

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 by the high productivity, high effective low energy high current, and preciseness of incident beam angle and dose uniformity. For the USJ process application, a cluster beam co-implantation is introduced. Carbon cluster co-implantation and the boron cluster beam implantation productivity are evaluated from a COO and CoC view point and compared with the conventional high current implanter.

1. Introduction

Cluster ion implantation which is characterized by using a cluster or molecular ion beam, is revealed to exhibit a drastically different physics compared to the conventional single atom ion implantation. These physics have been investigated by many researchers and the application technology has also been developed [1, 2]. For the application to semiconductor fabrication, it has very interesting characteristics and the useful advantages. First are efficient low energy beam transport and the effective high current implantation, which boasts the highest productivity for USJ formation [3, 4]. Second, the reduced space charge effect results in smaller beam size and beam divergence and leads to good controllability and repeatability. Additionally the charging phenomena can be ignored in cluster implantation so there is no need for plasma flooding systems. Third, the self-amorphization effect enables lower anneal temperatures, high re-crystallization efficiency, and high dopant activation [5, 6]. Using a carbon cluster co-implantation both with a boron cluster implant for PMOS and a with cluster phosphorus implant for

NMOS effectively suppresses dopant transient enhanced diffusion (TED), which is also presented in this conference [7, 8].

To enable full utilization of such an advantageous technology, the CLARIS cluster implanter has been developed through a joint development program between Nissin Ion Equipment and SemEquip.

In this paper, the tool performance features and characteristics are described to illustrate how cluster implant technology achieves production quality and reliability. Carbon cluster co-implantation with boron cluster implantation productivity are evaluated from the COO (Cost of Ownership) and CoC (Cost of Consumable) perspective, compared with the conventional high current implanters.

2. Equipment & Characteristics

A. Equipment & Specification

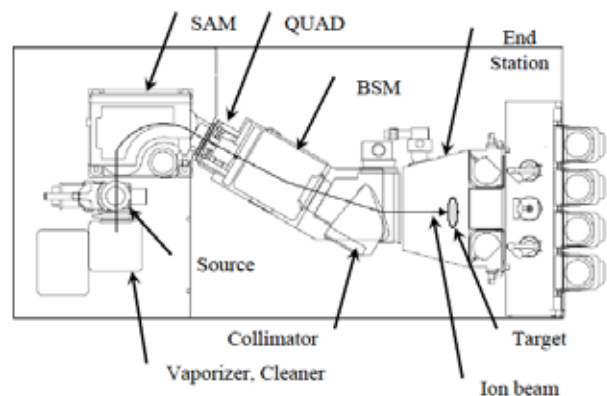


Fig.1 CLARIS Cluster Implanter LAYOUT

In Fig.1, the 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 parallelizing collimator magnet, and vertical scan wafer end station. This architecture is similar to a medium ion implanter except for the cluster ion source and the high mass number ion beam analyzer magnet. It is differentiated from a conventional high current ion implanter in its horizontal beam sweep and wafer vertical scan, which is called a hybrid scan system. Therefore it is capable of good dose uniformity and incident beam angle homogeneity across the entire wafer.

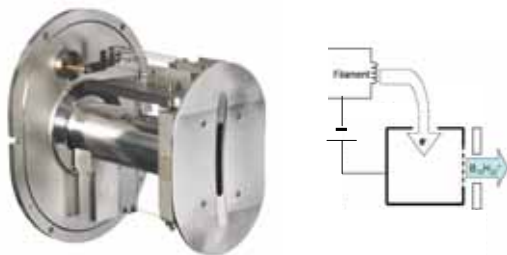
Table 1. CLARIS Specification

Ion Source	EB source
B/L	Fast magnetic beam scanner & Collimator, Hybrid implantation
E/S	Same as EXCEED series
Equivalent Energy & Beam Current	$B_{18}H_2$; B equivalent: ~3keV, ~20.7mA $B_{10}H_2$; B equivalent: ~7keV, ~15mA $C_{16}H_2$; C equivalent: ~3.6keV, ~16mA C_7H_2 ; 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, the CLARIS specification is shown. For boron cluster implantation, $B_{18}H_{22}$ (Octadecaborane) and $B_{10}H_{14}$ (Decaborane) are used, and for carbon cluster implantation, $C_{16}H_{10}$ (Pyrene) and $C_{14}H_{14}$ (Dibenzil) are used as source materials, respectively. $C_{14}H_{14}$ is easily dissociated to C_7H_7 , and for higher energy cluster carbon implantation applications like a stress engineering [9], C_7H_7 is used. As for N-type dopant, P_4 and As_4 are used and are now under further development.

B. Ion Source & Life Time



ClusterIon.
Source

Fig.2 Cluster Ion Source Schematics

In Fig.2, the ClusterIon[®] source developed by SemEquip is shown. In Fig.3, the ion source material feed system is shown. The source materials like

$B_{18}H_{22}$ and $C_{16}H_{10}$ are supplied in crucible bottles.

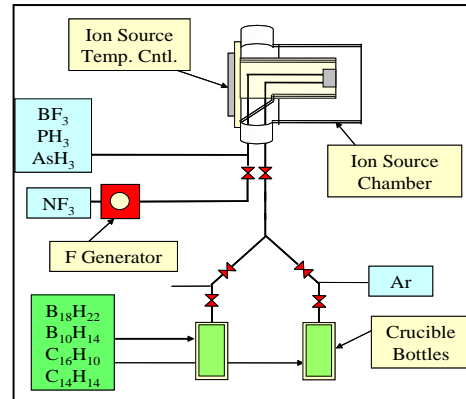


Fig.3 Ion Source Material Feed System

For the cluster ion beam production, it is required that the source material gas molecule is ionized but not dissociated, so the electron supplying filament is set out of the chamber to maintain cold chamber wall. As a result, feed compounds are deposited inside the chamber, and the source operation time is limited. For elongation of the operation time, CLARIS has an auto NF_3 gas cleaning system. The ion source operates B_{18} for 8 hours and after that a 35min NF_3 gas auto-cleaning is done. It is recognized that NF_3 gas cleaning works well and continuous beam operation of 170hours is confirmed.

3. Productivity

A. Ion Beam Current & Throughput

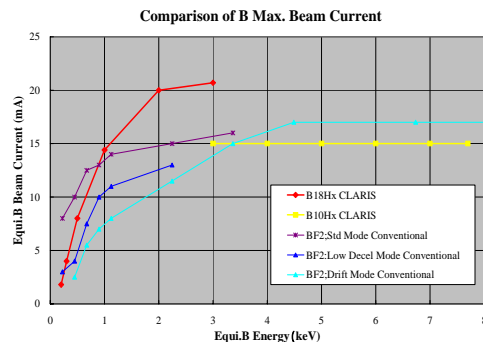


Fig.4 Boron Maximum Beam Current

Fig.4 shows the boron single atom equivalent energy versus single atom equivalent beam current. $B_{18}H_{22}$ achieves the highest current but the maximum energy is limited to 3.2keV by the source analyzer magnet. $B_{10}H_{14}$ is used for higher energy and is limited to 7.5keV by the acceleration voltage supply.

Compared to a conventional high current implanter operating in drift mode, CLARIS shows twice the boron beam current (using $B_{18}H_{22}$) below

about 2keV. For energies up to 7.5keV (using $B_{10}H_{14}$) the beam currents are slightly lower than a conventional implanter, however the cluster implantation process has demonstrably superior uniformity, controllability and charging characteristics.

Regarding carbon single atom equivalent energy and single atom equivalent beam current, the $C_{16}H_{10}$ ion beam achieves high current but the maximum energy is limited to 3.7keV. The C_7H_7 ion beam is used for higher energies up to 10.5keV.

CLARIS achieves higher carbon beam currents than a conventional high current implanter over its entire energy range (up to 10.5keV), with more than twice the beam current below 3.7keV.

B. COO & CoC Comparison

A typical DRAM PMOS recipe consists of a PAI and carbon co-implantation for the source drain extension process. In the conventional high current process, the PAI is done by Ge implantation and TED suppressing carbon co-implantation is done by single carbon implantation. The validity of the CRARIS Cluster process is presented in this conference [6]. In the CLARIS cluster process, PAI and co-implantation is replaced by C_{16} implantation, which also improves the productivity. Moreover, SDE and SD implantation replaces BF_2 with B_{18} , while Gate implantation replaces B with B_{18} , which also much improves them. In the COO calculation for the CLARIS process, a 35min. NF_3 cleaning step is assumed after every 8 hours of B_{18} operation.

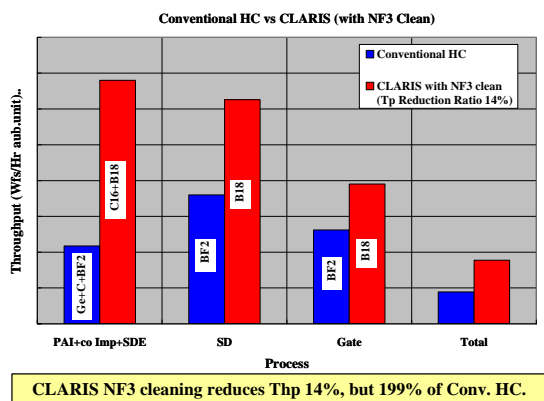


Fig.5 Comparison of Throughput for DRAM-PMOS recipe

In Fig.5, the comparison of the throughput of them is shown clearly. We conclude that even allowing for a 14% throughput reduction for cleaning, the total throughput of CLARIS process is still 199% higher than that of the conventional high current process.

Comparison COO & CoC of Conventional HC vs CLARIS

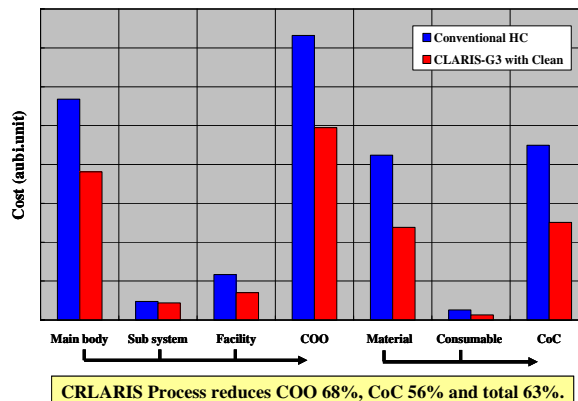


Fig.6 Comparison COO & CoC of Conventional HC vs. CLARIS processes

Fig 6 shows a comparison of COO and CoC models for DRAM-PMOS recipes with conventional HC and CLARIS cluster processes. It is assumed that COO equals the sum of capital price of the implantation system, subsystems and facilities divided by wafer throughput, so that the throughput is the decisive parameter. On the other hand CoC equals to the material cost plus the consumables cost, so that the material cost is the main parameter. For the DRAM process, Ge PAI is the highest cost implant step, so that cluster carbon replacement of the Ge PAI reduces the CoC cost significantly.

COO and CoC results show that COO and CoC are reduced to 68% and 56%, respectively. The total CLARIS process reduces total cost to 63% of the conventional high current process.

4. Summary

The CLARIS cluster ion implanter has advantages of effective low energy high current with good dose and angle uniformity compared with conventional high current implanters. It achieves 199% higher throughput and 37% lower cost sum of COO and CoC for DRAM PMOS recipe. Carbon cluster co-implantation and boron cluster implantation are promising applications not only for DRAM but also for Flash Memory and Logic.

For NMOS applications the advantage will be clarified soon.

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