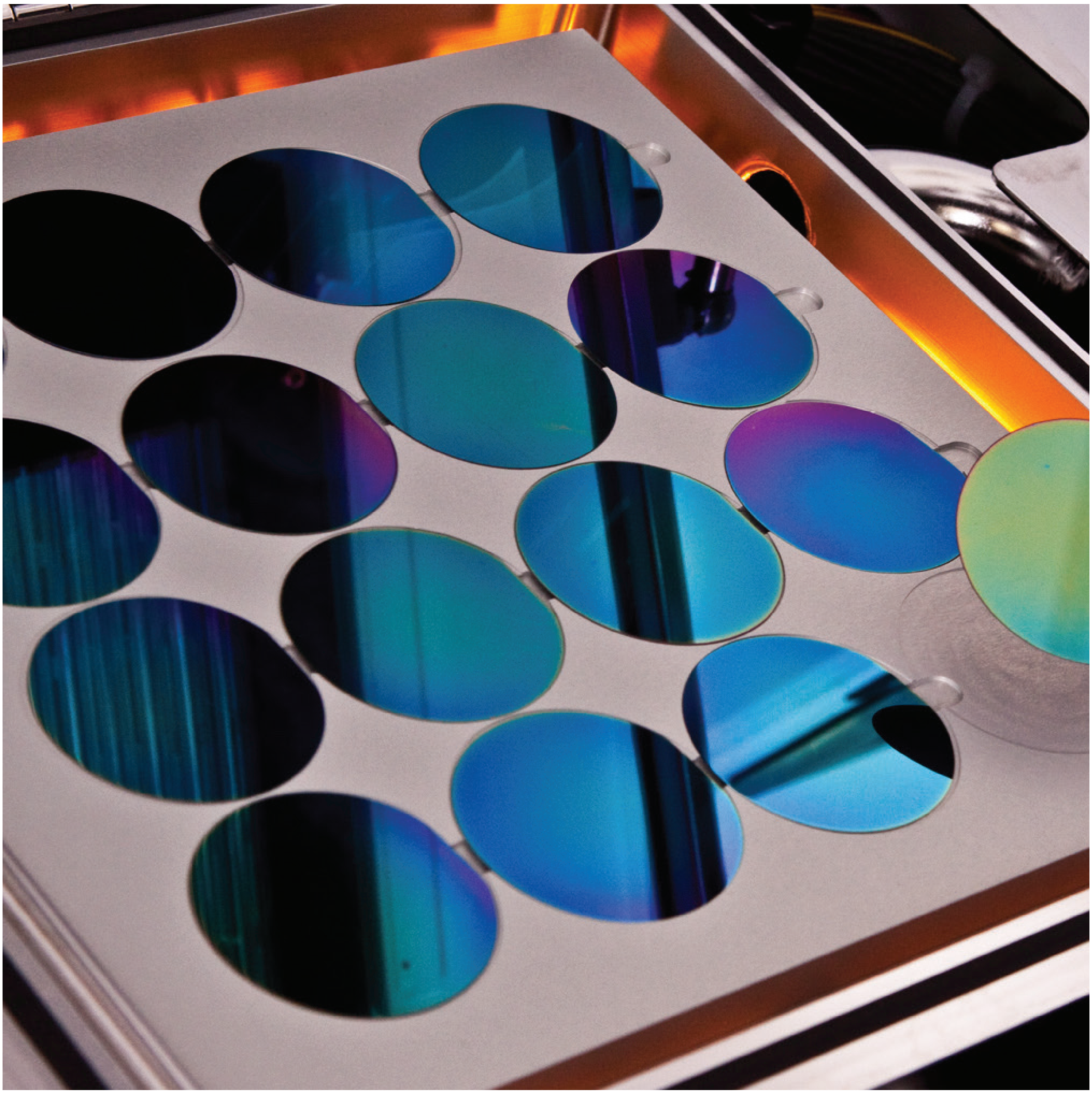
PHOTO-ENHANCED CHEMICAL VAPOR DEPOSITION REACTOR



TYSTAR

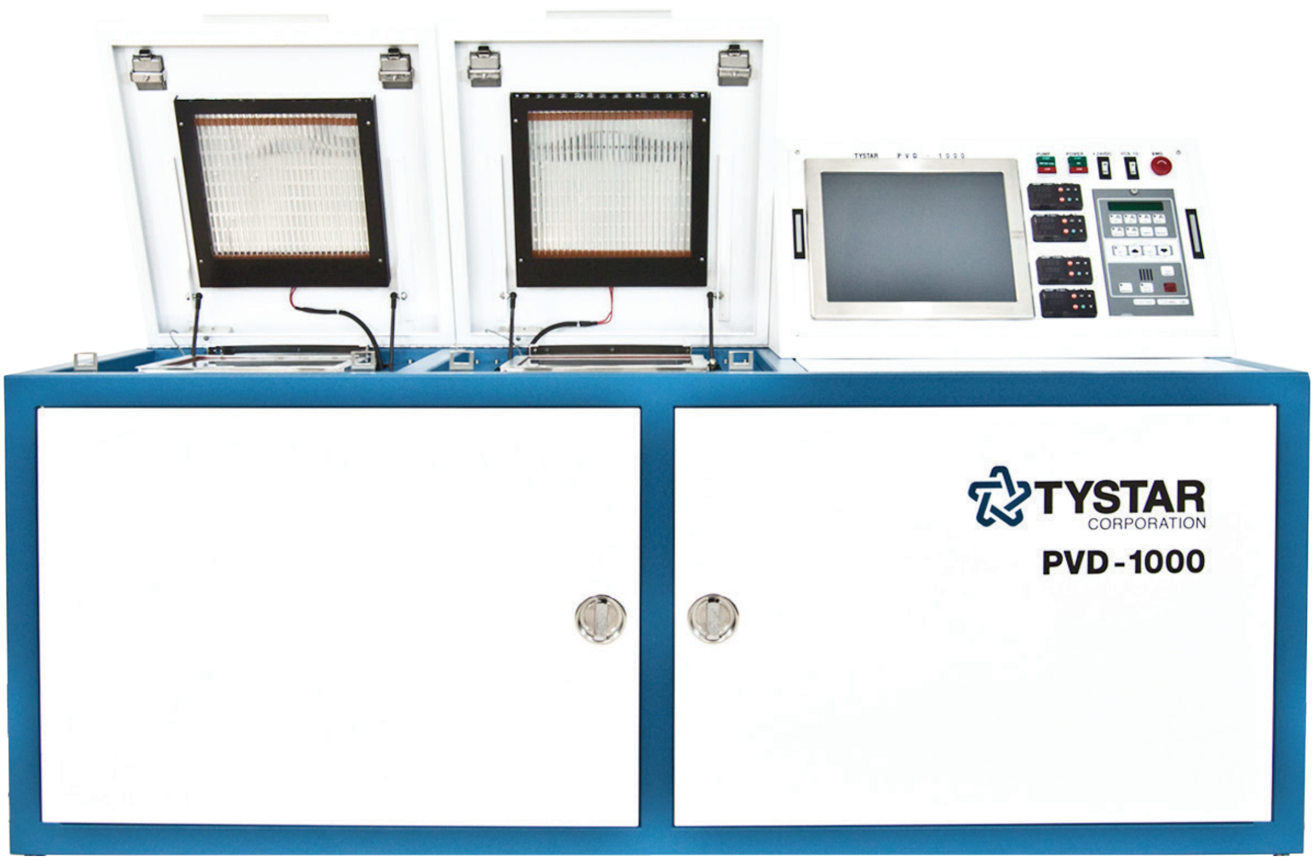
PHOTO-ENHANCED CHEMICAL VAPOR DEPOSITION REACTOR

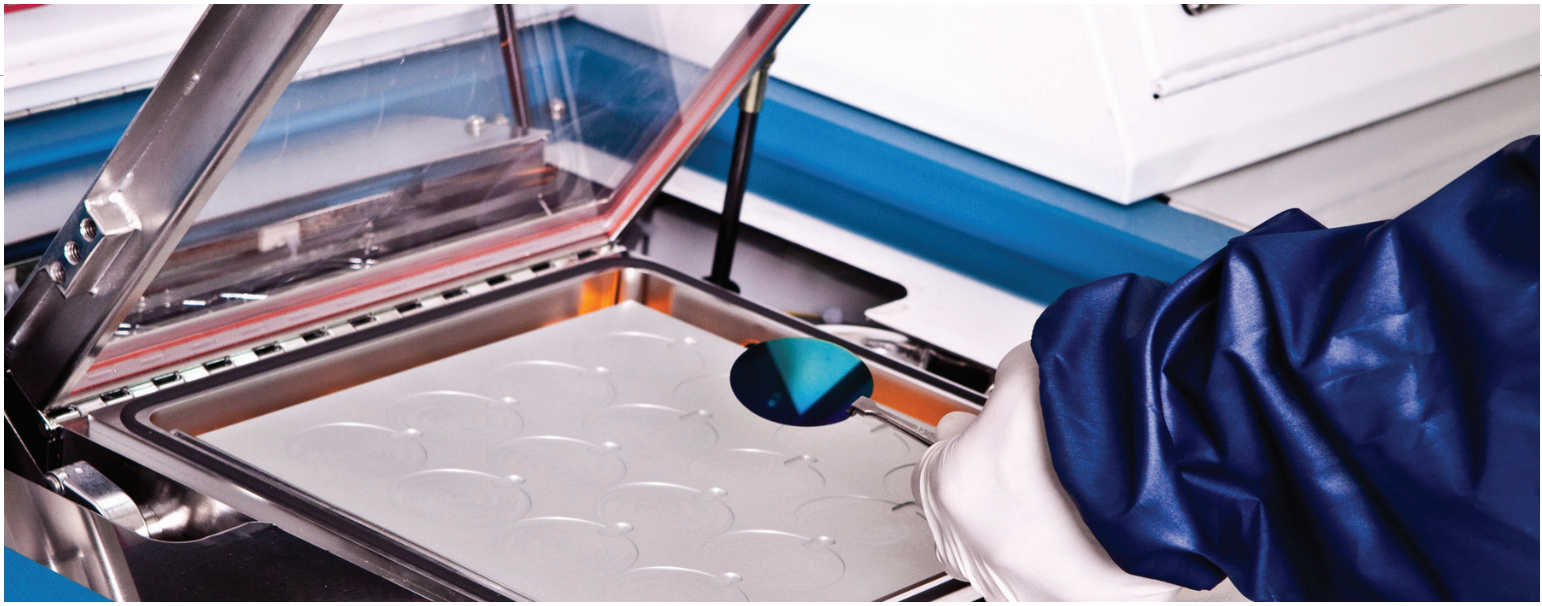
Low Temperature CVD (down to 80°C)

Excellent Step Coverage

No Radiation-Induced Damage

Low Particle Generation Reactor





The Photo-Enhanced CVD

The Tystar PVD 1000 is a low-pressure CVD reactor utilizing photo-enhanced processes for the low-temperature deposition of dielectric thin films, such as silicon dioxide (SiO_2), silicon nitride (Si_3N_4), and silicon oxynitrides. Tystar has made several improvements to enhance the performance of the new PVD 1000 reactor, resulting in higher deposition rates, lower base pressure, higher reliability, and reduced maintenance.

The main benefits of the PVD 1000 are:

- The photo-enhanced activation of the reactant gases permits film deposition at very low temperatures (75 – 250°C).
- The absence of electrically charged particles as encountered in plasma enhanced CVD processes eliminates radiation-induced damage to sensitive semiconductor devices.
- The low deposition temperature minimizes the thermally-induced stress in the deposited films that is caused by the mismatch in thermal expansion coefficients of substrate and deposited film.
- Excellent step coverage.

Process Reaction

The PVD 1000 Reactor uses a low pressure, 254 nm Ultraviolet (UV) light source and mercury vapor as sensitizer. The chemical reactions are:

$$Si_3N_4: \quad 3SiH_4 + 4NH_3 \xrightarrow[Hg]{h\nu} Si_3N_4 + 12H_2$$

$$SiO_2: \quad SiH_4 + 2N_2O \xrightarrow[Hg]{h\nu} SiO_2 + 2N_2 + 2H_2$$

Films with varying stoichiometric composition, such as oxynitrides, can be deposited simply by varying reactant gas ratios and/or the combination of gases, e.g. N_2O and NH_3.

Applications

Dielectric films deposited by photo-enhanced CVD have found numerous applications over the last decade:

- Opto-electronic Devices
- Solar Cells
- MIS Gate Dielectrics
- Hybrid Circuit Passivation
- Dielectric Films for Multilayer Interconnections
- Antireflective Coatings
- Low-Temperature Masking & Sacrificial Dielectric Films in Semiconductor Device Manufacturing
- Surface Passivation of III-V & II-VI compound semiconductor devices

Reactor Configuration

The PVD 1000 Reactor has one or two independent 316 Stainless Steel reactor chambers. The chambers are covered with a low-absorption quartz window for the IR-radiation of the substrates with UV light. A high-intensity UV grid lamp guarantees uniform substrate illumination. The substrates to be coated are loaded from the top onto a 10 x 10 in. (250 x 250 mm) heated substrate plate. All operator controls are placed on a control panel which includes a programmable touchscreen process controller (FCS 10/30), a microprocessor-based gas and pressure controller (MFS 460), chamber selection switch and temperature controllers for the substrate heaters. The DCS 30 host computer control and data collection system allows for recipe writing, storage, and downloading to the FCS 10/30, and also provides complete continuous data capture and graphical display of temperature, pressure, and gas flow.

The process controller permits automatic operation of pre-programmed recipes as well as manual operation. The MFS 460 gas control system activates and controls up to 6 independent gas flow loops with mass flow controllers. In addition, this unit performs system purge, system leak check and reactor chamber pressure readout. The temperature controllers are 3-mode PID controllers, assuring minimal temperature overshoot and accurate substrate temperature control.

For the reactant gases, mass flow controllers are used exclusively. VCR fittings and orbitally-welded 316L stainless steel joints guarantee the maximum leak integrity. All gas lines are electropolished (Ra 16 µin surface finish) for reduced particle generation and surface entrapment. Pneumatically-controlled bellows-sealed gas valves are used for reactant gas positive shut-off. 0.003 micron point-of-use filters are used for all reactant gas lines. All reactant gas lines are equipped with an additional pneumatic valve, permitting purging and/or evacuation. This is important for initial gas line conditioning, leak checking and safe equipment shutdown.

A distributed gas injector at the chamber's reactive gas inlet assures higher film uniformity across the entire load. Thickness uniformities better than 5% can be obtained.

The vacuum module assembly consists of a dry pump (Edwards iH80 or equivalent), 316 stainless steel pump manifold tubing with NW/KF flanges, pneumatically-operated gate valves, vacuum soft-start, pressure gauges (capacitance manometers at the chambers and a Pirani gauge at the pump inlet), particle/Hg traps, and closed-loop N_2 pressure control.

An optional corrosion-resistant turbo-molecular pump can be installed to reduce the reactor chamber base pressure into the 10^{-6} Torr range. This provides higher quality and more controllable deposition for films sensitive to oxygen and water in the background. A Penning gauge permits the reading of pressures into the 10^{-7} Torr range.

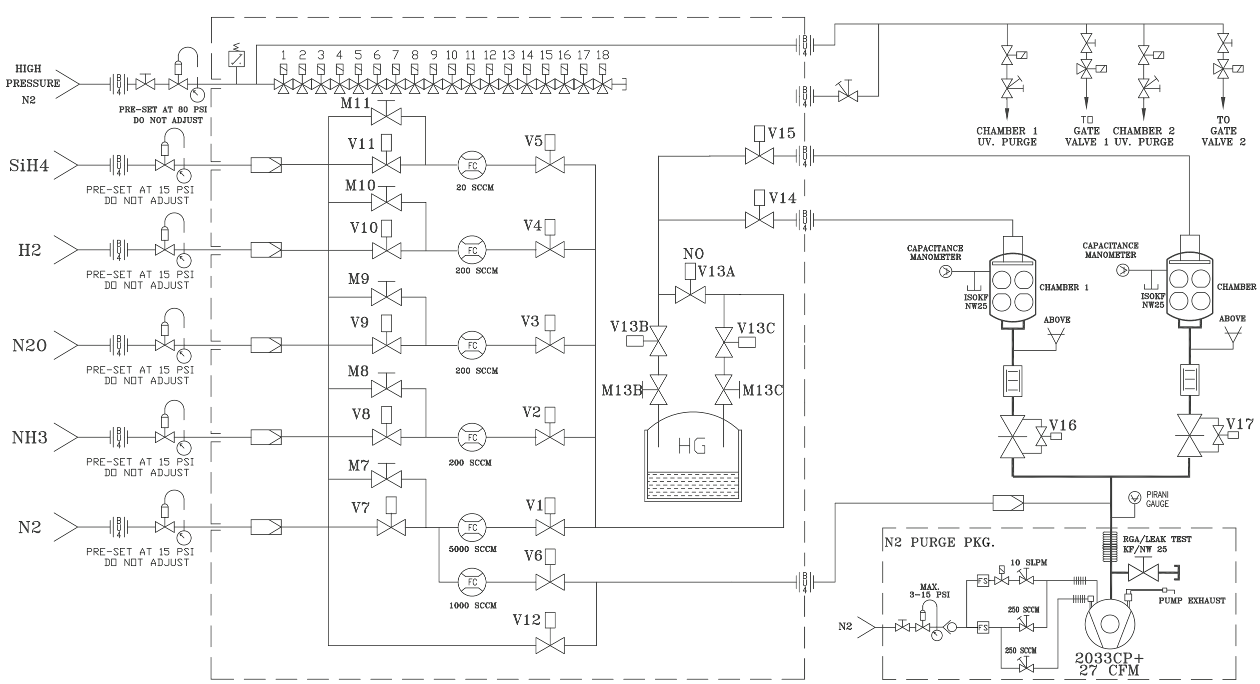
Reactant Gas / Exhaust Requirements

PVD 1000 requires high-quality reactant gases for satisfactory operation. It is recommended to use only semiconductor grade or electronic grade gases. The PVD 1000 operates typically with a SiH4 flow of only 2 sccm. The unreacted gases are diluted in the vacuum pump exceeding a 40:1 ratio, which simplifies the disposal of the pump exhaust line. The exhaust gases are further diluted with air and vented through a 100 cfm blower, resulting in a 25000:1 exhaust dilution.

PVD 1000 Process Data	Si_3N_4	SiO_2
Thickness Uniformity Across Substrate	< ±8%	< ±5%
Thickness Repeatability	< ±5%	< ±3%
Deposition Rate (150ºC, 1 Torr)	60 Å/min.	120 Å/min.
Cycle Time (1500Å)	55 min.	45 min.
Substrate Temperature	50 - 250ºC	50 - 250ºC
Reactor Pressure	0.3 - 0.5 Torr	0.3 - 1 Torr

PVD 1000 Film Characteristics (TYPICAL DATA)	Si_3N_4	SiO_2
Film Density	1.8 - 2.4 g/cm^3	2.10 g/cm^3
Refractive Index	1.8 - 2.0	1.45 - 1.48
Dielectric Constant	5.5	3.9
Dielectric Strength	4 x 10^6 V/cm	6 x 10^6 V/cm
Particle Density	< 10/cm^2	< 10/cm^2
Film Adhesion (Tension)	7 x 10^6 Pa	70 x 10^6 Pa
Etch Rate	60 - 100 Å/sec. in 1:10HF	90 Å/sec. in B.O.E.

Gas Flow Diagram



Safety Features & Interlock

The PVD 1000 is designed for safe operation and operator protection.

Gas Leak Integrity

The gas control system incorporates interlocks which shut off reactant gas flow in the event of leaks or if N_2 blanket purge flow rate drops below 500 sccm. (A N_2 purge blanket is installed for the high intensity UV lamps to prevent ozone generation.) All gas control components are mounted in a sealed steel enclosure vented to an exhaust line.

Chamber Interlocks

The reactor chambers are interlocked with the reactant gas flow controls and the UV light source. The chamber cannot be opened if either one is activated.

Pump Exhaust

N_2 is injected into the pump at high flow rates to dilute any residual, unreacted gas to a safe level for disposal. 316 stainless steel pump exhaust lines are used for safety.

Mercury Vapor Control

A minute amount of mercury vapor is used in the PVD as photo-sensitizer. The mercury reservoir is enclosed in a hermetically-sealed, transparent DURAN® glass container which permits visual inspection of the Hg surface. The container is coated with a transparent, resilient plastic coating for operator safety.

The mercury container assembly includes shut-off valves and connecting fittings. The NW/KF 40 flange permits easy disassembly and cleaning of the container. Residual mercury vapor in the reactor chamber is removed by several purge cycles before the reactor chamber can be opened for unloading and loading.

Reactor Specifications

Dimensions / Weight

Height	41 in. / 1041 mm
Depth	28 in. / 711 mm
Width	81 in. / 2057 mm
Weight	970 lbs. / 427 kg

Gas Supplies

Reactant Gases

Fittings: 1/4” Metal Face Seals (VCR)

SiH_4	20 sccm / 15 psi
NH_3	200 sccm / 20 psi
N_2O	200 sccm / 20 psi

Reactant Gases

Fittings: 1/4” Compression Nut & Ferrule

N_2	5 slpm / 40 psi
Auxil. N_2	80 psi

Electrical Power

Input Power

208 / 220 VAC, 3 Phase, 40 A, 60 Hz

220 / 380 VAC 3 Phase, 25 A, 50 Hz

Exhaust Requirements

Connections

3” O.D. Tube Stub for Gas Box Exhaust

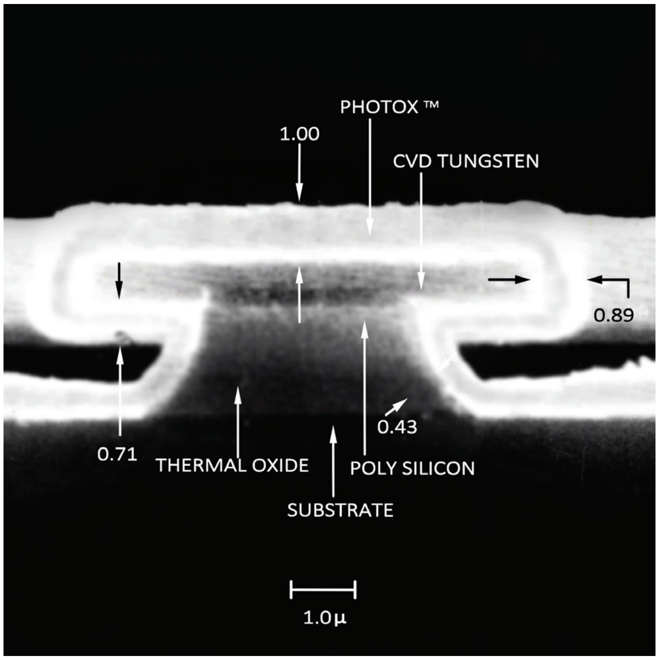
1.5in. NW/KF 40 Flange for Pump Exhaust

Exhaust Blower

100 cfm

Step Coverage

One of the characteristics of a good semiconductor film, alongside sparsity of pin holes, is conformal step coverage. A smooth and conformal film similar to the SiO_2 film in the SEM image shown below ensures minimal electromigration and resistant pathways. This is one of the benefits of using a PVD-1000 system in thin film deposition.



New Features

Adhering to our policy of unceasing improvement, Tystar has recently implemented a large number of new features. Some of the highlighted changes made to the system are:

General Improvements

- Dovetail groove to hold the o-ring in place for tighter vacuum seal
- Improved surface substrate plate finish and wafer pick-up recesses

Temperature Control

- Dual thermocouple temperature control
- Closed loop temperature control of the mercury bubbler for enhanced process stability
- Special type thermocouple bonded to a wafer for real-time temperature reading

Gas Flow

- Redesigned gas injector for smooth laminar flow across the substrate plate
- Vacuum manifold design upgrade to laminate gas flows inside the chamber
- Side rails to improve gas flow and suppress deposition on the chamber walls

UV Lamps

- Closed loop control of the spectral UV lamp power for accurate and stable process temperature
- UV probe inserted through the chamber for direct UV measurements

References

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The PVD 1000 is manufactured under license from Hughes Aircraft Company, El Segundo, CA

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