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Contamination Control in Ion Implantation – An Additional Approach

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Abstract. The investigation and elimination or control of metallic contamination in ion implanters has been a leading, continuous effort at implanter OEMs and in fabs/IDMs alike. Much of the efforts have been in the area of control of sputtering through material and geometry changes in apertures, beamline and target chamber components. In this paper, we will focus on an area that has not, heretofore, been fully investigated or controlled. This is the area of lubricants and internal and external support material such as selected cleaning media. Some of these materials are designated for internal use (beamline/vacuum) only while others are for internal and/or external use. Many applications for selected greases, for example, are designated for or are used for platens, implant disks/wheels and for wafer handling components. We will present data from popular lubricants (to be unnamed) used worldwide in ion implanters. This paper will review elements of concern in many lubricants that should be tracked and monitored by all fabs.

Proper understanding of the characteristics, risks and the control of these potential contaminants can provide for rapid return to full process capability following major PMs or parts changes. Using VPD-ICPMS, Glow Discharge Mass Spectrometry and Ion Chromatography (IC) data, we will review the typical cleaning results and correlation to "on wafer" contamination by elements of concern – and by some elements that are otherwise barred from the fab.

Keywords: contamination, alkali metals, ICPMS, GDMS
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INTRODUCTION

The requirements for ever decreasing demand in the levels of elemental contamination places considerable restraint on ion implanter beamline and target chamber design. Much effort is put on the materials selection and the geometry of critical beam strike components such as apertures, electron flood assemblies, beam dumps, platens and other components. Many papers [1 - 3] have been produced over the years that show typical performance for the time of their publication. The focus of this paper will be two-fold:

- Provide a summary of possible contaminants from a heretofore loosely monitored area – the area of critical lubricants and other cleaning materials used in the majority of fabs.
- Present a review of contamination sources in newly refurbished parts that are fundamental in providing production ready and yield ready performance in a short period of time.

BACKGROUND

There are a great many ways for elemental contamination to appear in ion implanters. One comprehensive list of ten separate routes was presented [4] that describe, within the total, 4-5 various sputtering mechanisms in the beamline and near and on the wafer itself. We want to introduce an area that has been overlooked by many - either in the manufacturing engineering phase of initial implant product design or in the maintenance control within fabs once the implanter is in production. This area of contamination introduction is through the use – *or misuse* of the many lubricants within the vacuum system of the implanter – especially in the beamline and the target chamber. Core's experience in the requirements for cleanliness in both its refurbishment services and implant foundry service has led a broad range of knowledge about many lubricants and lubricant types as well as and cleaning aids that are different, in some cases, than materials recommended by the implant equipment suppliers. A number of common and some unique lubricants have been evaluated, predominantly by VPD-ICPMS, to assess the levels of undesired elements. The results of this testing were provided to the IDMs along with recommendations for alternative lubricants It is clear that IDMs need to analyze and track and control every lubricant specification and actual elemental ingredient as uncontrolled changes could lead to use of materials which result in yield loss. The pressure for cost containment has sometimes led to the use of a less expensive lubricant with high % by weight of Na or Ca compounds or other undesirable material. Table 1 shows a comparison of the top 5 elemental constituents of the "normal" lubricants – OEM recommended. The product labeled CD-20 vs. the replacement lubricant CD-21 are listed since they were reported to be direct replacements. (Note that no commercial names are used here. The labels used are those designated for the analysis labs). The CD designated lubricants were reported as the same - except for one additive – refer to Table 1.

Investigation and Techniques

Monitoring maintenance activities it is seen where many types of grease are applied in quantities of 10s to 100s of milligrams depending on a specific part, i.e, ball screw assemblies, harmonic drives, bearing assemblies, slides, etc. With experience of high levels of Na and Zn in some serial implanters we decided on testing other greases used in our facility as well as greases we came across in selected fabs that were visited. Over a 2.5 year period, we characterized > 30 different greases and selected cleaning agents that were used routinely. Here, in Table 1, are a few selected greases all characterized by VPD-ICPMS. Some were found in many fabs and different companies. A surprising number contained lithium in levels of 0.2% by weight up to 24% by weight. Even if handled with extreme caution, the risk to product is just too great especially when hand tools are not dedicated. There should be separate hand tools – one set by maintenance personnel for external implanter and another set for internal implanter parts. In >75% of greases tested, all contained high levels of at least one alkali metal, i.e., Na, Li, K and Ca or Mg in the "top 5" of measured elements. The Lithium is especially troublesome since it is not allowed in many fabs – in any form. When reviewing the likelihood of alkalis migrating their way to the gate oxide, much is said of Na, K but little is said about lithium since its potential presence in a fab seems so unlikely [5]. While this appears, on the surface, to be a safe statement – the lithium does get into the beamline and target chamber through various maintenance activities as described here. The greases found to contain the very lowest amount of possible contaminants and still perform well in the various applications needed for ion implanters – internally and externally are the majority of perfluoropolyether (PFPE greases). Other greases that have product series that are near ideal for implanters from a low contamination and vapor pressure point of view are mutiply-alkylated cyclopentanes (MACs) and many of the Polyphenolethers (PPEs). Even some of the above greases have selected products with high levels of Li – in the form of Lithium based soap as a binder. As with any product placed in the beamline and other sections of the implanter, the greases should be selected based on the user's assessment of a small sample checked with VPD-ICPMS or other analytical tool. It is difficult to find a vendor that can supply information of even the base materials in their lubricant. It is also incumbent on the user to ensure that the vapor pressure of the grease is appropriate for ion implanter vacuum systems.

TABLE 1. VPD-ICPMS Assessment of Selected Greases

	CD-20 Lubricant (ppm)	CD-21 Lubricant (ppm)	CF-11 Lubricant (ppm)	FF-10 Lubricant (ppm)	MV-21 Lubricant (ppm)	NJ-20	Notes
1	Ca; 4250	Na; 4180	Li; 24% (by wt)	Li; 14% (by wt)	Zn; 4700	Ca; 1.5% (by wt	Additive in CD-21 $NaNO_3$ - *As a rust inhibitor*
2	Fe; 310	Al; 1352	Si; 850	Ca; 1.8% (by wt)	Li; 2100	Zn; 1220	
3	Al; 290	Fe; 1400	Zn; 340	Si; 1240	Ca; 440	Mo; 930	
4	Na; 82	Ca; 1255	Si; 110	Ca; 660	Fe; 284	Na; 650	
5	Ni; 65	Zn; 184	Na; 90	Zn; 82	P; 190	All others < 10	
All data from ICPMS. CD-20 is designed for internal (vacuum/beamline/Target Chamber. CF-11 and FF-10 were designed for external use only but are frequently used internally.							

Na – A Common Problem

In many fabs, small beads are used under high pressure for cleaning parts extending from the source (arc chambers) to target chamber parts. The beads are used either dry or in a slurry, with water. Another nomenclature for the more typical bead is soda-lime beads – and as the name suggests, these contain a relatively high % of sodium. These Na based beads are the main cause of high sodium in newly refurbished parts either cleaned in the fab or by a third party. This includes source parts such as arc chambers. Many disks today contain a silicon coating deposited either by using a flame-spray technique, PVD or PECVD. Regardless of the level of dry bead or bead-slurry cleaning prior to the silicon coating, these coated disks have barely detectable Na in the initial performance on wafers. One recent *silicon coated* disk showed <1.5E10/cm^2 of Na on the wafer with a test that was done immediately after acceptable vacuum was achieved – no beam conditioning. There are no reports on any disk type of elevated Na on silicon coated disks whether PVD or flame-spray.

Non-silicon coated disks - perhaps 30-40% of all operational disks, which are cleaned with dry or slurried beads, can have a Na "memory" that lasts from 1-4 hours during initial ion beam conditioning. The conditioning can be sometimes longer depending on the final cleaning methods. This time also depends on the type of handling and cleanliness that the disk was subjected on its move from the shipping dock into the implanter. Core routinely cleans bare aluminum disk shields in a mild acid solution followed by a DI H_2O rinse in 2-3, sometimes more, cycles followed by a post clean measurement on multiple shields or apertures using Ion Chromatography (IC) to ensure low surface Na concentration and fast qualification in the implanter. In then early phases of this cleaning and IC characterization, several different cleaning cycles were run – some multiple times in order to determine the most effective technique.

For bare Al parts which are conditioned with beam, a post Na cleaning target of <60,000E10/cm^2 with Ion Chromatography, must be met. This has been correlated with feedback on ability to meet a Na level, 5E9 – 1E10, with VPD-ICPMS – within 1 hour for 1E10/cm^2 and < 2 hours for 5E19/cm^2 Na. See the summary in Table 2 that shows comparison of a run of thirty (30) of the most recent uncoated disk surface sodium samples following refurbishment to Na on wafer performance – within the time window of the customer's spec. It should be noted that levels of Na > 250,000 have a high chance of failure to meet even moderate Na-on-wafer spec levels in a short time of conditioning. Note that we do suggest a test implant of As, 60 or 80 keV, 1E16 at 10 mA or more for proper comparisons. All of the data represents VPD-ICPMS but from the use of somewhat different test implants – all are 60-80 keV, 5E15 – 1E16/cm^2 but with three different species - As (88%), BF_2 (9%), Ar (3%). Typical Na levels with IC following bead cleaning with just several steps of DI H_2O flush average 650K at/cm^2 Na with highs exceeding twice that number.

Table 2. Bare Silicon Disk Low Na Readiness

Na Level (post clean) x 1000/cm^2	Total Disks in Set	Met Na and Time Targets (< 1 & 2 hour)	Met Fab Na Targets Required Added Time *
0-50K	12	12	
50 – 100K-	9	8	1
100 – 150K	6	5	1
150K+	3	3	
* One disk in this category was exposed in a non-controlled environment			

For the majority of top fabs, the initial benchmark for acceptable elemental performance is Na and Fe. Once these two key elements are in control, selected product tests can commence in parallel with other elemental contamination tests. When determining the levels of
elemental contamination from local sputtering near a disk or single wafer platen one of the most common measurement techniques is surface SIMS – or SSIMS a system and technique which is recommended used extensively including OEMs and IDMs[6]. This is a common tool used for contamination data comparison implanter to implanter – along with a reference implant recipe. Four of the top elements of concern for any initial, new equipment test using SSIMS are Al, Fe, Na, K which are ASTM approved [7]. It is always a good practice to ensure that particles levels are in control before commencing characterization for elemental contamination of any kind. The use of VPD-ICPMS and other "large area" surface measurements can and will report the particle material as an elemental contamination. This is true also for TXRF due to its low angle of incidence – at least as low as 0.13 to 0.20º for standard systems [3].

For disks of various types that are not silicon coated, levels of Na >> 1E10/cm^2 sputtered onto wafers may need several hours of ion beam conditioning before Na <1E10/cm^2 is achieved. Several attempts have been made over a few years to reduce this time to < 2 hours and also, for many fabs, meet a spec for 1E10 or 5E9/cm^2 in ≤ 1 and ≤ 2 hour of beam conditioning respectively.

See Table 3 which shows the "top 7" elements of the traditional glass beads – as a % by weight from Glow Discharge Mass Spectrometer (GDMS) data of standard cleaning beads (soda-lime).

Table 3: Cleaning Beads – GDMS; Top Elements

Element	% (or ppm) by Wt
Si	26%
Na	25%
Ca	8%
Mg	2%
Al	0.2%
Fe	670 ppm
K	500 ppm

There are alternate types of beads such as borosilicate beads and, as the name suggests, might be ideal for implanter applications even if a small residue remains. These beads, unfortunately, are only generally available in very small sizes (10 – 40 μm) and they change their shape quite rapidly. It should be added that the borosilicate beads contain Ca 31% by weight. Further improvement to existing processes and alternate post bead cleaning solutions are being tested.

Backside Contamination

Two pedestals from a set from Core were placed on a qualified disk and two clean wafers (200mm) were placed upside down on these pedestals and the disk spun up for 3 minutes, wafers removed and the wafer frontside – the side that was against the pedestal surface, was measured with VPD-ICPMS. See Table 4 that shows each measured element with the average PPM of the two pedestals. All are << customer spec. Underlined are considered critical by the customer.

Table 4. Pedestal Surface Measurement (XE10/cm^2)

Elem	PPM	Elem	PPM	Elem	PPM
B	88	<u>Fe</u>	3.8	Sn	4.2
Na	<u>1.05</u>	<u>Co</u>	0.012	Ba	0.25
Mg	<u>0.55</u>	<u>Ni</u>	0.92	Ta	0.0068
Al	<u>10.8</u>	<u>Cu</u>	1.11	W	0.121
Ti	<u>1.9</u>	<u>Zn</u>	3.1	Pb	0.034
Cr	<u>1.15</u>	As	2.22	K, Y, Y, Hf, Ce	All < dl
Mn	<u>0.10</u>	Mo	0.22		

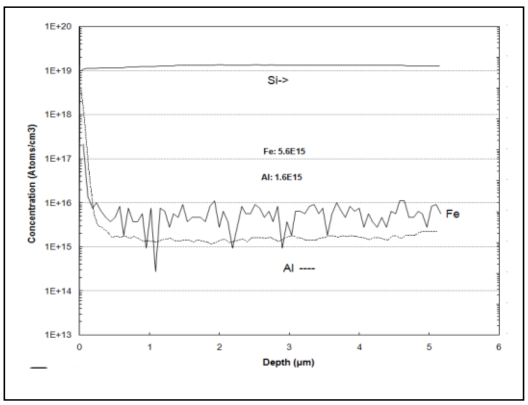
There are reported cases where selected solvents, i.e., mold cleaner, mold release agents or other low molecular weight silicone oils/fluids (LMWS), have diffused through the thin elastomer to the surface [8]. This may explain certain events where surface coloration differences appear in non-uniform patterns in earlier cases but special mold cleaning and manufacturing controls have all but eliminated this.

Silicon Coating Control

Various types of silicon coating are used for various applications in beamlines in order to reduce sputter of Al 6061 and its constituents, i.e, Fe, Cr Cu, Ni, Mg, Mn where Mg, Fe and Si are the highest % by weight. These three are each in the range of 0.5-1.2% typically [9]. Silicon coatings became a key option for disks and selected apertures between 1995-1997. With silicon coatings, PVD for example, that are done offsite, control is needed to avoid system “memory” where the last process target material remains in the system for extended periods – titanium being a common contaminant in this manner.

See Figure 1 showing Magnetic Sector SIMS of only Al and Fe for the sake of clarity. In this coating the Fe is the highest at 5.6E15/cm^2 and the Al is at 1.6E15/cm^2. The PPM (of silicon) is 0.11 and 0.032 PPM respectively. Of the remaining elements checked the next two highest were Cu and Mg at 0.06 and 0.05 PPM respectively. All other elements tested were < 0.05 PPM. This is a level ideal for Disks as well as apertures or other Aluminum assemblies in or near the beam.

Figure 1. SIMS of Silicon Coating Showing Fe and Al



SUMMARY

It is the responsibility of the fab to verify that each and every lubricant used in and near the implanter or any fab equipment for that matter, does not contain any materials that are otherwise banned from the fab. Key fab personnel should also ensure that the lubricant is used in the right location based on certain elements. The types of lubricants found in many fabs are often different that any lubricants designated by the OEM. In a few special cases, even OEM prescribed lubricants need to be reviewed since they tend to be used in locations for which they were not designated – this includes Li based greases. Alternative grease types where many product types are very low in contaminants was presented. Even these should be tracked by the fab.

In the characterization and qualification of large, newly refurbished components such as wafer disks, apertures and the like, it is strongly recommended that the particles be in control before commencing elemental contamination tests to avoid misinterpretation of data.

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