WEI Technical Release

Impact of Gas Panel Components on SDS® Gas Utilization

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Abstract

The efficient control and safe delivery of sub-atmospheric ion implant source gases requires specific design consideration demands on implanter hardware and software. The implanter delivery system hardware must have minimal pressure drop (maximum conductance) over the entire range of operating pressures to assure maximum utilization of the SDS source gas cylinder. Further, the critical mass flow controller component must have a dynamic range sufficient to produce repeatability over what is becoming an ever decreasing inlet pressure and lower flow rates specified by optimized recipes. Historically the focus for optimum cylinder utilization has been on the pressure drop of the flow controller. However many implanters were converted for SDS gas source operation without consideration for maximizing conductance in other critical flow path components and optimum source utilization is not achieved. In this technical release, the characteristics of all the delivery system components such as MFCs, valves, tubing, filters, etc. and their impact on optimum source gas utilization are discussed. Pressure drop data for these individual components and for a series of integrated components over varying inlet pressures and gases is also considered.

Fig. 1. Arsine SDS2 pressure vs. capacity.

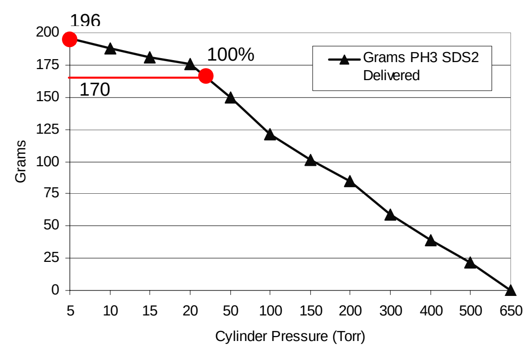


Fig. 2. Phosphine SDS2 pressure vs. capacity.

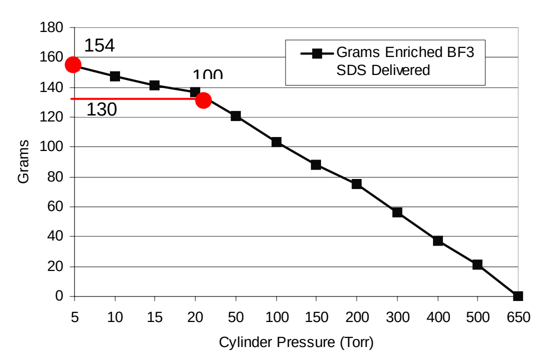
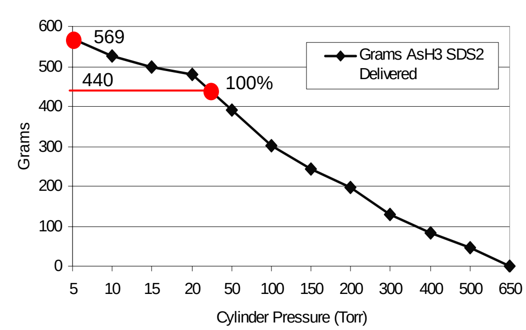


Fig. 3. BF3 SDS pressure vs. capacity.



I. INTRODUCTION

Since early 1996 [1] the SDS sub-atmospheric gas source has gained wide acceptance from the implant community. However, the large pressure drop (conductance losses) experienced throughout the components of the delivery path feeding the process, has inhibited widespread use of this technology because significant and costly amounts of potentially usable source material remained in the container vessel following process bottle change outs.
Reducing the conductance differential influences to levels below 5 torr across the entire delivery path results in significant increased utilization of source material to as much as 129% [2] of the gas supplier's advertised material availability.

It is key to note that much of the source gas available from the SDS cylinders is stored below 100 torr (see Figs. 1-3). This becomes significant while examining the analytical predictions that follow and critical when comparing these empirically calculated numbers with actual accumulated field data.

II. SDS SOURCE GAS DELIVERY CONFIGURATIONS

Multiple methods and approaches have been used in the attempt to adopt and incorporate the SDS source technology for both new implanters as well as systems currently operating in manufacturing environments with an attempt to extend the life and efficiencies of already mature production processes.

Three of the more common methods have been identified, detailed and evaluated throughout the following sections. These methods are categorized as:
1) Original High Pressure Gas Stick with SDS Bottle Connection only
2) Typical Gas Stick Retrofit for SDS Sources.
3) Optimized SDS Delivery Solution.(WEI's BKS System)
Each of these systems is identified and examined analytically in the following section:

System 1: Original High Pressure Gas Stick with SDS Bottle Connection Adapter

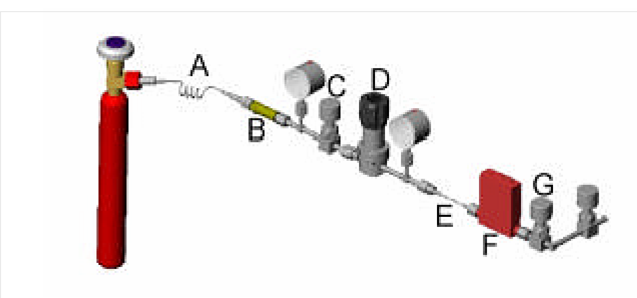


Fig. 4. System 1 Details.

A) VCR bottle connection with 1/8" pigtail
B) Standard gas filter
C) Upstream isolation valve
D) Manual regulator (coarse adjustment)
E) Flexible 1/8" tubing with Swagelock® connections
F) Conventional thermal MFC
G) Downstream species isolation valve

System 2: Typical Gas Stick Retrofit for SDS Sources [4].

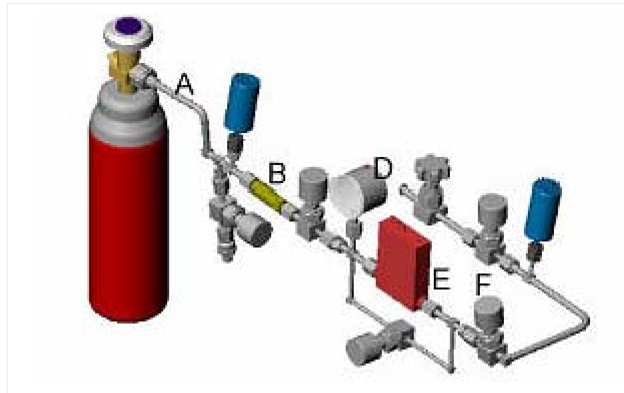


Fig. 5. System 2 Details.

A) VCR bottle connection with 1/4" tubing run
B) Gas filter selected for minimal pressure drop
C) Upstream isolation valve
D) 1/4" tubing with VCR connections
E) Thermal MFC designed for SDS applications
F) Down stream species isolation valve

System 3: Optimized SDS Gas Delivery Solution for Ion Implanation [5]

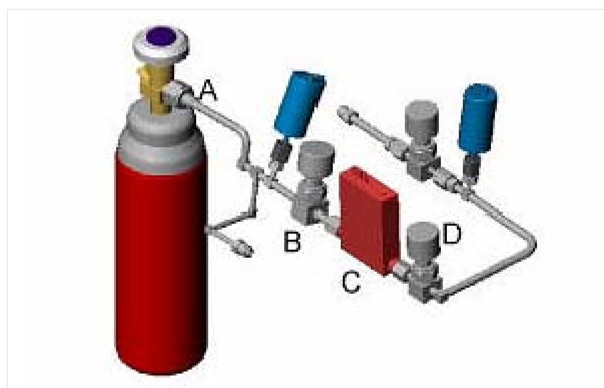


Fig. 6. System 3 Details.

A) VCR bottle connection with 3/8" tubing runs
B) High-flow engineered upstream isolation valve
C) Specifically designed pressure sensitive MFC for SDS applications
D) Down stream isolation valve

Fig. 4 represents a common method used to investigate the adoption of SDS from high-pressure or solid source delivery used in older implanters currently in production. Modifications

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included changing bottle connections from CGA to VCR and replacing mechanical needle valves with an MFC method of metering gas flow. Focus is typically on feasibility studies while making only the minimal investment. Frequently performed on a single gas stick for qualification purposes.

Fig. 5 depicts a recommended upgrade method for adopting SDS over previous alternative gas delivery methods. Focus is on suggesting a delivery design that could achieve the Cost of Ownership models for material availability that is published by the source gas suppliers. Target has been on new design considerations for OEMs but can also be applicable to upgrade efforts, as well.

Fig. 6 illustrates an engineered gas delivery system specifically designed for optimizing SDS source gas utilization in pressure dependent implant applications. Focus was on reaching < 5 torr remnant bottle pressures by minimizing all conductance losses throughout the source gas delivery path while maintaining all S2 recommended safety guidelines. Design also includes and allows for automated operations targeted at minimizing operator exposure and interaction with the source gas as well as guaranteed adherence to documented S.O.P. line purge sequencing (end user definable).

III. Analytical Pressure Drop Comparisons

Basic fluid dynamic principles can be applied to predict and explain source gas flow characteristics during transport through a sub-atmospheric delivery path. This includes investigating each of the components that are presented and referred to throughout this technical publication. Real-time data has also been accumulated from actual production environment implant systems that substantiate and validate the theoretical formulas used to formulate the reported calculations. Proprietary implant recipes and process stability requirements outside of the gas delivery system may play a role in explaining some minor discrepancies between the analytical and field gathered source data.

After applying engineering concepts of fluid dynamics [6], thermodynamics [7], and mechanical engineering [8], the following graph (Fig.7) was generated to compare the effect that each fluid path component contributed to the delivery efficiencies of the 3 variations in gas delivery methods presented previously for consideration.

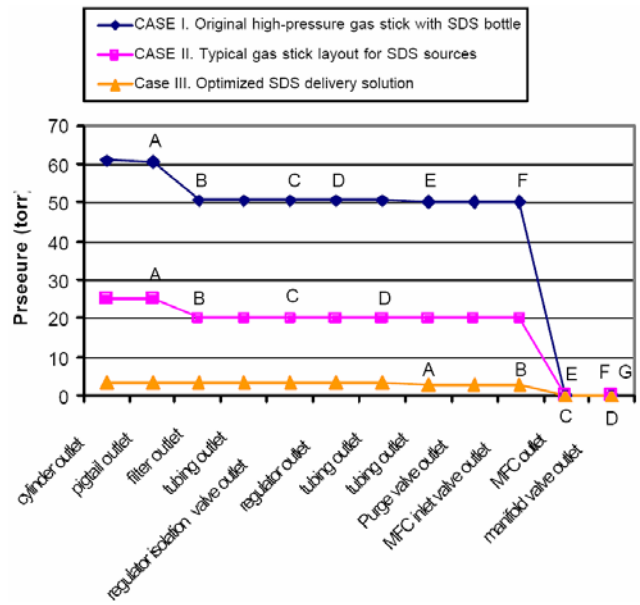

Fig. 7. Conductance Losses vs. Location Along Gas Delivery Path.

These analytically computed results indicate that components along the gas delivery path have compromising influences over the efficient use and optimization of the SDS source materials.

Note: The values used in the above calculations were either obtained from supplier specification collateral or an application of the "ideal gas law" for laminar flow across the individual components. Ion implant process influences outside the gas delivery system were not considered in the above calculations.

IV. Field Pressure Drop Measurements and Data

Although theoretical calculations can provide valuable design consideration parameters, the data collected from actual manufacturing process equipment has proven to be quantifiably the best method of measuring a delivery system's performance. Each of the (3) various methods for gas delivery mentioned above has associated real-time data regarding SDS bottle pressure measurements collected and recorded following a number of end-user species source bottle change outs.

Wolfe Engineering, Inc. designed and developed an **SDS Bottle Pressure Tester** apparatus for use by their potential customers requesting budgetary justifications to upgrade from their standard gas delivery methods into optimized systems using SDS.

The accumulated field data is presented for System 1 gas delivery systems in Fig.8.

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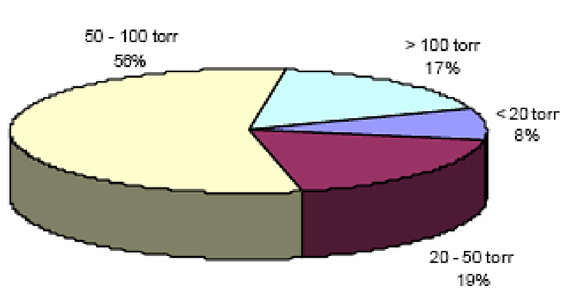

Fig. 8. System 1 Remnant Bottle Pressure Test Data Results.

Gas delivery systems in production applications, modified with comparable components to the System 2 method, generated the post bottle change field data results graphed in Fig.9

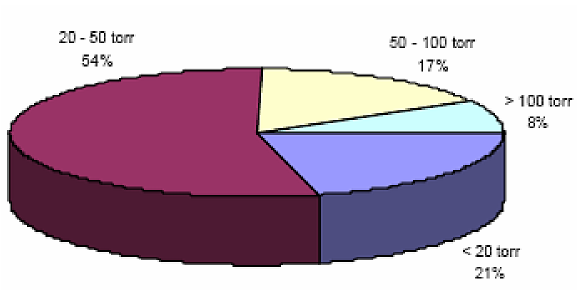

Fig. 9. System 2 Remnant Bottle Pressure Test Data Results.

Field data accumulated from delivery systems designed according to System 3 criteria was taken from upgrade gas delivery units designed and produced by Wolfe Engineering, Inc. Bottle pressures were recorded at the time of source change via electronic pressure transducer readings with high accuracy in the lower pressure regions.

The compiled data is presented in Fig.10.

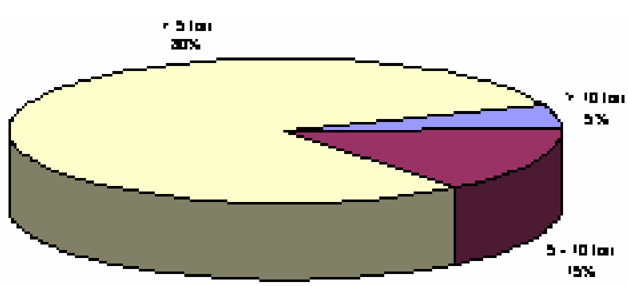

Fig. 10. System 3 Remnant Bottle Pressure Test Data Results.

The presented field data indicates a substantiated correlation with the analytical models.

Considerations should also be given to additional process parameters associated with implant applications, outside of the gas delivery methods previously detailed, that may also contribute to the efficient usage of the available source gas.

V. Process Control

Monitoring and controlling gas flow rates from the SDS gas source is critical for optimization of the cylinder contents [9]. This is extremely important in any upgrade as the efficient monitoring and controlling of the SDS gas source can extend cylinder lifetime and allow for the delivery of gas well in excess of the ideal published quantities.

The two most critical components necessary for monitoring and controlling gas flow are the pressure transducers and mass flow controllers. The performance accuracy of these components within an SDS gas delivery system is crucial to properly managing the optimization of source gas usage.

Additionally, in System 3 applications all components and fluid path elements were designed with the ultimate goal of optimizing the conductance of the vacuum based process they supply. Accurate bottle pressure readings provide critical information for process optimization and material usage considerations.

VI. Summary

The SDS gas delivery technology has become an acceptable standard for most ion implant applications. The EH&S and financial benefits have proven to be significant enough that migration away from traditional gas delivery methods (High Pressure and Solid Source) is being recognized and accepted at every level of the semiconductor fab decision making process.

Although many methods of adoption and conversion exist for implementing this technology, the data presented above indicates that justification of an optimized gas delivery method (such as System 3) deserves serious consideration.

Whatever method one chooses for adopting the SDS technology of gas delivery into their Ion Implant process, consider that options exist especially for older implanters that have significant process life and performance capabilities remaining.

Anyone considering adopting this technology for use in their older implant processes should note that the design recommendations presented in this technical paper have already been implemented by most of the major OEMs as a standard on their latest ion implant process tools being offered in the market today.

Safety is a consideration that can not be compromised in any fashion. Safety complimented by cost effective engineered solutions can make even the most stringent ROI calculations even easier to be recognized for the benefits they bring to all levels of an organization.
Wolfe Engineering, Inc. can assist you in your ROI calculations with our new **SDS Bottle Pressure Tester** program. See our website for details on how we have simplified the justification process by allowing your input to generate the output needed to make this an easy decision for your company to make.

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The author of this paper hopes that the materials and data presented assist in making an educated analysis of the variables necessary to meet your specified process goals, and budgetary objectives.

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Acknowledgements

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Also, we would like to specifically thank Fred Walker, P. E., for his investigations and contributions regarding theoretical gas delivery analysis and empirical calculations.

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