Managing the Vacuum Environment of a Source Collector Module

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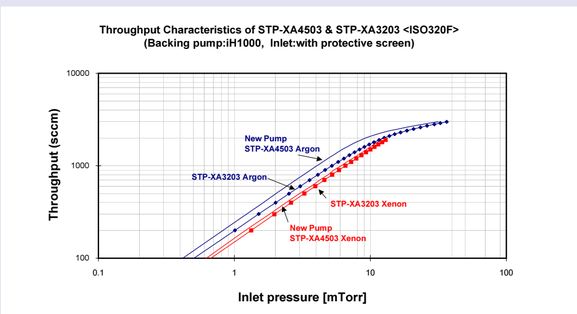
1 Introduction

Xenon and Tin have both been successfully demonstrated as source materials for EUV light production at 13.5 nm. Both source materials present their own set of challenges for the source-collector module environment.
In the case of xenon, there are thermal challenges in pumping high throughputs of heavy gases. The high cost of xenon has an important cost of ownership impact to the overall operating cost of the EUV tool. Xenon recycling will be critical to enabling cost effective xenon based EUV sources.
In the case of tin, careful thermal management of the system is essential to avoid tin deposition and various debris mitigation and cleaning schemes have been implemented. Managing the vacuum pumping of gas mixtures which may include corrosive and /or condensable species is important to maintain source performance.
In both cases, the increase in EUV source power places a higher demand on debris & fast ion mitigation strategies. This has a strong influence on the vacuum system design and pumping requirements, particularly in the case of high flows of argon purge gas.

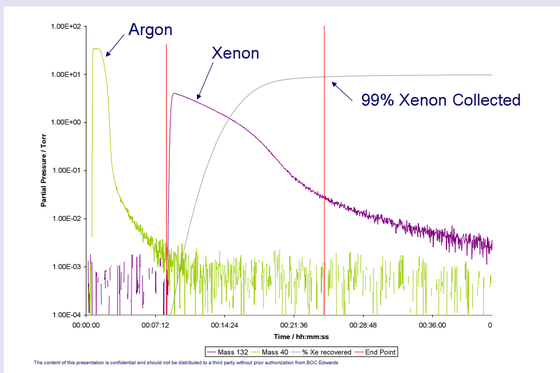
2 Challenges of Pumping Xenon Sources

- Xenon has a low thermal conductivity (0.00415 W/mK) and high molecular weight m = 132; combined with high flows of argon, these properties can present significant thermal issues for pump mechanisms
- BOC Edwards has developed an optimised pump structure for high gas throughputs:
- Optimised rotor stator design for lower heat generation
- Optimised heat transfer structure
- Optimised cooling system
- Continuous maximum gas flow rate can be further improved by addition of light gas purging



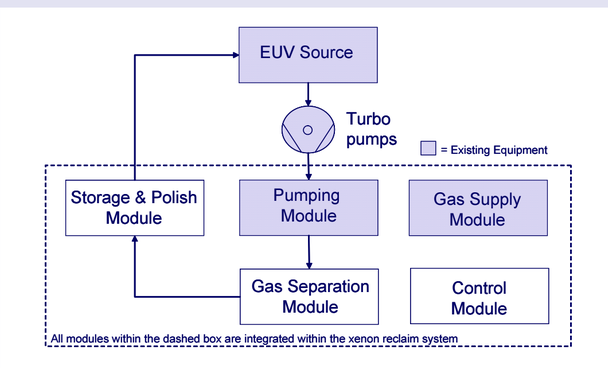
3 Xenon Gas Separation & Purification

- Xenon based EUV sources typically use additional gases such as argon and light gases for fast ion mitigation
- In order to recover the xenon, efficient separation of these noble gases is required
- For this application we have selected to combine two technologies:
- Gas-Solid Chromatography (GC) is used to provide very effective separation and isolation of xenon
- Membrane technology is then used to separate the xenon from the helium used in the GC column and enrich to > 99.5% xenon
- Recovery efficiency is ≥ 98% and non-noble gas impurities ≤ 10ppm, this is largely independent of feed gas composition providing reliable, robust operation at comparatively low capital & operating costs vs other technologies



4 Xenon Recycling

- Schematic overview of modular system

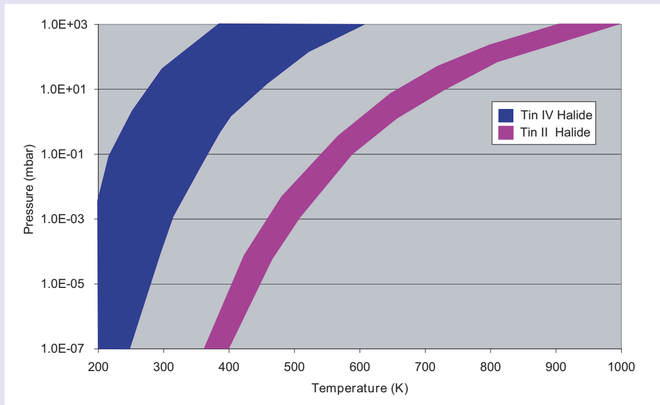


- Systems are integrated in a modular approach and are scaleable to gas flow requirements. For the system shown, max total gas flow is 10 slm and max Xe flow is 2 slm. This approach also allows alternative technologies to be integrated for different application requirements

5 Challenges of Pumping Tin Sources

- Despite efforts to minimise the migration of Tin vapour to unwanted parts of the system this effect cannot be eliminated. As a result a thin film of metallic Tin will form on internal surfaces which needs to be removed periodically.
- Halogen gases can be used to react with metallic tin to form volatile Tin Halides.
- Tin (IV) Halides are more volatile than Tin (II) Halides and are therefore easier to manage in the gaseous phase
- Running a process with excess halogen precursor encourages formation of the preferable Tin (IV) Halide

- Example reactions:
  $Sn + 2HBr \rightleftharpoons SnBr_2 + H_2$
  $SnBr_2 + 2HBr \rightleftharpoons SnBr_4 + H_2$

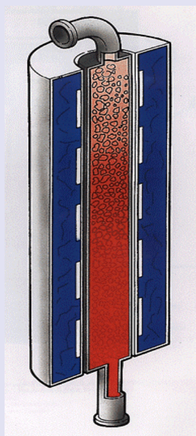


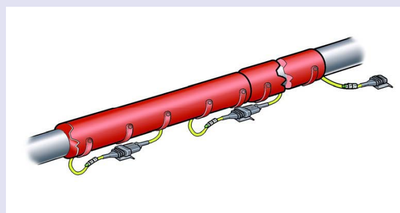
6 Exhaust Gas Management in Tin Sources

- Deposition of Tin (IV) Halides or decomposition of Tin (IV) to Tin (II) Halides must be avoided within the vacuum system. This can be achieved through partial pressure management of Tin (IV) compounds by raising system temperature and adding appropriate inert gas dilution.

- Trace heating pipework may be needed, particularly in backing pump exhaust lines.

- Heated packed beds provide the ideal exhaust management solution for source modules. In these units, toxic and corrosive halogen gases and tin halides are converted to non toxic inert inorganic compounds





7 Conclusions

- Whilst there are very specific requirements to manage the vacuum environment of xenon & tin based sources, many of the considerations are similar:

Thermal management of the input materials
- In the case of xenon, managing high throughputs of heavy gases e.g. Xe & Ar
- In the case of tin, maintaining tin halide by-products resulting from the cleaning steps in the gaseous state, in addition to high throughputs of argon purge gas

Managing the output streams
- In the case of xenon, the high cost and rarity of xenon dictate that recycling of xenon gas is advantageous
- In the case of tin, maintaining materials in the gaseous phase whilst under vacuum and using abatement technology to convert toxic and corrosive halogen gases and tin halides to non-toxic, inert inorganic compounds

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