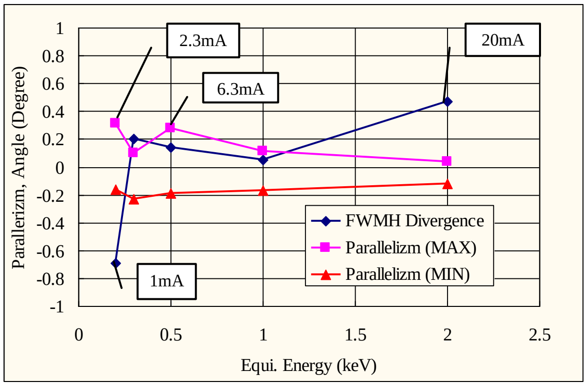

FIGURE 2. Beam parallelism and divergence in horizontal plane plotted against equivalent B energy.

Dose Uniformity Within a Wafer and Repeatability Within a Lot

With the above confirmed angle precision, the beam is scanned in the horizontal plane and dose uniformity is controlled by this scanning velocity, which can precisely control the implant dose as is well established by the Nissin Exceed series. In Figure 3, a dose uniformity measured with T.W. is shown for equivalent 300 eV, 2.1 pmA drift mode implantation. It should be noted that even at such a low energy, the implant dose uniformity is precisely controlled to 0.23%.

The implant uniformity was not only confirmed by T.W. measurements but also by as implanted SIMS profiles at three different positions: the center of the wafer, and the left and right edge of the wafer in the beam sweep direction. In Figure 4, only the ^{11}B component is plotted for demonstration purposes, but from this plot it is clear that all three profiles are identical, which shows the implant profile uniformity in addition to implant dose uniformity.

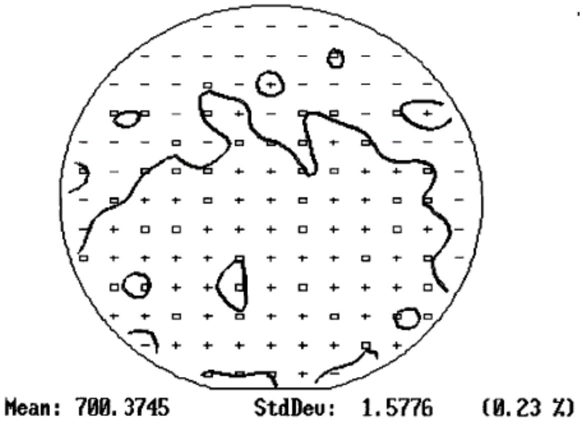

FIGURE 3. Dose uniformity within a wafer measured with TW after implanted with equivalent 300 eV.

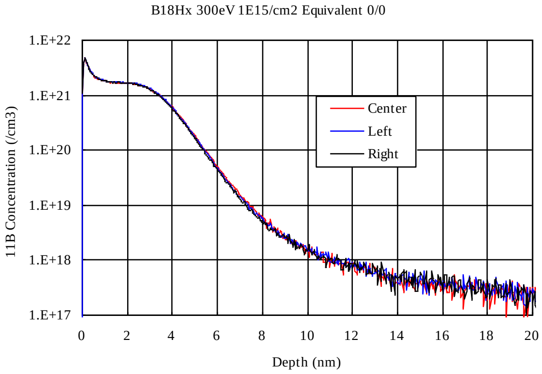

FIGURE 4. As implanted SIMS profile of B_{18} implanted wafer measured at left, center and right position on the wafer in beam sweep direction.

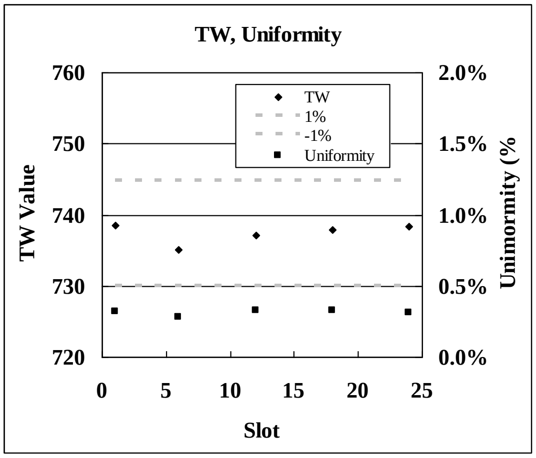

FIGURE 5. Dose repeatability within a lot.

Moreover, the repeatability data within a lot is shown in Figure 5. As can be seen from this data, the dose variation is well controlled within 1%, the standard deviation being 0.19% in this case.

Metal Contamination

It was also confirmed that although a beam with such a massive ion could have a large sputtering effects on the beam line walls, it did not increase any metal contamination to the wafer. In addition, since, as will be described later, the system needs to perform in-situ deposition cleaning, there was also concern as to whether any etched out component materials might somehow be carried in the beam to the wafer and increase the contamination. However, the data on metal contamination before and after in-situ cleaning after 100 hour beam operation in Table 1 show that such an effect is completely negligible. In Table 1, the results are shown in units of 1E10/cm2 for a wafer which was implanted with 500 eV 1E15 B/cm2 equivalent dose. All the measured elements were found to be less than 10 ppm which shows very clean implantation was achieved.

TABLE 1. Metal contamination on B_{18} implanted wafer before and after in-situ deposition cleaning.

Element	Al	Cr	Cu	Fe	Mg	Mo	Na	Ni	W	Zn
100H,Before FCL	0.44	—	0.80	0.098	0.19	—	1.3	0.078	—	0.38
100H,After FCL	—	—	0.70	—	0.19	—	0.60	0.078	—	0.28
Det. Limit	0.14	0.070	0.057	0.065	0.15	0.038	0.16	0.062	0.020	0.056

Wafer Throughput

It was also confirmed that even with such a precise and clean ion beam, the wafers can actually be processed with production worthy throughputs due to its large equivalent particle beam current as explained previously. Figure 6 shows the time chart of an equivalent 2 keV, 5E15 B/cm^2 implant with drift mode operation. The data show that such an implant can process 30 wafers per an hour, which is a good number for production use. Also, it was confirmed that 300 eV 1E15 B/cm^2 implants can be done at 32 wph throughput by using deceleration mode and a gas bleed into the beam line.

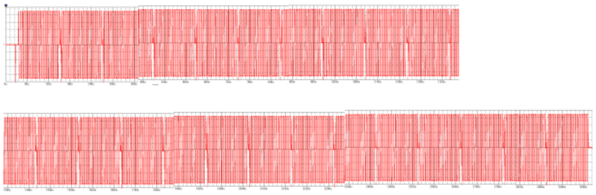

FIGURE 6. Equivalent 2 keV 5E15 implant throughput data recorded by mechanical scan velocity of the wafer.

TOOL STABILITY

In-situ Cleaning System

One of the key technologies for utilizing borohydride cluster implantation for production use is the solution for a large amount of insulating deposition inside the source. As a successful solution to this issue, an *in-situ* deposition cleaning system was developed [8].

In the new implanter system as a production tool, an advanced delivery system is equipped to supply the cleaning material gas from the ground potential either from the user's facility or from the cylinder cabinet placed in the beam line enclosure. Such a system enhances the advantage of the cleaning system by eliminating the tool down time for the replacement of material gas cylinder.

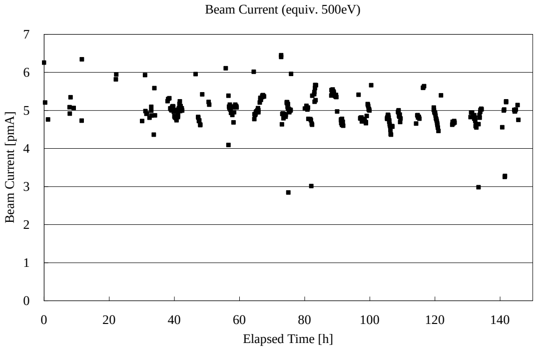

FIGURE 7. Equivalent 500 eV beam reproducibility over 100 h source operation including in-situ cleaning cycles.

Source Life

Figure 7 shows beam current data over continuous operation of the tool with implantation and in-situ cleaning alternatively cycled. In this run, several implant recipes have been used, but only the beam current of the equivalent 500 eV implant is plotted here. As can be seen from this plot, the ion source could deliver a cluster beam for over 150 h by periodically performing the *in-situ* cleaning.

Dose Repeatability Between Lots

While running the tool for 150 h, the dose repeatability was also examined between lots by T.W. measurements. Figure 8 shows the results. Although the mean value fluctuates more than in Figure 5, the standard deviation in this data was calculated as 0.67% which shows a good reliability as a production tool.

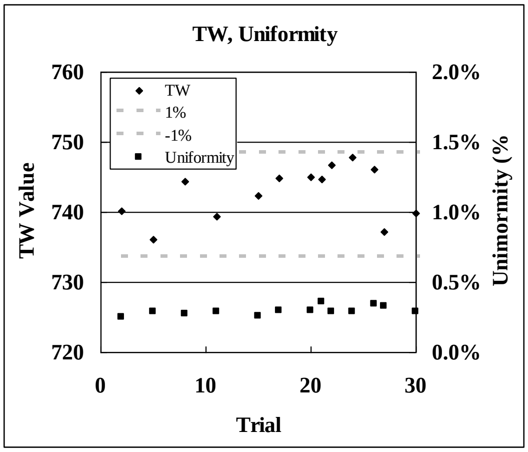

FIGURE 8. Equivalent 300 eV dose repeatability between Lots over 100 h source operation including in-situ cleaning cycles.

Particles

Some repeated data for particles both before and after the *in-situ* cleaning have been measured during this run. In Figure 9 data show that any particle increase is well below the tool specifications of 30 pcs.

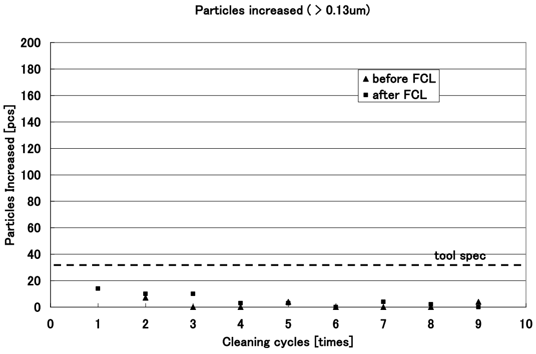

FIGURE 9. Added particles after B_{18} implant before and after in-situ cleaning cycles.

Though the available data for this measurement was restricted to the first few cleaning cycles due to measurement problems later on, the presented data imply that there is no significant trend of increasing particles that will be carried or generated by the beam while continuously implanting wafers, which is evidence for the reliability of the long term use as a production machine for advanced device fabrication.

CONCLUSION

A new cluster implanter has been realized through a Nissin-SemEquip joint development program. Its beam current and beam quality were confirmed to have desirable performance for implantations to form ultra-shallow junctions as well as poly gates with high throughput and good quality. The tool stability is also being continuously improved and the reliability for production use is now being rigorously evaluated. We will continue to investigate and validate its capability as a production machine for advanced semiconductor devices.

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