Enriched ^{11}Boron Trifluoride and Hydrogen Mixture for Performance Improvement on Applied Materials E-500 Implanter

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OBJECTIVE

Evaluating $^{11}BF_3$ mixtures on Applied Materials (Varian) E-500 implanter to maximize the equipment performance.

BACKGROUND

The presence of fluorine in the ion source arc chamber allows fluorine radicals to be created in the ion plasma. Through what is known as the halogen cycle, these radicals etch the relatively cooler tungsten or molybdenum arc chamber, or the arc chamber liner, and deposit the tungsten or molybdenum on the hotter filament in the ion source, increasing its mass. When the filament mass increases, the filament power supply cannot sufficiently heat the filament. This limits the generation of electrons needed to sustain the ion source plasma.

The addition of hydrogen to halogen-based implant source gases, such as BF_3, has been shown to effectively interrupt the halogen cycle.

TOOL/EXPERIMENTAL SETUP

The E-500 implanter used in this study was configured with a Bernas style source. The results of a comparison of SDS $^{11}BF_3$ and VAC $^{11}BF_3/H_2$ mixture demonstrate improved source life and lower cost of ownership using the $^{11}BF_3/H_2$ mixture.

VAC $^{11}BF_3/H_2$ QUALIFICATION PLAN

The initial qualification started with an Atomic Mass Spectrum to verify no unexpected changes with $^{11}BF_3/H_2$ (Figure 1). The process team's analysis confirmed that the standard $^{11}BF_3/H_2$ recipe showed only expected isotopes. Hydrogen – which is an active component of the mixture – was almost undetectable.

The next qualification step was to check Sheet Resistance (Rs). Several months of Rs data was compared to test results after installing $^{11}BF_3/H_2$. The red line in (Figure 2) identifies the introduction of $^{11}BF_3/H_2$. The outlier values have been identified by yellow boxes with an assignable cause not related to $^{11}BF_3/H_2$. Analysis by the process team found no significant change to sheet resistance after the introduction of $^{11}BF_3/H_2$.

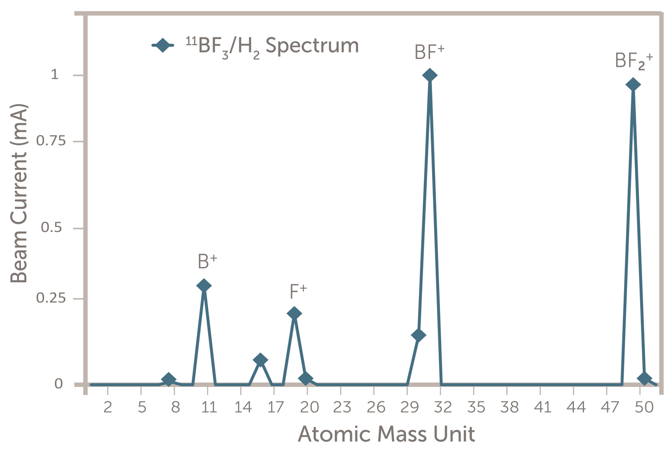

Figure 1. AMU spectrum

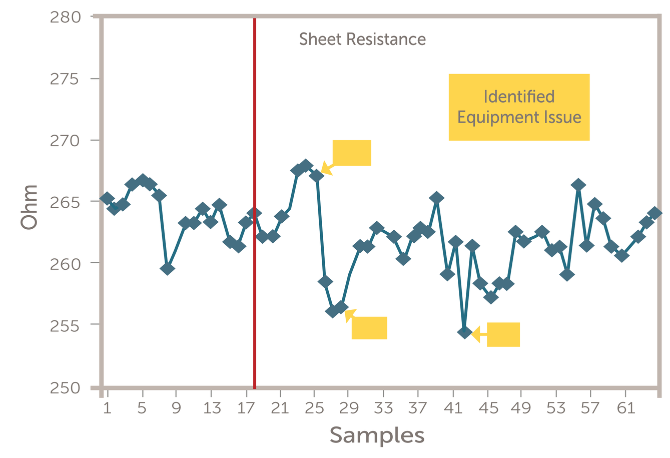

Figure 2. Sheet resistance

VAC $^{11}BF_3/H_2$ RESULTS

Beam Current

A comparison of the beam current trend over time suggests no change in beam performance (Figure 3). The red vertical bar on sample 16 is the date the material supply changed from $^{11}BF_3$ to $^{11}BF_3/H_2$. The use of a two-sample t-Test to compare the $^{11}BF_3$ mean beam current and the $^{11}BF_3/H_2$ mean beam current, revealed the two means were not significantly different ($p = 0.774$).

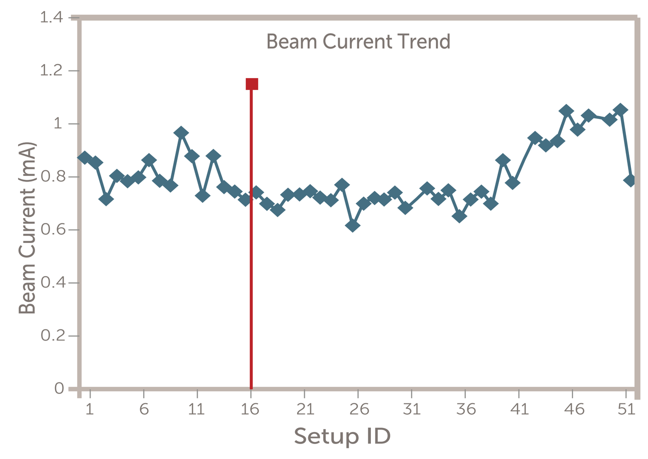

Figure 3. Beam current trend

CYLINDER LIFE

The cylinder change out frequency was not calculated in the cost of ownership improvement during this evaluation. The VAC $^{11}BF_3/H_2$ contains 525 grams of $^{11}BF_3$. For customer cylinders with a lower fill, moving to the 525 gram fill will reduce the cylinder change frequency. If needed, a larger cylinder package provides 1,650 grams of $^{11}BF_3/H_2$.

SOURCE LIFE

The source life graph (Figure 4) shows an average life of 99 hours with $^{11}BF_3$. Once the $^{11}BF_3/H_2$ mixture was introduced the average source life increased 111% to 209 hours (Figure 5). Reducing source changes by 50% and increasing uptime 1.7% allowed for more efficient use of technician time in maintaining the Implant module. Increasing uptime also provided additional time to process wafers, reducing module cycle time.

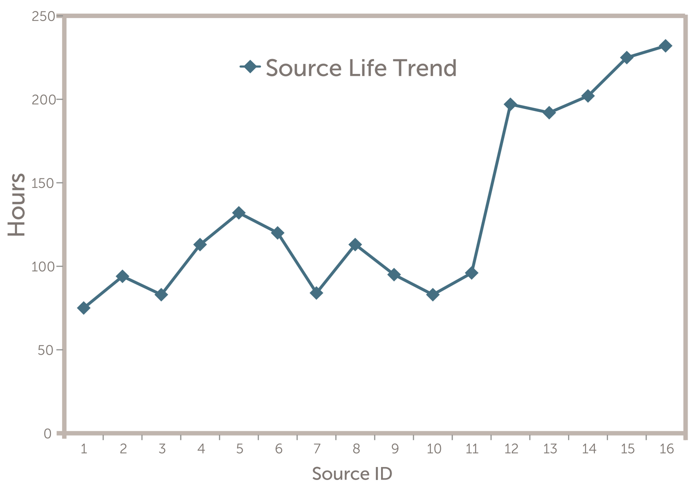

Figure 4. Source life trend

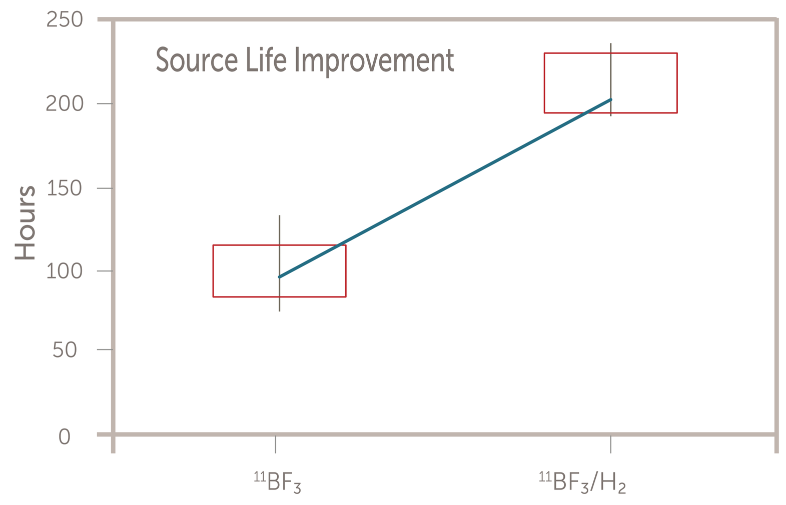

Figure 5. Box plot of source life

$^{11}BF_3$ MIXTURE SELECTION

Entegris offers more than one mixture to allow a single cylinder solution that is tailored to customer needs. Suppling the ideal mixture ratio in a single cylinder not only offers simplicity in use, it also removes the risk of a separate hydrogen cylinder and the risk associated with using two cylinders to accomplish the same benefit as a single VAC cylinder. The $^{11}BF_3/H_2$ mixture gas is offered in the VAC package, which is a Subatmospheric Gas Sources (SAGS) Type II gas delivery system. The cylinder stores the gas mixture at a pressure greater than 500 psig, but delivers the mixture at a pressure of less than 14.7 psia. The chemical stability of BF_3 and H_2 in this mixture is one of the most important safety and functional characteristics of this product. Thermodynamic calculations, as well as experimental evidence, show that no reaction occurs between BF_3 and H_2 at room or elevated temperatures as exemplified by the reaction equation (1).

$$BF_3(g) + 1.5H_2(g) = B(s) + 3HF(g) \quad \Delta rG25°C = 293 \text{ kJ} \quad (1)$$

For this reason, Entegris offers a 3 years shelf life on the VAC $^{11}BF_3$ / H_2.

SUMMARY

The VAC $^{11}BF_3/H_2$ mixture has demonstrated a doubling of source life on an Applied Materials E-500 implanter. This resulted in more wafer turns due to increased tool availability, and also enabled a reduction in manufacturing cost per wafer based on extended use of the ion source components. This was accomplished with no negatives impacts observed to beam current or sheet resistance.

As process controls increase to minimize process variation, the use of premixed process gases removes one source of implanter setup variation. This has the added benefit of less engineering intervention to maintain optimum implanter efficiency. The VAC $^{11}BF_3$ mixture allows customers to select the best mixture concentration for their specific process environment, with a package that is simple to install.

Furthermore, older designed implanter gas boxes typically only accept four cylinders. The VAC $^{11}BF_3/H_2$ mixture package can easily replace the existing BF_3 cylinder, allowing the user to realize the halogen cycle-inhibiting benefits associated with hydrogen.

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