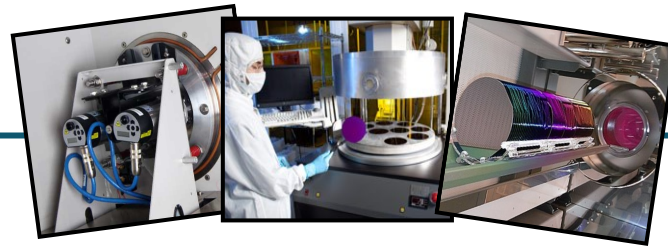


CSI Gas Delivery Systems Support

Chemical Vapor Deposition (CVD)

This page discusses the CVD processes often used for integrated circuits (ICs). Particular materials are deposited best under particular conditions. Facilitation recommendations are at the bottom of the page.

Polysilicon

Polycrystalline silicon is deposited from silane (SiH_4), using the following reaction:

$SiH_4 \rightarrow Si + 2H_2$

This reaction is usually performed in LPCVD systems, with either pure silane feedstock, or a solution of silane with 70-80% nitrogen. Temperatures between 600 and 650°C and pressures between 25 and 150 Pa yield a growth rate between 10 and 20 nm per minute. An alternative process uses a hydrogen-based solution. The hydrogen reduces the growth rate, but the temperature is raised to 850 or even 1050 degrees Celsius to compensate.

Polysilicon may be grown directly with doping, if gases such as phosphine, arsine or diborane are added to the CVD chamber. Diborane increases the growth rate, but arsine and phosphine decrease it.

Silicon dioxide

Silicon dioxide may be deposited by several different processes. Common source gases include silane and oxygen, dichlorosilane ($SiCl_2H_2$) and nitrous oxide (N_2O), or tetraethylorthosilicate (TEOS; $Si(OC_2H_5)_4$). The reactions are as follows:

$SiH_4 + O_2 \rightarrow SiO_2 + 2H_2$

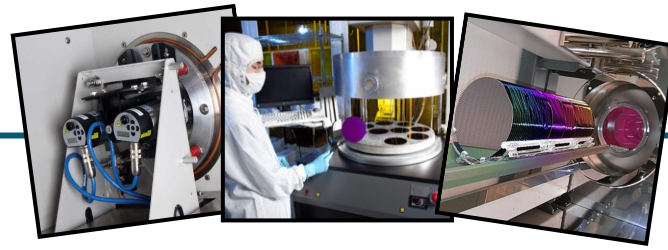
$SiCl_2H_2 + 2N_2O \rightarrow SiO_2 + 2N_2 + 2HCl$

$Si(OC_2H_5)_4 \rightarrow SiO_2 + \text{byproducts}$

The choice of source gas depends on the thermal stability of the substrate; for instance, aluminum is sensitive to high temperature. Silane deposits between 300 and 500°C, dichlorosilane at around 900°C, and TEOS between 650 and 750°C. However, silane produces a lower-quality oxide than the other methods (lower dielectric strength, for instance), and it deposits nonconformally. Any of these reactions may be used in LPCVD, but the silane reaction is also done in APCVD. CVD oxide invariably has lower quality than thermal oxide, but thermal oxidation can only be used in the earliest stages of IC manufacturing.

Oxide may also be grown with impurities (alloying or "doping"). This may have two purposes. During further process steps that occur at high temperature, the impurities may diffuse from the oxide into adjacent layers (most notably silicon) and dope them. Oxides containing 5% to 15% impurities by mass are often used for this purpose. In addition, silicon dioxide alloyed with phosphorus pentoxide ("P-glass") can be used to smooth out uneven surfaces. P-glass softens and reflows at temperatures above 1000°C. This process requires a phosphorus concentration of at least 6%, but concentrations above 8% can corrode aluminum. Phosphorus is deposited from phosphine gas and oxygen:

$4PH_3 + 5O_2 \rightarrow 2P_2O_5 + 6H_2$



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Glasses containing both boron and phosphorus (borophosphosilicate glass, BPSG) undergo viscous flow at lower temperatures; around 850 °C is achievable with glasses containing around 5 weight % of both constituents, but stability in air can be difficult to achieve. Phosphorus oxide in high concentrations interacts with ambient moisture to produce phosphoric acid. Crystals of BPO_4 can also precipitate from the flowing glass on cooling; these crystals are not readily etched in the standard reactive plasmas used to pattern oxides, and will result in circuit defects in integrated circuit manufacturing.

Besides these intentional impurities, CVD oxide may contain byproducts of the deposition process. TEOS produces a relatively pure oxide, whereas silane introduces hydrogen impurities, and dichlorosilane introduces chlorine.

Silicon nitride

Silicon nitride is often used as an insulator and chemical barrier in manufacturing ICs. The following two reactions deposit nitride from the gas phase:

$3SiH_4 + 4NH_3 \rightarrow Si_3N_4 + 12H_2$

$3SiCl_2H_2 + 4NH_3 \rightarrow Si_3N_4 + 6HCl + 6H_2$

Silicon nitride deposited by LPCVD contains up to 8% hydrogen.

Another two reactions may be used in plasma to deposit SiNH:

$2SiH_4 + N_2 \rightarrow 2SiNH + 3H_2$

$SiH_4 + NH_3 \rightarrow SiNH + 3H_2$

Metals

Some metals (notably aluminum and copper) are seldom or never deposited by CVD. As of 2002, a viable CVD process for copper did not exist, and the metal was deposited by electroplating. Aluminum can be deposited from tri-isobutyl aluminum, but physical vapor deposition methods are usually preferred.

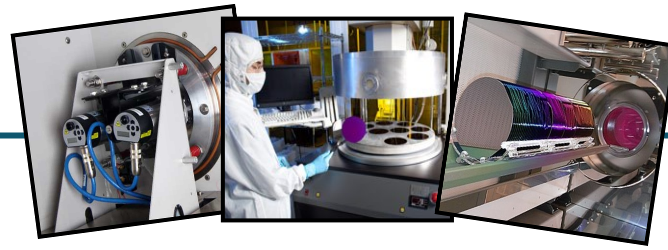
However, CVD processes for molybdenum, tantalum, titanium and tungsten are widely used. These metals can form useful silicides when deposited onto silicon. Mo, Ta and Ti are deposited by LPCVD, from their pentachlorides. In general, for an arbitrary metal *M*, the reaction is as follows:

$2MCl_5 + 5H_2 \rightarrow 2M + 10HCl$

The usual source for tungsten is tungsten hexafluoride, which may be deposited in two ways:

$WF_6 \rightarrow W + 3F_2$

$WF_6 + 3H_2 \rightarrow W + 6HF$



CSI Gas Delivery Systems Support

Chemical Vapor Deposition (CVD)

Facilitation Information:

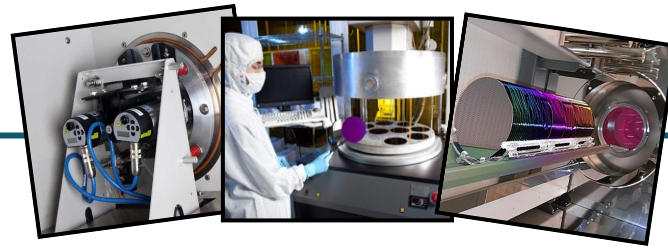
Silane (SiH4)
- Classification: Pyrophoric in concentrations higher than 1.37%
- Gas Cabinet with ESO Capability – Required for Indoor Use, Can be placed Outside per Code Requirements.
  - Must Comply with CGA Code G-13
- Pressurized Gas
- DISS 632 Connection Recommended
- Coax Tubing is Recommended but not required by Code
- Purge Gas of Helium/Nitrogen blend is recommended
- Purge Gas Purifier not necessary
- Hazardous Gas Monitor for Gas Supply Shutdown - Required

Ammonia (NH3)
- Classification: Flammable, Toxic
- Gas Cabinet with ESO Capability - Required
- Liquefied Gas
- DISS 720 Connection Recommended
- Single Containment Tubing is Permitted by Code
- Purge Gas of Helium/Nitrogen blend is recommended
- Purge Gas Purifier Strongly Recommended
- Hazardous Gas Monitor for Gas Supply Shutdown - Required

Hydrogen (H2)
- Classification: Flammable
- Gas Cabinet with ESO Capability – Not Required
- Pressurized Gas
- DISS 724 Connection Recommended
- Single Containment Tubing is Permitted by Code
- Purge Gas of Helium/Nitrogen blend is recommended
- Purge Gas Purifier Not Necessary
- Hazardous Gas Monitor for Gas Supply Shutdown - Required

Dichlorosilane (SiCl2H2)
- Classification: Flammable, Toxic
- Gas Cabinet with ESO Capability - Required
- Liquefied Gas
- DISS 636 Connection Recommended
- Coax Tubing is Recommended but not required by Code
- Purge Gas of Helium/Nitrogen blend is recommended
- Purge Gas Purifier Recommended
- Hazardous Gas Monitor for Gas Supply Shutdown - Required

Oxygen (O2)
- Classification: Inert
- Gas Cabinet with ESO Capability – Not Required
- Pressurized Gas
- DISS 714 Connection Recommended
- Single Containment Tubing is Permitted by Code
- Purge Gas Not Necessary
- Purge Gas Purifier Not Required
- Hazardous Gas Monitor for Gas Supply Shutdown – Not Required



CSI Gas Delivery Systems Support

Chemical Vapor Deposition (CVD)

Facilitation Information (cont.):

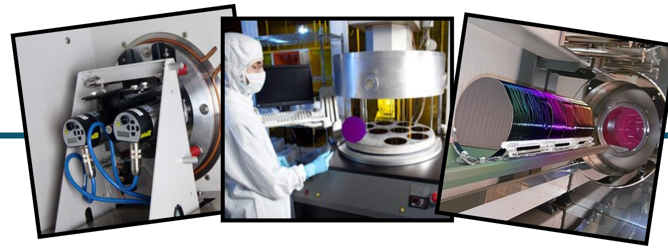
Phosphine (PH3)
- Classification: Pyrophoric, High Toxic
- Gas Cabinet with ESO Capability - Required
- Pressurized Gas
- DISS 632 Connection Recommended
- Coax Tubing is Recommended but not required by Code
- Purge Gas of Helium/Nitrogen blend is recommended
- Purge Gas Purifier Strongly Recommended
- Hazardous Gas Monitor for Gas Supply Shutdown - Required

Tungsten Hexafluoride (WF6)
- Classification: Corrosive, Toxic
- Gas Cabinet with ESO Capability - Required
- Liquefied Gas
- DISS 638 Connection Recommended
- Coax Tubing is Recommended but not required by Code
- Purge Gas of Helium/Nitrogen blend is recommended
- Purge Gas Purifier Strongly Recommended
- Hazardous Gas Monitor for Gas Supply Shutdown - Required

Trichlorosilane (SiHCl3)
- Classification: Flammable, Toxic, Corrosive
- Gas Cabinet with ESO Capability - Required
- Liquefied Gas
- DISS 636 Connection Recommended
- Coax Tubing is Recommended but not required by Code
- Purge Gas of Helium/Nitrogen blend is recommended
- Purge Gas Purifier Strongly Recommended
- Hazardous Gas Monitor for Gas Supply Shutdown - Required

Arsine (AsH3)
- Classification: Flammable, HighToxic
- Gas Cabinet with ESO Capability - Required
- Liquefied Gas
- DISS 632 Connection Recommended
- Coax Tubing is Recommended but not required by Code
- Purge Gas of Helium/Nitrogen blend is recommended
- Purge Gas Purifier Strongly Recommended
- Hazardous Gas Monitor for Gas Supply Shutdown - Required

Diborane (B2H6) (Mixtures – Blended with Inerts, H2 and SiH4)
- Classification: Depends on Blend, Common are Flammable, Toxic, Corrosive
- Gas Cabinet with ESO Capability - Required
- Liquefied Gas
- DISS 632 Connection Recommended
- Use of Dual Stage Regulators Recommended
- Cylinders Should be Chilled During Use for Best Results
- Coax Tubing is Recommended but not required by Code
- Purge Gas of Helium/Nitrogen blend is recommended
- Purge Gas Purifier Strongly Recommended
- Hazardous Gas Monitor for Gas Supply Shutdown - Required



CSI Gas Delivery Systems Support

Chemical Vapor Deposition (CVD)

Gas Scrubber – Gas scrubbers are selected based on three items. The gases to be abated, the mixture of gases being abated and the flow rate of each particular gas plus the purge gas. As the required scrubber can vary greatly for CVD applications, please contact Critical Systems directly for your specific application. Below are a few of the scrubber types and what they are best used for.

Dry Resin Bed Scrubber – Can be used with a variety of gas types by varying the layers of the resin bed. Resin mix reacts with the hazardous gas to produce harmless solids Required disposal once the canister is depleted. Can be sized for high flow applications. Brands - Novapure EGS237 and EGS400

Hot Bed Scrubber – Best when isolated to a single or a few specific gases, the hot bed scrubber uses a gas reactor cartridge to convert the hazardous gases into harmless inorganic salts. Limited to 60 SLPM total gas flow including purge gas Brands – Edwards M150 and D150 GRCs

Water Scrubber – Good for high flows and uses a series of water wash steps to abate water soluble effluent gases and particulate.

Burn Box Scrubber – Good for high flow rates and used to elevate combustible gases beyond their auto ignition temperature to thermally oxidize residual process gases such as phosphine, arsine, silane, diborane and others.
Brands – ATMI Guardian G4 and G8, Unisem UN2000, Edwards PCS

Burn Box / Water Wash Scrubber – Combines the features of a burn box scrubber and a wet scrubber to handle both combustible and water soluble gases plus particulate. Brands – Delatech CDO 858 and 859

Note: CSI always recommends enlisting a professional engineer to determine the Codes your facility will be required to meet for your installation. CSI's information above is for informational purposes only and not intended to serve as a statement of what is legally required to meet local and national compliance.