

Indium Performance on the V810

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Abstract. Indium has been used as an alternative p-type dopant to boron in a number of implant applications. Typically, solids such as InCl_3 have been used as source feed materials, which have proven problematic for a number of reasons. Issues have included charge life, conditioning & PM recovery time (e.g. where hydroscopic materials have been used). This paper presents productivity improvements made to the V810 for running indium ion beams, along with advances made in process control.

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I. INTRODUCTION

Indium continues to be used as an alternative p-type dopant to boron for applications requiring steep implant profiles, such as retrograde channel & halo implants [1,2]. The choice of source feed material for indium beam generation can have a significant impact on the tool performance and productivity [3,4]. Typically, solids such as InCl_3 have been used as source feed materials, which have proven problematic for a number of reasons. Issues have included charge life, conditioning and PM recovery time (e.g. because the material is hydroscopic). This paper presents advances made in running indium implants on a standard V810 EHP [5] using indium (I) iodide as the source feed material.

II. INDIUM PERFORMANCE

Indium (III) chloride (InCl_3) has been in use as a source material for generating indium beams for many years [6]. While providing productive beam currents and stable performance, InCl_3 does suffer from a couple of limitations.

The first limitation is a result of the hydroscopic nature of the pure solid. Even with careful handling, it is very difficult to keep the solid dry. Fully hydrated InCl_3 is nearly liquid, requiring the solid to be heated to at least 100°C to drive off the water. This outgassing operation, which involves heating the solid gently in vacuum, needs to be completed prior to being

able to run indium ion beams. If heated too quickly, the escaping water vapor leads to the charge within the vaporizer blowing out into the arc chamber. This can result in significant clean up within the vacuum system.

During operation, indium and chlorine related by-products, which are also hydroscopic, form on the source or in the source area. If the source area remains vented for any significant period of time, the deposits absorb water vapor from the air. Although not difficult to remove, they do constitute an additional requirement for maintenance. Any region within the vacuum system not properly cleaned will greatly impact the vacuum recovery time, due to the time taken to outgas the water.

A second issue with InCl_3 is the chemical reactivity of the breakup products generated in the ion source. For every indium atom, there are three chlorine atoms, which have significant chemical reactivity. Although not an issue with a well maintained ion source, there is a known isobaric interference between $^{115}\text{In}^{++}$, $^{56}\text{Fe}^+$ and $^{58}\text{Ni}^+$ (and $^{58}\text{Fe}^+$, but with a natural abundance of only 0.33%, this is not a significant concern) [7]. In the event of iron or nickel containing materials (e.g. stainless steel) entering into the ion source environment, it is possible to get energetic iron and nickel metal contamination in the wafer. Naturally, if less halogen related material was available, or if the chemical reactivity of the halogen were reduced, this becomes even less of a concern [8].

Indium (I) Iodide (InI) has been investigated as an alternative source feed material that will maintain all

the advantages of InCl_3 , while mitigating the aforementioned issues.

III. RESULTS & DISCUSSION

A. Maintenance Recovery Performance

InI and InCl_3 have very similar operating temperatures, ranging from 360°C to 400°C , depending on the amount of material in the vaporizer. This allows the same preexisting optimized vaporizer hardware and control algorithms to be used.

Figure 1 presents a comparison between InCl_3 and InI in terms of the time taken to condition a fresh charge ready for normal operation (outgassing time). The sample was loaded into a standard vaporizer, installed into the ion source and the whole system pumped down to $<1\text{e-}6$ Torr. The vaporizer temperature was then ramped steadily to outgas the charge, while maintaining the system vacuum below a predetermined limit.

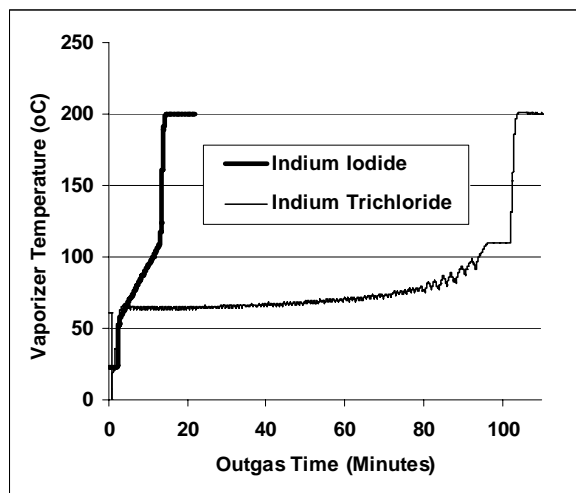


FIGURE 1. Comparison of InI and InCl_3 Outgassing Performance.

The vaporizer charged with 8g of InCl_3 required nearly two hours to reach the required stand-by temperature of 200°C , the point at which the feed material is sufficiently conditioned for use in the ion source. The 10g InI sample achieved this same operating condition within 20 minutes, which is a significant reduction in time. In both cases, care was taken with the material handling, particularly regarding the time exposed to atmosphere. In the case of InI , this is not as important, since the material is significantly less hygroscopic than InCl_3 . Additionally, once InI has been heated to operating temperature, the material forms a solid lump in the

vaporizer with a greatly reduced surface area. Again, this reduces the hygroscopic material concerns.

InI is denser and can be packed more efficiently into a standard vaporizer than InCl_3 . This allows the largest charge to be $\sim 30\text{g}$ for InI , compared to only $\sim 8\text{g}$ for InCl_3 , without any significant increase in the required outgassing time. Charge life observed with a single vaporizer running continuous indium ion beams has been measured at >160 hours. A standard VISta V810 ion source is able to accommodate two vaporizers simultaneously, allowing >320 hours of dedicated indium operation. For a recipe mix with $<50\%$ indium operation, the charge life will not limit the source maintenance cycle.

After running the system for ~ 120 hours with InI , the system was vented for inspection. The source and source area were very clean, with no signs of hygroscopic deposits. No maintenance was required and vacuum recovery was comparable to a standard recovery when not operating with InCl_3 .

B. Contamination Performance

As part of the InI characterization work, the potential for isobaric interference of iron and nickel with $^{115}\text{In}^{++}$ was investigated. Multiple implants were performed using a standard $\text{In}^{++}/150\text{keV}$ beam setup at various times during the InI charge life (9.5, 65, 97 and 150 hrs of charge life). The implant dose was set at $5\text{e}15$ at/cm^2 to improve the potential of detecting energetic $^{57}\text{Fe}^+$ or $^{58}\text{Ni}^+$ using Secondary Ion Mass Spectroscopy (SIMS). Figure 2 below shows the SIMS results for $^{57}\text{Fe}^+$ and Figure 3 shows the SIMS results for $^{58}\text{Ni}^+$. The SIMS spectrum for an unimplanted wafer from the same batch is included as a control.

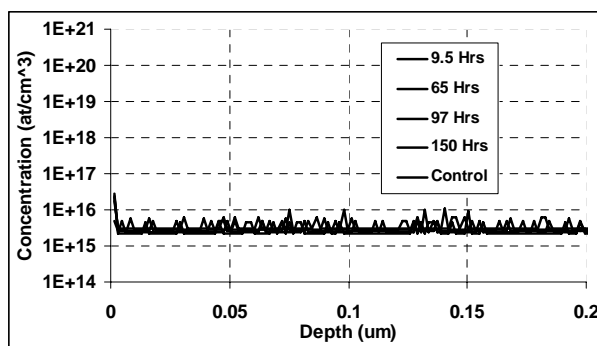


FIGURE 2. SIMS Profile of ^{57}Fe after $\text{In}^{++}/150\text{keV}/5\text{e}15$ Implant.

Based on calculations using SRIM [9], the expected projected range for $^{57}\text{Fe}^+$ and $^{58}\text{Ni}^+$ are

~0.06 μ m. In all cases, no peak in the SIMS plot could be seen, indicating no energetic metal contamination is present, as expected.

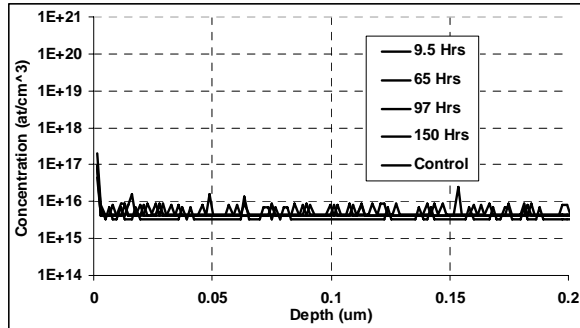


FIGURE 3. SIMS Profile of ^{58}Ni after $\text{In}^+/150\text{keV}/5\text{e}15$ Implant.

Figure 4 shows a typical mass spectrum measured in the mass/charge range of 56 to 59. Two peaks are clearly seen, representing the two isotopes of indium at 56.5 m/q & 57.5 m/q. The natural abundance of ^{113}In and ^{115}In is 4.2% and 95.8% respectively [7], which can be seen in Figure 4. Based on the full width at half maximum (FWHM) of the $^{115}\text{In}^{++}$ peak shown in Figure 4, the mass resolution can be calculated to be >115 . This allows easy separation of indium isotopes.

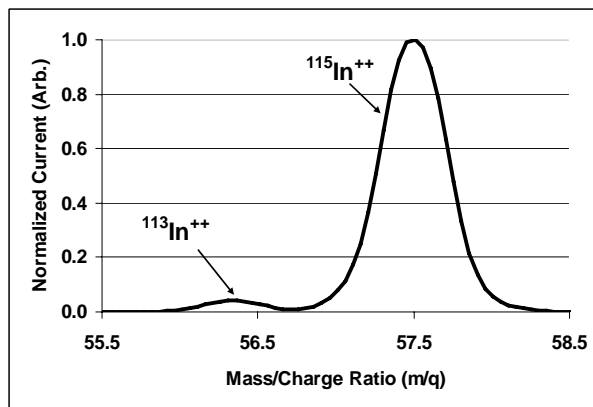


FIGURE 4. Mass Spectrum Showing In^{++}

In the event of foreign parts finding their way into the source area, the various metal isotopes can typically be measured in the mass spectrum when using InCl_3 feed material. If the relative contamination information is convolved with the mass resolution, it is possible to predict the contamination level expected in the wafer. This prediction allows the Varian patent-pending interlock to be set within the software that can be used to ensure that the required metal performance is achieved for $^{115}\text{In}^{++}$ implants. Clearly it is optimal to

utilize a less chemically reactive feed material, and use recommended source materials. In this event, there is no contamination issue.

C. Productivity

Figure 5 shows the 300mm uniform beam current as a function of beam energy for InI . The VISta 810EHP uses In^+ up to 130keV and In^{++} at higher energies, irrespective of whether InCl_3 or InI is used as the feed material. The indium beam current specifications for the product are the same for both feed materials.

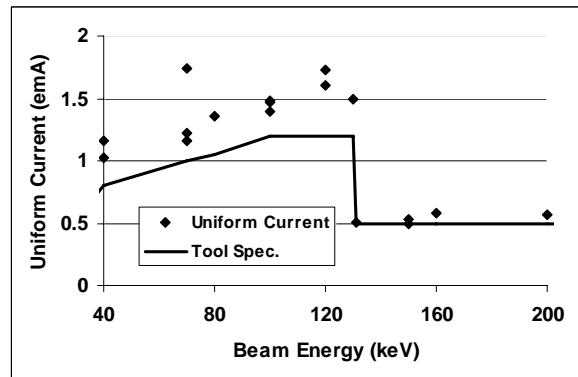


FIGURE 5. 300mm Uniform Beam Current as a Function of Beam Energy

Two implants were chose to demonstrate productivity. $\text{In}^+/130\text{keV}/3\text{e}13\text{at}/\text{cm}^2$ was chosen to represent an indium halo implant, which is performed as a quad (four position) implant at $30^\circ/0^\circ$ tilt/twist angles. $\text{In}^{++}/180\text{keV}/1\text{e}13\text{at}/\text{cm}^2$ represents a typical super steep retrograde (SSR) channel implant. The implant was performed as a single rotation implant at $7^\circ/22^\circ$ tilt/twist angles. The throughput results can be seen in Table 1 for the three cycles that were performed. Excellent setup-to-setup repeatability results in little variation in the measured throughput.

Recipe	Run Rate (WPH)			Tune Time (Mins)
	Min	Max	Mean	Mean
$\text{In}^+/130\text{keV}/3\text{e}13; \text{Q}30/0$	245	247	246	12:49
$\text{In}^{++}/180\text{keV}/1\text{e}13; 7/22$	255	257	256	9:02

TABLE 1. Run rate achieved for two indium recipes during three cycles.

Table 1 also shows the average beam tuning time for a gas-to-solid transition, since tune times need to be considered when discussing implanter productivity. As can be seen, high productivity can be achieved for indium implants.

IV. CONCLUSIONS

In this paper we have discussed how the choice of source feed material for indium beam generation can have a significant impact on tool performance and productivity. The medium current VISta 810EHP offers high productivity, over a broad operating range, when using indium iodide as the source feed material. At the same time it provides superior capability with respect to dose performance, mass resolution, tune time, charge lifetime and cross contamination.

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