

# A Phosphine Sub Atmospheric Delivery System (SADS) applied to Low Pressure Chemical Vapor Deposition (LPCVD) of in situ doped Polysilicon.

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Phosphine gas is widely used as the phosphorus source for the deposition of in-situ doped n-type polysilicon. Typically, high pressure bottled phosphine gas is used for this purpose with excellent results. However, the safe use of a pressurized gaseous phosphine source requires a remote gas cabinet in a suitable location, double walled stainless steel tubing, and multiple toxic gas sensing points. The cost of this infrastructure can be prohibitive for many research laboratories. As a safe means around this cost issue, we have successfully implemented a commercially available phosphine SADS as the dopant source for in situ doped polysilicon. SADS has been proven as a safer source and can be installed locally, inside the source cabinet attached to the LPCVD furnace stack meeting all semiconductor industry safety requirements [1]. Based on the enhanced safety and reduced infrastructure requirements, we implemented SADS in the CNST NanoFab LPCVD system. In selecting an alternate phosphine source for in-situ doped n-type polysilicon deposition, several important factors must be addressed such as the ability to provide a sustained gas flow over long deposition periods, length of time between source changes, and process results consistent with industry standards. The sub-atmospheric delivery system uses an adsorbent material to store phosphine. The dopant gas is extracted by the pressure differential between the cylinder and the LPCVD chamber with high pressure differentials resulting in higher extraction rates. A low differential pressure mass flow controller (MFC) and 1.27 cm delivery line were used to minimize pumping impedance resulting in sustained gas flows of  $10 \text{ cm}^3/\text{min}$  for greater than 20 h. The total amount of gas extractable is proportional to the final gas bottle pressure with lower pressures resulting in more gas extracted. The MFC and larger gas line make final bottle pressures of less than 2.7 kPa possible. Lowering the final bottle pressure from 6.7 kPa to 2.7 kPa results in 35 % more gas extracted. Our process produces a doped polysilicon film with a 4 nm/min deposition rate and better than  $\pm 5 \%$  non-uniformity. The typical final bulk resistivity after a 30 min  $1000^\circ \text{C}$  nitrogen anneal is less than  $0.002 \Omega\text{-cm}$  which corresponds to an approximate atomic doping concentration of  $3 \times 10^{19} \text{ cm}^{-3}$ . These results are consistent with films deposited using high pressure phosphine gas delivery.

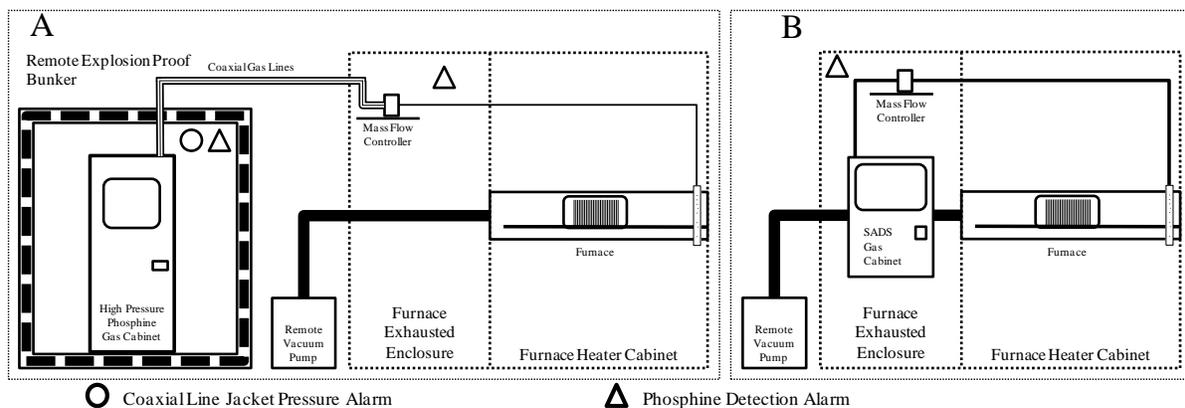


Figure 1: Infrastructure required for [A] pressurized phosphine source and [B] sub-atmospheric phosphine source.

In summary, a phosphine SADS has been fitted to a conventional LPCVD furnace system. Through careful design and implementation, we have demonstrated an inherently safe system with significantly lower infrastructure requirements and costs that meet all semiconductor industry safety requirements.

## References:

[1] M.W. Raynor, V.H. Houlding, R. Frye, K. Olander, Safety benefits of using a sub-atmospheric pressure hydride gas source for MOCVD, 2004