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# Improvement of Productivity by Cluster Ion Implanter: CLARIS

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## Abstract

The cluster ion beam implanter named CLARIS has been developed for beyond 45nm device production use, which is characterized with the high productivity by the effective low energy high current and the preciseness of incident beam angle and dose uniformity. For the USJ process application, a carbon cluster beam co-implantation is introduced. The performance of the cluster carbon co-implantation and the cluster boron beam implantation productivity are evaluated with COO and CoC view point and compared with the conventional high current implanter.

## 1. Introduction

Cluster ion implantation which is characterized with using a cluster ion including a molecular ion beam, is revealed to have a drastically different physics comparing to the conventional single atom ion implantation. Those physics has been investigated many researchers and the application technology has also been developed [1, 2]. For the application to the ion implantation of semiconductor fabrication, it has very interesting characteristics and the useful advantages. At first those are the efficient low energy beam transport and the effective high current implantation, which leads the high productivity for USJ formation implantation [3, 4]. Next, the low space charge effect makes small beam size and beam divergence and leads to good controllability and repeatability. Additionally the charging phenomena are much ignored by cluster implantation like no need of plasma flooding system. Third one is the self-amorphization effect which makes lower anneal temperature and high re-crystallization efficiency and high dopant activation [5, 6]. Using the cluster carbon

co-implantation with cluster boron for PMOS and with cluster phosphorus for NMOS both suppress the dopant transient enhanced diffusion (TED) effectively, which is presented in this conference[7, 8].

For a sufficient utilization of such an advantageous technology, CLARIS cluster implanter has developed through a joint development program between Nissin Ion Equipment and SemEquip.

In this paper, the tool performance features and characteristics are described to understand how it serves the cluster implant technology with production quality and reliability, and the cluster carbon co-implantation with the cluster boron implantation productivity are evaluated with COO and CoC view point comparing with the conventional high current implanter.

## 2. Equipment & Characteristics

### A. Equipment & Specification

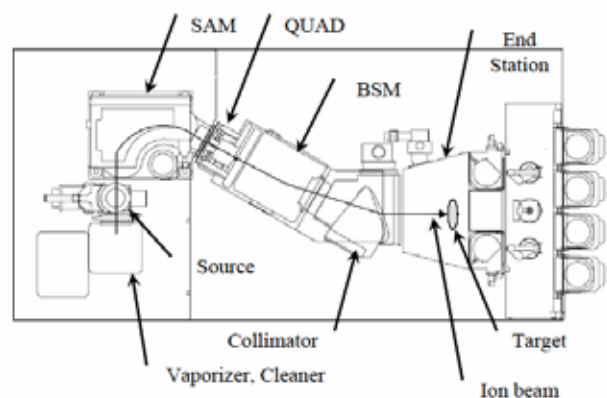


Fig.1 CLARIS Cluster Implanter LAYOUT

In Fig.1, CLARIS layout is shown, which consists of the cluster ion beam source, ion source analyzer magnet, beam shape control Quad lens, beam

horizontal sweep magnet, beam parallelize collimator magnet, and wafer vertical scan end station. This system is almost similar to medium ion implanter except cluster ion source and the high mass number ion beam analyzable magnet. Comparing to the conventional high current ion implanter it is different to adopt beam horizontal sweep and wafer vertical scan, which is called hybrid scan system. Therefore it is capable of good dose uniformity and incident beam angle homogeneity on a whole wafer.

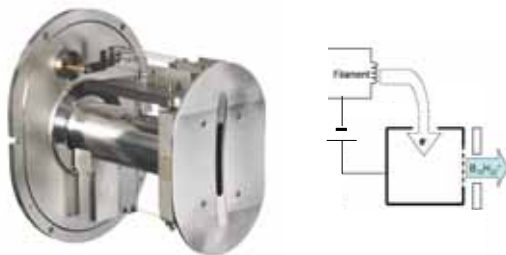
Table 1. CLARIS Specification

Ion Source	EB source
B/L	Fast magnetic beam scanner & Collimator, Hybrid implantation
E/S	Same as EXCEED series
Equivalent Energy & Beam Current	B <sub>18</sub> H <sub>x</sub> ; B equivalent: ~3keV, ~20.7mA
	B <sub>10</sub> H <sub>x</sub> ; B equivalent: ~7keV, ~15mA
	C <sub>16</sub> H <sub>x</sub> ; C equivalent: ~3.6keV, ~16mA
	C <sub>7</sub> H <sub>x</sub> ; C equivalent: ~10.5keV, ~10.5mA
Uniformity & Repeatability	<1.5% (Depends on Anneal condition)
Horizontal Parallelism	< +/- 0.5 degree
Metal contamination	Al < 50ppm, others < 10ppm
Particle	<30pc (particle size > 0.12um)

Preliminary Specifications. Subject to Change without Notice.

In Table 1, CLARIS specification is shown. For boron cluster implantation, B<sub>18</sub>H<sub>22</sub> (Octadecaborane) and B<sub>10</sub>H<sub>14</sub> (Decaborane) are used, and for carbon cluster implantation, C<sub>16</sub>H<sub>10</sub> (Pyrene) and C<sub>14</sub>H<sub>14</sub> (Dibenzil) are used as source materials, respectively. C<sub>14</sub>H<sub>14</sub> is easily resolved to C<sub>7</sub>H<sub>7</sub>, that for high energy cluster carbon implantation like a stress engineering application [9], C<sub>7</sub>H<sub>7</sub> is used. As for N-type dopant, P<sub>4</sub> and As<sub>4</sub> are used and are now under developed.

### B. Ion Source & Life Time



ClusterIon Source

Fig.2 Cluster Ion Source Schematics

In Fig.2, it is shown Cluster ion source which is developed by SemEquip. In Fig.3, it is shown ion source material feed system. The source materials like B<sub>18</sub>H<sub>22</sub> and C<sub>16</sub>H<sub>10</sub> are settled in crucible bottles.

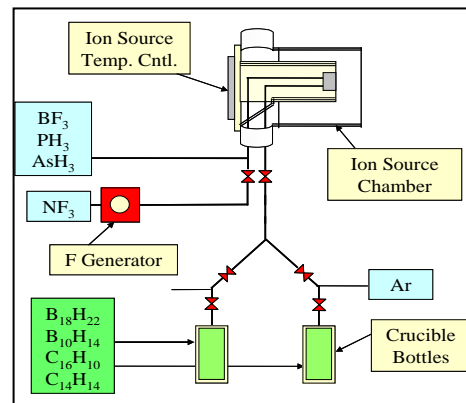


Fig.3 Ion Source Material Feed System

For the cluster ion beam production, it is required the source material gas molecule is ionized but not resolved, for that purpose the electron supplying filament is set out of the chamber to maintain cold chamber wall. As the result, inside the chamber produced compound are deposited and the source operation time is limited. For elongation of the operation time, CLARIS has an auto NF<sub>3</sub> gas cleaning system. As the ion source for 8 hours B<sub>18</sub> operation and after that 35min NF<sub>3</sub> gas auto-cleaning is done. It is recognized that NF<sub>3</sub> gas cleaning works well and continuous beam operation is confirmed till 170hours.

## 3. Productivity

### A. Ion Beam Current & Throughput

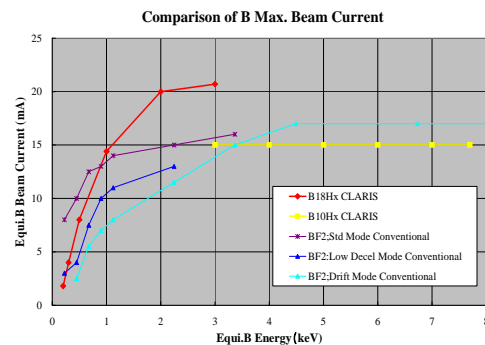


Fig.4 Boron Maximum Beam Current

In Fig.4, it is shown the boron single atom equivalent energy versus single atom equivalent beam current. B<sub>18</sub>H<sub>22</sub> ion beam is got high current but the maximum energy is limited to 3.2keV by the source analyzer magnet ability. B<sub>10</sub>H<sub>14</sub> ion beam is used higher energy and is limited to 7.5keV by acceleration voltage.

Comparing to the conventional high current implanter, on the drift mode operation, CLARIS shows two times higher beam current in B<sub>18</sub>H<sub>22</sub> beam

energy condition. For  $B_{10}H_{14}$  beam energy condition, it is smaller than that of conventional implanter but for realistic operation, it is limited by the uniformity, controllability and charging phenomena, and  $B_{10}H_{14}$  has advantages for those characteristics.

For the carbon single atom equivalent energy versus single atom equivalent beam current.  $C_{16}H_{10}$  ion beam is got high current but the maximum energy is limited to 3.7keV.  $C_7H_7$  ion beam is used for the higher energy and is limited to 10.5keV.

Comparing to the conventional high current implanter, on the drift mode operation, CLARIS shows more than two times higher beam current in  $C_{16}H_{10}$  beam energy condition. For  $C_7H_7$  beam energy condition, it is larger than that of conventional implanter.

### B. COO & CoC Comparison

At the typical DRAM -PMOS recipe, it consists of PAI and carbon co-implantation for source drain extension process. With the conventional high current process, PAI is done by Ge implantation and TED suppressing carbon co-implantation is done by single carbon implantation. The validity of CRARIS Cluster process is presented in this conference [6]. With CLARIS cluster process, PAI and co-implantation is replaced by  $C_{16}$  implantation, which improves the productivity, too. Moreover, SDE and SD implantation are replaced from  $BF_2$  to  $B_{18}$  and Gate implantation is replaced from B to  $B_{18}$ , which also much improves them. In the estimation for CLARIS process,  $NF_3$  cleaning process is taken into account for 35min cleaning time to every 8 hour operation.

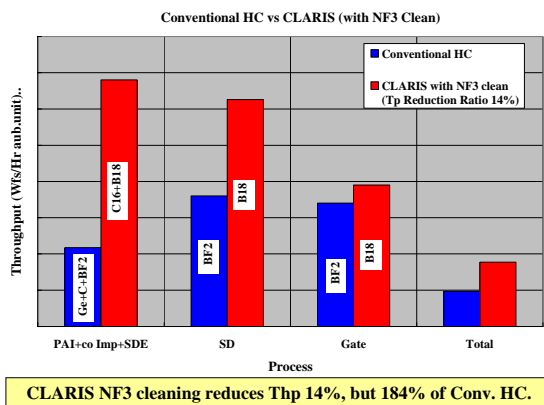


Fig.5 Comparison of Throughput for DRAM-PMOS recipe

In Fig.5, the comparison of the throughput of them is shown clearly. As the conclusion, the throughput of CLARIS process is reduced 14% but it is 184% higher total throughput than that of conventional high current process.

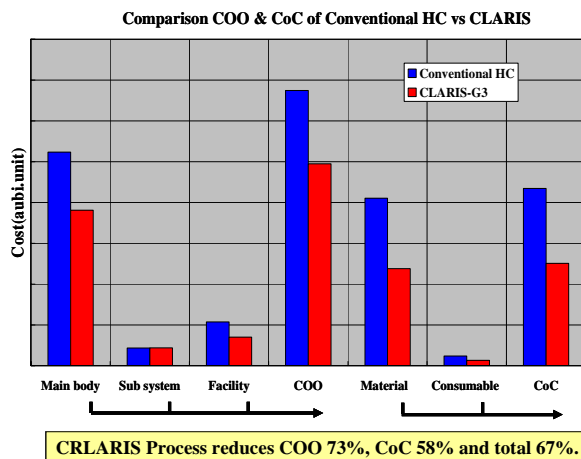


Fig.6 Comparison COO & CoC of Conventional HC vs. CLARIS processes

In Fig 6, it is shown the comparison of COO and CoC estimation for DRAM-PMOS recipe with conventional HC and CLARIS cluster processes. It is recognized that COO equals to the sum of capital price of main body, subsystem and facilities divided by wafer throughput that the throughput is the decisive parameter. On the other hand CoC equals to the material cost and the consumable cost that the material cost is the main parameter. For DRAM process Ge PAI is most high cost that cluster carbon replacement reduces CoC cost.

COO and CoC results that COO and CoC are reduced to 73% and 58%, respectively. Total cost is reduced to 67% with CLARIS cluster process to conventional high current process.

### 4. Summary

CLARIS cluster ion implanter has advantages of effective low energy high current with good dose and angle uniformity comparing with conventional high current implanter. It leads 184% higher throughput and 67% lower cost sum of COO and CoC for DRAM PMOS recipe. Cluster Carbon co-implantation and cluster Boron implantation are promising application not only for DRAM but also Flash Memory and Logic application.

For NMOS application the advantage will be clarified soon.

### References

- [1]. T. Aoyama et al., Decaborane Ion Implantation for Sub-40-nm Gate-Length PMOSFETs to Enable Formation of Steep Ultra-Shallow Junction and Small Threshold Voltage Fluctuation, IWJT2005.

pp. 27.

- [2]. Ootsuka et al, IEEE Trans.on ED, April 2008, p.1042-1049
- [3]. N. Hamamoto et al. , Development of Nissin new boron cluster ion implanter, IWJT2007, pp. 125.
- [4]. S.Umisedo et.al,AIP Conference 1066, Proceedings of IIT2008,p.296
- [5]. M. Tanjyo et al., Extend abstracts 2008 IWJT Workshop on Junction Technology, pp.55.
- [6]. H. Onoda et al, Proceeding of IWJT2010
- [7]. B.J. Powlak et al., Appl, Phys. Letters 89, 062102(2006)
- [8]. T. Nagayama et. al, 17<sup>th</sup> IIT 2008, pp.434-437 & T. Nagayama et al, Proceeding of IWJT2010

**Key words: Cluster, co-Implantation, Carbon, Boron, COO, CoC**

The author(s) should provide a list of key words on a separate sheet of paper to be used in preparing the subject index for the complete proceedings.