Correlation Of Beam Transport Characteristics And Mass Resolving Power To Analyzing Magnet Pole Piece Wear In Axcelis HE Ion Implanters

Ron Johnson[1], John Schuur[1] and Randy Tysinger[2]

1. INNOViON Corporation
4253 NE 189th Avenue
Gresham, OR 97230 US
rcjohnson@innovioncorp.com, jschuur@innovioncorp.com

2. Maxim Integrated Products
14320 Jenkins Road
Beaverton, OR 97005 US
Randy_Tysinger@or.mxim.com

Abstract. An investigation into odd analyzing magnet tuning behavior on an Axcelis HE ion implanter revealed a correlation to excessive wear on the analyzer magnet pole pieces. Though the lifetime is generally quite good, the pole pieces are internal to the beamline design and are exposed to and sputtered by the ion beam during mass analysis. This erosion of the pole piece surfaces affects beam focus and transport, especially for lower current ion beams. Eventually, automatic beam set-up fails altogether as the system is unable to locate the correct amu peak. It is important to understand and correct any deficiencies in pole piece condition as long-term neglect will eventually lead to process errors. Data is presented to illustrate good and bad pole piece condition and a method is suggested for non-invasive testing.

Keywords: analyzing magnet, pole piece, mass resolution, amu, Axcelis HE.
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INTRODUCTION

Odd analyzer tuning behavior seen in an Axcelis HE ion implanter was, at first, difficult to interpret as final implant data logs (IDLs) and the on-board tool SPC package were not giving indications of any problems with actual process delivery. End of line data from devices processed on the tool during this period of odd amu tuning also showed no significant trends, shifts or patterns in the data. No devices or wafers were ever the subject of scrap as a result of the observed anomaly. Specifically, during some Phosphorus ion beam set-ups, the Auto Beam software was consistently setting the amu to either 30 or 32 at the Injector Faraday (a beam current measuring element that precedes the Linac). Once the beam was routed through the Linac, subsequent 'AMU Tune' operations resulted in a final amu setting of 31, as expected. This paper presents the findings of an investigation to resolve the amu tuning problem.

PROBLEM DISCOVERY

Lengthy source set-up times for some Phosphorous processes alerted Operators to potential recipe problems. Observation of Auto Beam function for these processes was initially inconclusive as the ion source amu tune was inconsistent – on some trials the amu was low, on some trials it was high and for others it was nominal. This occasionally odd problem was not observed however once the ion beam had been accelerated through the Linac, that is to say, the amu was always correct for the final ion beam set-up (ion beam current was correct, etc). For the ion implanter in question, a daily sheet resistance monitor was processed which also used Phosphorous; this monitor process had approximately 10x ion current v. the process with amu tuning problems. Eventually, consistent failure to low amu inspired more investigation, including on-board tool SPC, IDL review and review of amu spectrums. Figure 1 is analyzer spectrum data from an HE machine with the amu tuning problem. For both monoatomic and diatomic Phosphorous there is a 'horns' phenomena in the spectrum that has peaks above and below the target peak amu. (+/- 1 amu for $^{31}P^{+}$ and +/- 2 amu for $^{31}P_2^{+}$).

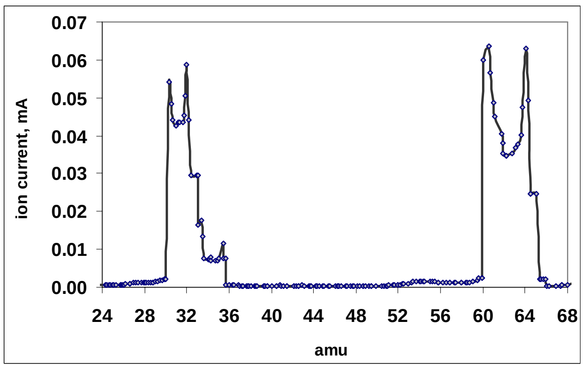

FIGURE 1. An illustration of the 'horns' phenomena observed for both $^{31}P^{+}$ and $^{31}P_2^{+}$ on an HE implanter.

PROBLEM IDENTIFICATION

Using the varying behavior of two well known processes with respect to the emergence of the amu tuning issue as a guide, a number of spectra were taken at different ion source Arc Current settings for both Phosphorous and Argon plasmas. The data is plotted in Figures 2 and 3, respectively. (Note: this data is taken from a different HE machine.)

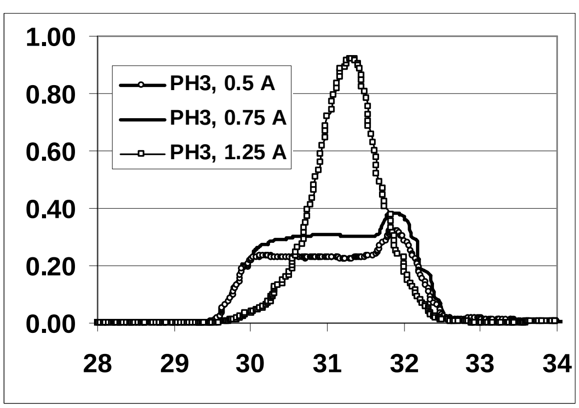

FIGURE 2. Change in PH3 amu spectrum for affected HE machine as a function of Arc Current.

Both Figures 2 and 3 show a clear dependence on Arc Current with respect to evolution of amu peak mismatch. It should be noted that this data was generated simply by varying Arc Current with all other source parameters, such as: Arc Volts, Gas Flow, Source Magnet, Suppression Voltage, etc. were held constant.

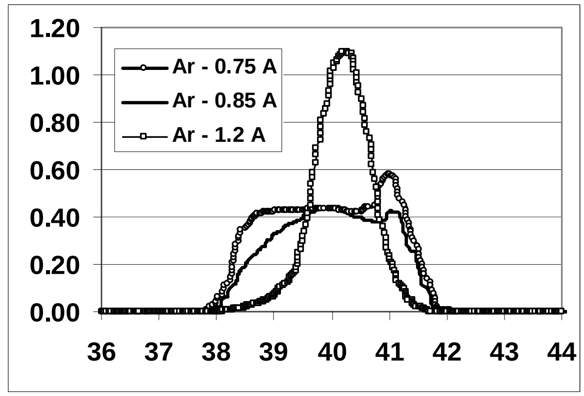

FIGURE 3. Change in Argon amu spectrum for affected HE machine as a function of Arc Current.

The data in Figures 2 and 3 inform us that the problem will be masked for many process set-ups – as beam current (Arc Current) increases, the problem with peak location is reduced.

PROBLEM RESOLUTION: MASS RESOLVING CAPABILITY

At this time, the source and beamline was inspected physically for abnormalities, and it was noted that the amu pole pieces, particularly those closest to the ion source and extraction assembly were severely eroded. As these are replaceable, it is a matter of correct Preventive Maintenance (PM) management to avoid issues with the pole pieces.

For the purposes of developing a diagnostic tool to improve the ability to identify and correct the problem in future operations, mass resolution of the analyzer magnet was measured before and after renewal of the analyzer pole pieces.

Per OEM specification[1], the expected mass resolution ($M/\Delta M$) of an Axcelis HE machine is ≥ 50. The method for mass resolution measurement was to review a detailed amu spectrum and calculate the ration of the amu to the fill-width, half-maximum value of the amu peak.

The data in Table 1 clearly show a very poor mass resolution capability for the worn pole pieces which contrasts very strongly with the mass resolution values obtained for a newly installed set of analyzer pole pieces.

TABLE 1. Mass Resolution (M/ΔM) of Axcelis HE with "worn" and "new" analyzer pole pieces

Species	"worn" = o; "new" = X	Ion current, uA	M/ΔM
$^{31}P^{+}$	o	320	13
$^{31}P^{+}$	**X**	**390**	**121**
$^{40}Ar^{+}$	o	360	13
$^{40}Ar^{+}$	o	1500	46
$^{40}Ar^{+}$	**X**	**660**	**120**

This exercise suggests a straightforward procedure for detecting amu pole piece problems. In the normal course of operations, the pole pieces will wear gradually over time; the data used in this paper were taken from machines which had been in continuous operation for > 5 years. So it is important to have a metric that lets you know when erosion of the pole pieces is causing an actual problem. The method of measuring mass resolution using a defined set of source parameters and comparing to an established standard (for example, mass resolution ≥ 50, 60, other).

CONCLUSION

Odd amu tuning behavior was noted in an Axcelis HE ion implanter for some processes. Investigation led to the understanding that the problem was limited to low current ion beam set-ups. A physical inspection of the beamline revealed worn analyzer pole pieces. The effect of this excessive wear on the pole pieces was confirmed by the measurement of poor mass resolution for ion beam set-ups of interest.

Replacement of the worn pole pieces resulted in an elimination of amu tuning issues for all processes. Subsequent measurement of very good mass resolution suggested a method for detection of the problem's recurrence.

REFERENCES

1. GSD/HE Specification # 58130, March 2003, Axcelis Corporation.