DECEMBER 2019

Application Solutions Guide

THIN FILM API PRODUCTION

Experience In Motion

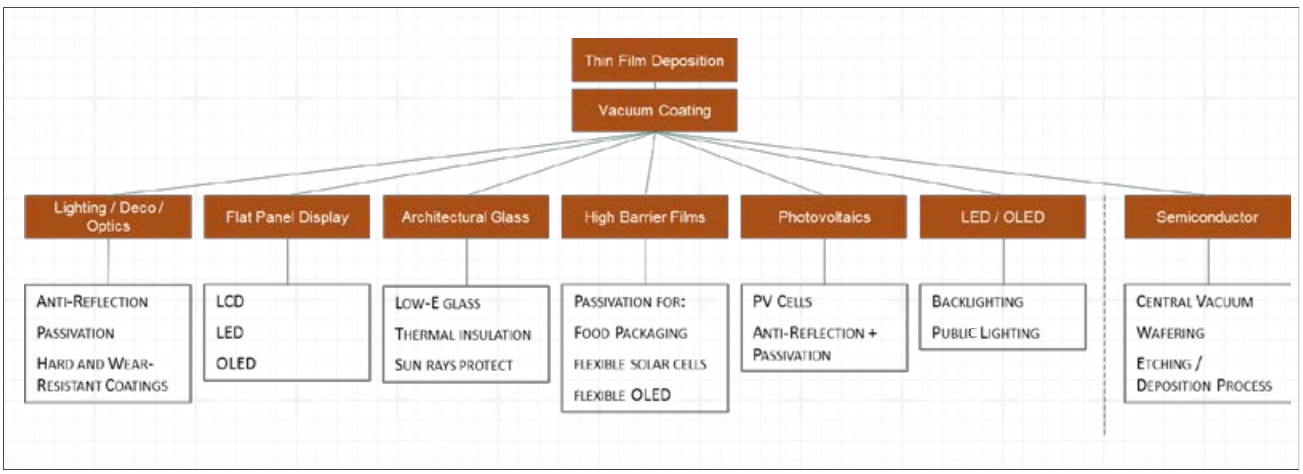
TABLE OF CONTENTS

GLOBAL THIN FILM LANDSCAPE

Overview

Thin film semiconductors are the foils fabricated from artificial semiconductor materials, with thicknesses ranging from nanometers to several hundred millimeters. The demand for thin film semiconductors has increased in recent years due to advantages such as higher efficiency, low weight, less space consumption, and shape flexibility compared to conventional silicon (c-Si). They are widely used in various applications such as solar photovoltaic panels, dynamic random access memories (DRAMs), microprocessors and wearable technologies, among others. Moreover, emerging technologies such as AMOLED display, flexible OLED displays and EMES, among others, make use of thin film semiconductors.

Figure 1: Overview of thin film deposition applications



A Closer Look at Thin Film Applications

Optical Coating

An optical coating is one or more layers of material deposited on an optical component such as a lens or mirror, which alters the way in which the optic reflects and transmits lights. One type of optical coating is an antireflection coating, which reduces unwanted reflections from surfaces; it is commonly used on spectacle and photographic lenses. Another type is high-reflector coating, which can be used to produce mirrors that reflect greater than 99.99% of the light which falls on them. More complex optical coatings exhibit high reflection over a range of wavelengths and anti-reflection over another range, allowing the production of dichroic thin-film optical filters.

Photovoltaic

In the familiar rigid solar panel, the energy of incoming photons is converted to electricity in cells containing two thin layers of crystalline silicon. What makes roll-to-roll production of flexible film solar products possible is the replacement of crystalline silicon with amorphous silicon, supplied in high-solids slurries that can be deposited onto substrates by web-converting processes like slot die coating. Microlayer film such as EDI can outfit its contour cast film dies with a new system, based on a technology license.

Semiconductor

Historically, the semiconductor industry has relied on flat, two-dimensional chips upon which to grow and etch the thin films of material that become electronic circuits for computers and other electronic devices. This thin layer (only a few nanometers thick) can be transferred to glass, plastics or other flexible materials, opening a wide range of possibilities for flexible electronics. In addition, the semiconductor film can be flipped as it is transferred to its new substrate, making its other side available for more components. This doubles the possible number of devices that can be placed on the film. By repeating the process, layers of double-sided, thin film semiconductors can be stacked together, creating powerful, three-dimensional electronic devices.

For non-computer applications, flexible electronics are beginning to have significant impact. Solar cells, smart cards, radio frequency identification (RFID) tags, medical applications and active-matrix, flat-panel displays could all benefit from the development. Techniques could allow flexible semiconductors to be embedded in fabric to create wearable electronics or computer monitors that roll up like a window shade.

Flat-Panel Displays

The flat-panel display (FPD) fabrication environment is among the world's most competitive and technologically complex. Device designers and manufacturers continually strive to satisfy worldwide consumers' appetites for larger displays, greater pixel resolution and feature-rich performance, all at a lower cost than the previous technology generation. The need to control contamination in air, gas and liquid process streams is now a paramount focus of process engineers and designers.

THIN FILM DEPOSITION PROCESSES

The vast varieties of thin film materials, their deposition processing and fabrication techniques, spectroscopic characterization and optical characterization probes are used to produce the devices. It is possible to classify these techniques in two ways:

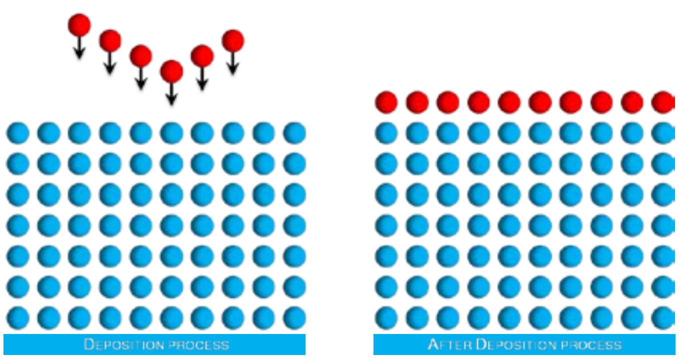
- Physical process
- Chemical process

The physical method covers the deposition techniques, which depend on the evaporation or ejection of the materials from a source, i.e., evaporation or sputtering, whereas chemical methods depend on physical properties. Structure property relationships are the key features of such devices and the basis of thin film technologies. Underlying the performance and economics of thin film components are the manufacturing techniques on a specific chemical reaction. Thus, chemical reactions may depend on thermal effects, as in vapor phase deposition and thermal growth. However, in all these cases, a chemical reaction is required to obtain the final film.

There are two classes of film deposition by chemical methods:

- Chemical formation of the film from medium. Typical methods involved are electroplating, chemical reduction plating and vapor phase deposition.
- Formation of the film from precursor ingredients such as iodization, gaseous iodization, thermal growth, sputtering ion beam implantation, vacuum evaporation and chemical vapor deposition.

Figure 2: Thin film deposition



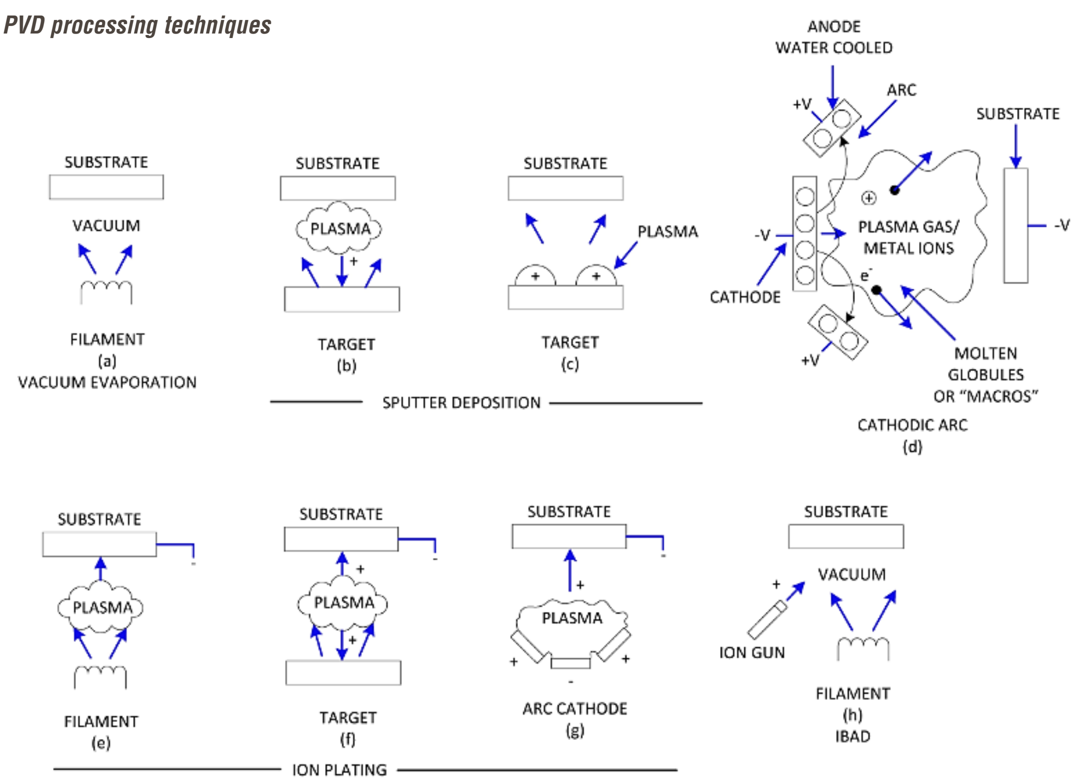
Physical Vapor Deposition (PVD) Process

PVD processes (often referred to as *thin film processes*) are atomistic deposition processes in which materials are vaporized from a solid or liquid source in the form of atoms or molecules and transported in the form of a vapor through a vacuum or low-pressure gaseous (or plasma) environment to the substrate, where it condenses. Typically, PVD processes are used to deposit films with thicknesses in the range of a few to thousands of nanometers; however, they can also be used to form multilayer coatings, graded composition deposits, very thick deposits and freestanding structures. The substrates can range in size from very small to very large, e.g., the 10’ x 12’ glass panels used for architectural glass. The substrates can range in shape from flat to complex geometries such as watchbands and tools bits. Typical PVD deposition rates are 10–100 Å (1–10 nanometers) per second.

PVD processes can be used to deposit films of elements and alloys as well as compounds using reactive deposition processes. In reactive deposition processes, compounds are formed by the reaction of the depositing materials with the ambient gas environment such as nitrogen (e.g., titanium nitride, TiN) or a co-depositing material (e.g., titanium carbide, TiC). Quasi-reactive deposition is the deposition of films of a compound material from a compound source where loss of the more volatile or less reactive species during the transport or condensation process is compensated for by having a partial pressure of reactive gas in the deposition environment, e.g., the quasi-reactive sputter deposition of ITO (indium-tin oxide) from an ITO sputtering target using a partial pressure of oxygen in the plasma.

The main categories of PVD processing are vacuum deposition (evaporation), sputter deposition, vapor deposition and ion plating, as shown in Figure 3.

Figure 3: PVD processing techniques



Vacuum Deposition (Vacuum Evaporation)

Vacuum deposition, which is sometimes called *vacuum evaporation*, is a PVD process in which materials from a thermal vaporization source reach the substrate with little or no collision with gas molecules in the space between the source and substrate. The trajectory of the vaporized material is “line of sight”. The vacuum environment also provides the ability to reduce contamination from gases in the deposition system to a low level. Typically, vacuum deposition takes place in the gas pressure range of 10^{-5} to 10^{-9} torr, depending on the level of gaseous contamination that can be tolerated in the deposition system. The thermal vaporization rate can be very high compared to other vaporization methods. The material vaporized from the sources has a composition proportional to the relative vapor pressures of the material in the molten source material. Thermal evaporation is generally done using thermally heated sources such as tungsten wire coils or a high-energy beam (e-beam) heating the source material itself. Generally, the substrates are mounted at an appreciable distance away from the evaporation source to reduce radiant heating of the substrate by the vaporization source.

Vacuum deposition is used to form optical interference coatings, mirror coatings, decorative coatings, permeation barrier films on flexible packaging materials, electrically conducting films, wear-resistant coatings and corrosion-protective coatings.

Sputtering

Sputtering deposition is the deposition of particles vaporized from a surface ("target") by the physical sputtering process. Physical sputtering is a non-thermal vaporization process where surface atoms are physically ejected from a solid surface by momentum transfer from an atomic-sized energetic bombarding particle, which is usually a gaseous ion, accelerated from a plasma. This PVD process is sometimes just called *sputtering*, i.e., "sputter films of particulate," an improper term because the film is not sputtering. Generally, the source-to-substrate distance is short compared to vacuum deposition. Sputter deposition can be performed by energetic ion bombardment of a solid surface (sputtering target) in a vacuum using an ion gun or low-pressure plasma (<5 m torr) where the sputtered particles suffer few or no gas phase collisions in the space between the target and the substrate.

Sputtering can also be done in a higher plasma pressure (5–30 m torr) where energetic particles sputtered or reflected from the sputtering target are "thermalized" by gas phase collisions before they reach the substrate surface. The plasma used in sputtering can be confined near the sputtering surface or may fill the region between the source and the substrate. The sputtering source can be an element, alloy, mixture or a compound; the material is vaporized with the bulk composition of the target. The sputtering target provides a long-lived vaporization source that can be mounted and vaporized in any direction. Compound materials such as TiN and zirconium nitride (ZrN) are commonly "reactively sputter deposited" by using a reactive gas in the plasma. The presence of the plasma "activates" the reactive gas ("plasma activation"), making it more chemically reactive.

Sputter deposition is widely used to deposit thin film metallization on semiconductor materials, coating on architectural glass and reflective coatings on compact discs (CDs), and for magnetic films, dry film lubricants, hard coating (tools, engine parts) and decorative coatings.

Ion Plating

Ion plating, which is sometimes called *ion-assisted deposition* (IAD) or *ion vapor deposition* (IVD), utilizes concurrent or periodic bombardment of the depositing film by atomic-sized energetic particles to modify and control the properties of the depositing film. In ion plating, the energy, flux and mass of the bombarding species along with the ration of bombarding to depositing particles are important processing variables. The depositing material may be vaporized by evaporation, sputtering, arc erosion or the decomposition of a chemical vapor precursor.

The energetic particles used for bombardment are usually ions of an inert or reactive gas, or in some cases, ions of the condensing film materials ("film ions"). Ion plating may be done in a plasma environment where ions for bombardment are extracted from the plasma, or it may be done in a vacuum environment where ions for bombardment are formed in a separate "ion gun". The latter ion plating configuration is often called *ion beam-assisted deposition* (IBAD). By using a reactive gas in the plasma, films of compound materials can be deposited. Ion plating can provide dense coatings at relatively high gas pressures where gas scattering can enhance surface coverage.

Ion plating is used to deposit hard coatings of compound materials, adherent metal coatings, optical coatings with high densities and conformal coatings on complex surfaces.

Chemical and Electrochemical Methods

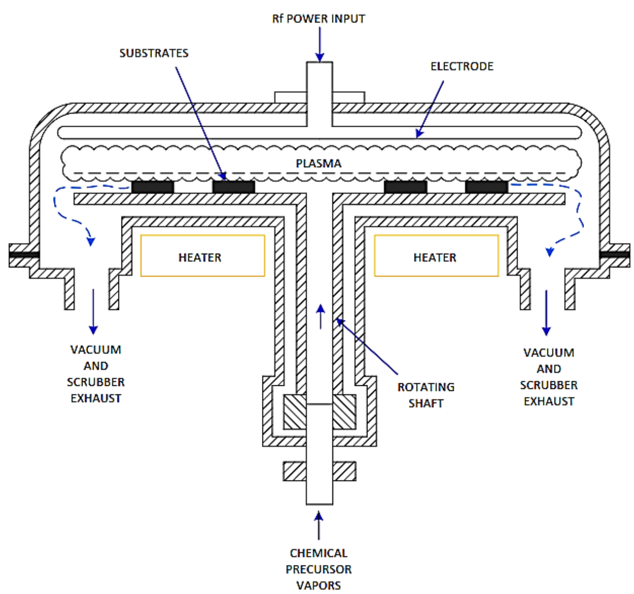
Among chemical and electrochemical methods, the most important are chemical vapor deposition, cathode electrolytic, anodic oxidation and chemical bath deposition.

Chemical Vapor Deposition (CVD)

Thermal chemical vapor deposition, or *vapor plating*, is the deposition of atoms or molecules by the high-temperature reduction or decomposition of a chemical vapor precursor species, which contains the material to be deposited. Reduction is normally accomplished by hydrogen at an elevated temperature. Decomposition is accomplished by thermal activation. The deposited material may react with other gaseous species in the system to give compounds (e.g., oxides, nitrides). Chemical vapor deposition processing is generally accompanied by volatile reaction by-products and unused precursor species. CVD has numerous other names and adjectives associated with it, such as *vapor phase epitaxy* (VPE) when CVD is used to deposit single crystal films; *metalorganic CVD* (MCVD) where the precursor gas is a metalorganic species; *plasma-enhanced CVD* (PECVD) where a plasma is used to induce or enhance decomposition and reaction; and *low-pressure CVD* (LPCVD) when the pressure is less than ambient.

Plasmas may be used in CVD reactors to “activate” and partially decompose the precursor species. This allows deposition at a temperature lower than thermal CVD. This process is called *plasma-enhanced CVD* (PECVD) or *plasma-assisted CVD* (PACVD). The plasmas are typically generated by radio frequency (rf) techniques. Figure 4 shows a parallel plate CVD reactor that uses rf power to generate the plasma. This type of PECVD reactor is in common use in the semiconductor industry to deposit silicon nitride (SI_3N_4) and phosphosilicate glass (PSG), encapsulating layers a few microns thick with a deposition rate of 5–100 nm/min. At low pressure, concurrent energetic particle bombardment during deposition can affect the properties of films deposited by PECVD.

Figure 4: Parallel plate plasma-enhanced chemical vapor deposition (PECVD) reactor



Plasma-based CVD may also be used to deposit polymer films (plasma polymerization). In this case, the precursor vapor is a monomer that becomes cross-linked in the plasma and on the surface to form an organic or inorganic polymer film. These films have very low porosity and excellent surface coverage. When plasma-depositing films form organo-silane precursors, oxygen can be added to the plasma to oxidize some of the silicon in the film.

Chemical Bath Deposition

Among the chemical methods of thin film deposition, *chemical bath deposition* (CBD) is probably the simplest method available for this purpose. It is also known as *chemical solution deposition* (CSD) or *chemical deposition* (CD). The only requirements of these methods are a vessel to contain the solution (usually an aqueous solution of common chemicals) and the substrate on which deposition is to be carried out. In addition to this, a mechanism for stirring and a thermostated bath to maintain a specific and constant temperature are options that may be useful.

Arrested Precipitation Technique

Arrested precipitation technique (APT) is a modified chemical bath deposition process. APT is a simple and inexpensive method used for the deposition of a wide variety of metal chalcogenide thin films. APT can be distinguished from other conventional techniques as follows:

- It is ideally suited for large-area, thin film deposition; substrate surface of both accessible and non-accessible nature could easily be deposited.
- It is simple, inexpensive and does not require sophisticated instrumentation.
- The deposition is usually at low temperature and avoids oxidation or corrosion of the metallic substrates.
- Stoichiometry of the deposits can be maintained, since the basic building blocks are ions, rather than atoms.
- Slow film formation process facilitates better orientation of the crystallites with improved grain structures over the substrate surface.
- Dope and mixed films could be obtained by merely adding the mixant/dopant solution directly into the reaction bath.
- Electrical conductivity of the substrate materials is not an important criterion.
- An intimate contact between reacting species and the substrate's material permits pinhole-free and uniform deposits on the substrates of complex shapes and sizes.
- Wide varieties of conducting/non-conducting substrate materials can be used.
- The dissociation rate of organometallic complex to release free metal ions for reaction is controlled well by maintaining the pH of the reacting solution.

Anodic Oxidation

Anode oxidation is used mainly in the formation of films of the oxides of certain metals, e.g., Al, Ta, Nb, Tu and Zr. The oxidized metal is an anode dipped in the electrolyte from which it attracts the oxygen ions. The ions pass through the already formed oxide film by diffusion forced by a strong electric field and combine with metallic atoms to form molecules of the oxide. For anode oxidation, it is possible to use either the constant current or voltage method. Solutions or melts of various salts (or in some cases, acids) are used as electrolytes. This is an electrolytic method for producing oxide films on the surface of the metal.

Cathodic Deposition

This is a standard method of electroplating. Two metal electrodes are dipped into an electrolyte solution, and on the application of an external field across the electrodes, metal ions from the solution are deposited on the cathode as a film. Deposition of the films is mainly controlled by electrical parameters such as electrode potential and current density. The mass of the substance deposited is proportional to the amount of electrical charge.

THE THIN FILM INDUSTRY-FLOWSERVE INTERFACE

The Flowserve Fit in the Thin Film Industry

Flowserve, through our global presence and chemical capabilities, has the distinct advantage of being a one-stop supplier of process equipment needed in the thin film industry. We have the unique opportunity to provide an array of products and services ranging from pumps and precision mechanical seals to control and manual valves.

Competition in the thin film industry is extremely steep and challenging. Critical success factors are linked to price, quick response to field service requests with short delivery supported by the right level of inventories as a primary requirement to support the fast turnaround requisite.

Products for the Thin Film Industry — At a Glance

There are many different processes and project scales for a thin film manufacturer. The products which Flowserve caters to in the thin film industry will vary accordingly. At a high level, Flowserve products and services offerings for thin film applications can be categorized as follows:

Pumps

A variety of pumps and pumping applications is found in the thin film industries in the various production process. Therefore, there is a wide range of high-quality pumps to cater to most of the needs for thin film applications. Key among them are:

Vacuum Systems:

- Single-Stage
  - Dry Running Screw Booster Vacuum Pump
    - SIHI*boost*
      - SIHI*boost* CA (3500, 5000, 6500, 8000)
    - SIHI*dry*
      - Compact Design – SIHI*dry* CD S/SIHI*dry* CD V (S160, S400, S630, S1000 and V250, V400
      - General Design – SIHI*dry* GD S/SIHI*dry* GD V (S160, S400, S630, S1000 and V250, V400)
- Dual-Stage
  - Compact Design
    - Dry Running Screw Booster Vacuum Pump With Dry Running Screw Vacuum Backing Pump
      - SIHI*boost* CD (3500, 5000, 6500, 8000)
    - Dry Running Screw Booster Vacuum Pump With Liquid Ring Vacuum Backing Pump Fitted With Single Seals
      - SIHI*boost* CL (3500, 5000, 6500, 8000)
  - Modular Design
    - Dry Running Screw Booster Vacuum Pump With Liquid Ring Vacuum Backing Pump
      - SIHI*boost* GL (3500, 5000, 6500, 8000)

Valves

In thin film application plants, the more commonly used valves include:

- Ball
- Butterfly
- Diaphragm

In addition, the valves for the thin film industry need to be of ultra-high purity due to clean room requirements. The valves in the thin film industry are both plastic and metal, mostly 316L stainless steel. The interval valve surface finish in the thin film industry uses 5RA as a standard, and the valves are manufactured in an ISO Class 3 clean room. Stainless steel's corrosion resistance results from a protective passive film on the surface.

Valves manufactured in a clean room must be suitable and rated (pressure, temperature or caustic capable) for clean-in-place (CIP) or sterilization-in-place (SIP). These valves are also made to be self-draining and without threads or any crevice on any wetted surfaces. This is done to prevent any 'hold-up' volume of water, condensate or process fluid, thus eliminating places for bacteria to grow.

The thin film industry uses ultra-pure water in its processes. The valves in such processes are made of Polyvinylidine fluoride (PVDF) and are usually on/off and pressure relief in the size of ½ to 12 inches. Most of the valves supplied to this market are manually operated instead of actuated. The valves for ultra-pure water applications are either diaphragm or butterfly types. They are manufactured in a clean room and then double-bagged. Once in operation, the valves are sterilized with chemical or in a clean-in-place process hotter than 200°F. Thin film manufacturing plants also use stainless steel valves for their gas lines.

Seals

The majority of the pumps used in the thin film industry are vacuum pumps. Flowserve has different combinations to serve this market, depending on a customer's use requirements, e.g., a liquid ring vacuum pump in combination with SIHI*boost*. Flowserve liquid ring vacuum pumps use a mechanical seal to seal the system. Liquid ring vacuum pumps have a high potential, especially in very harsh and high particle-loaded PECVD processes. This is SIHI's core competence for more than 80 years as a leading supplier of liquid ring vacuum pumps, with a wide range of process and related markets. But most thin film customers are quite unsure about the liquid in their pump, possible effects on their processes and of their final product quality. As for the usual vacuum pumps, there are no mechanical seals used to seal the pumps.

More details can be obtained from the Commercial Ops team when required.

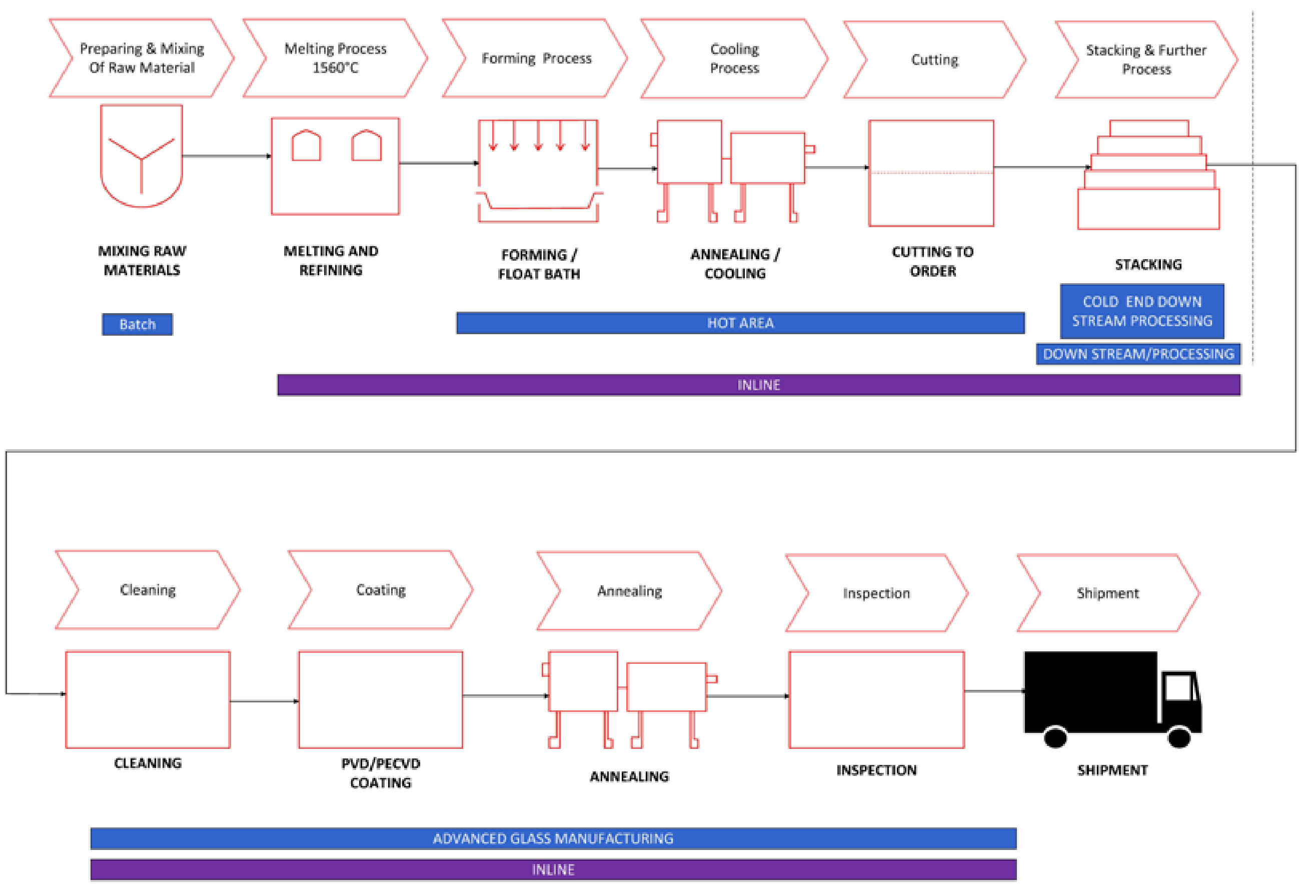
FLOWSERVE OPPORTUNITIES IN THE THIN FILM INDUSTRY

Overview

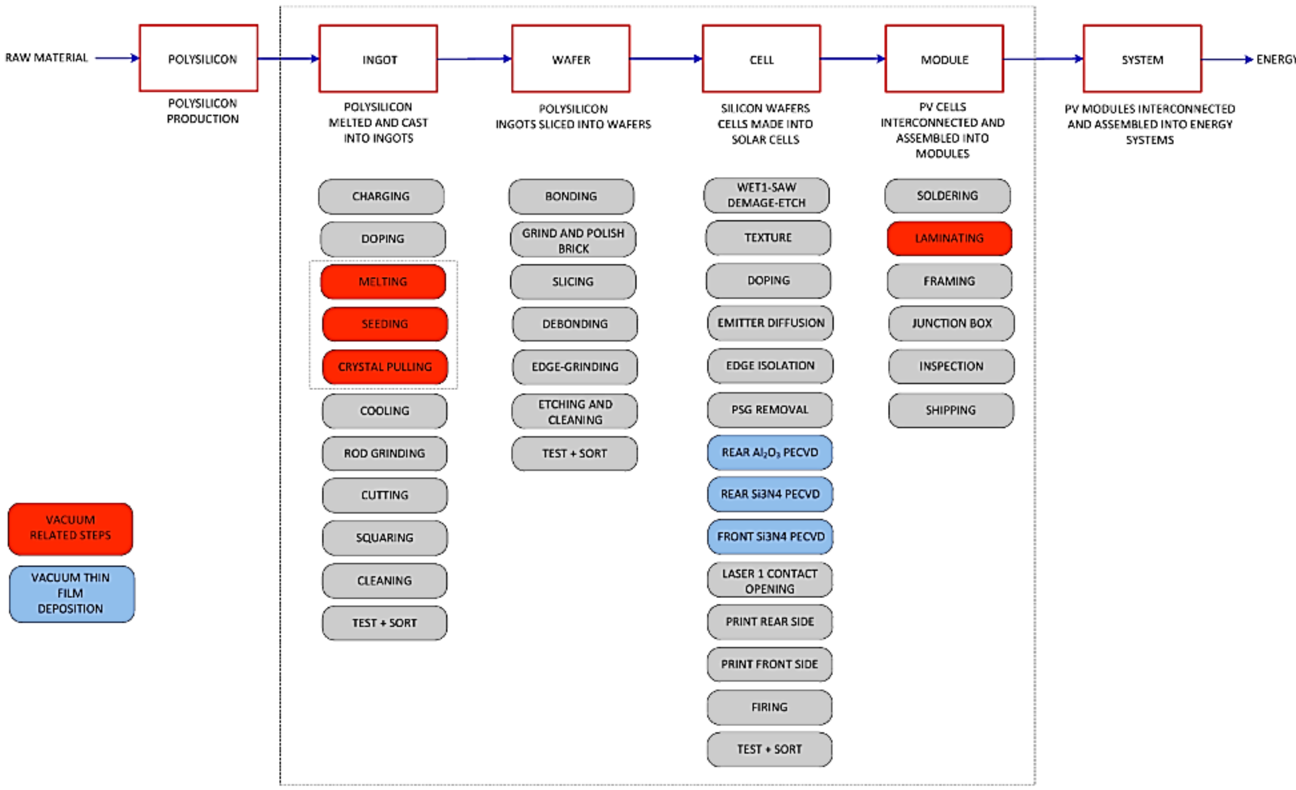
In general, the basics of the thin film application process have been broadly explained in earlier sections. The thin film application process is a subset of many high-technology manufacturing industries such as flat-panel display, architecture glass, LED/OLED, semiconductors, photovoltaics, etc.

Below are some examples of thin film applications:

Architecture glass process



Photovoltaic — Crystalline Silicon Process



Products

Pumps

Single-Stage Vacuum System

SIHI*boost* screw booster vacuum pumps have been developed for the requirements of booster pumps in fine vacuum pressure industrial applications. Offering a high compression ratio allows significantly lower backing pump capacity.

Deep process pressure as well as load lock applications can be realized with almost every backing pump technology, like liquid ring and claw vacuum pumps.

This pump offers the following unique features:

- Handling of gases and condensable vapors
- Optimized for process and load lock applications
- Capable of handling solid carryover
- Entirely oil-free operation
- Simple to maintain
- Highly reliable
- Low noise and vibration
- Condition monitoring option adaptable

SIHI*boost* CA (Size 3500, 5000, 6500, 8000)

Pressure Range:	<0.001 to 1010 mbar 0.00075 to 760 torr
Suction Speed:	2800 to 5700 m^3/h 1648 to 3649 cfm

SIHI^{dry} vacuum systems' compact design has been especially developed for use in industrial applications. It is based upon a dry running, twin-screw principle working as a single-stage vacuum pump.

The pump offers the following unique features:

- No wear parts/contact-free shaft sealing
- Low ultimate pressure with only one-stage vacuum pump
- High resistance regarding particles due to big gaps and top-down flow
- Very silent operation
- Lowest vibration level
- Absolutely free of oil/no gear oil
- Plug and pump for shortest commissioning
- Condition monitoring
- Pre-failure detection
- Disassembly and assembly of the pump chamber can be done in situ by one's own staff members

The compact design of SIHI^{dry} CD vacuum systems has been especially designed for users' optimized handling and connection. With its superior and fully integrated control, SIHI Control offers:

- Autonomous supervision and control of all integrated actors and sensors
- Local control via HMI touch interface
- Condition monitoring options adaptable

The SIHI^{dry} S-Version has been designed to perform maximum pumping speed at atmospheric pressure. This offers fast volume evacuation coming from a higher pressure.

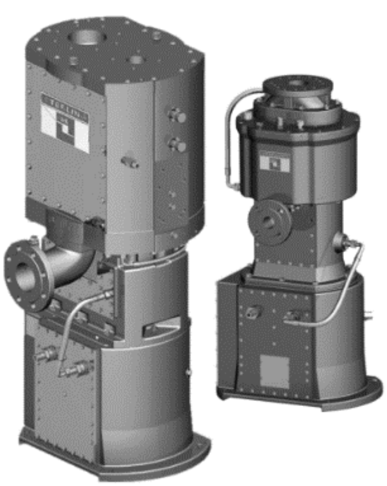
The SIHI^{dry} V-Version has been designed to perform at a high pumping speed at low suction pressure at the lowest power consumption. This offers the lowest cost of ownership.

The SIHI^{dry} vacuum pump is completely dry running and has no mechanical shaft seals.

SIHI^{dry} CD S/V
(Size S160, S400, S1000 and V250, V400)

Pressure Range: <0.001 to 1013 mbar
0.00075 to 760 torr

Suction Speed: 160 to 1000 m^3/h
94 to 588 cfm



SIHI^{dry} GD S/V
(Size S160, S400, S1000 and V250, V400)

Pressure Range: <0.001 to 1013 mbar
0.00075 to 760 torr

Suction Speed: 160 to 1000 m^3/h
94 to 588 cfm

Dual-Stage Vacuum System

The SIHI*boost* CD vacuum system has been developed for the requirements of industrial applications in a fine vacuum pressure range. The compact skid consists of a SIHI*boost* screw booster vacuum pump combined with a SIHI*dry* dry running backing pump.

Offering a high compression ratio allows significantly lower backing pump capacity.

SIHI*boost* CL vacuum systems have been developed for the requirements of industrial applications in a fine vacuum pressure range. The compact skid consists of a SIHI*boost* screw booster vacuum pump combined with a liquid ring vacuum backing pump.

Particles from process carryover are washed out in the liquid ring vacuum pump, which acts like a scrubber in order to provide a pre-cleaned discharge flow.

The compact design of SIHI*boost* CD/CL vacuum systems has been especially designed for user-optimized handling and connection. With its superior and fully integrated control, SIHI Control offers:

- Autonomous supervision and control of all integrated actors and sensors
- Local control via HMI touch interface
- Condition monitoring
- Pre-failure detection

SIHI*boost* CD (Size 3500, 5000, 6500, 8000)

Pressure Range: <0.0008 to 1013 mbar
0.0006 to 760 torr

Suction Speed: 2800 to 5900 m^3/h
1648 to 3472 cfm

SIHI*boost* CL (Size 3500, 5000, 6500, 8000)

Pressure Range: <0.004 to 1013 mbar
0.0023 to 760 torr

Suction Speed: 2700 to 5700 m^3/h
1589 to 3354 cfm

SIHI*boost* GL vacuum systems have been developed for the requirements of industrial applications in a fine vacuum pressure range. The modular skid consists of a variable amount of SIHI*boost* screw booster vacuum pumps combined with a liquid ring vacuum backing pump.

Particles from process carryover are washed out in the liquid ring vacuum pump, which acts like a scrubber in order to provide a pre-cleaned discharge flow.

SIHI*boost* GL vacuum systems mechanically combine independent components to offer optimized modular solutions matching your actual process requirements.

- Selection of the most efficient pump combination is always targeted on actual process requirements
- Providing a modular framework offers even easier future adaptation to the vacuum system to be always aligned on improved process requirements

The dual-stage system solution offers the following unique features:

- Handling of gases and condensable vapors
- Optimized for process applications
- Capable of handling solid carryover
- Entire dry and oil-free operation
- Simple to maintain
- Highly reliable
- Low noise and vibration

SIHI*boost* GL (Size 3500, 5000, 6500, 8000)

Pressure Range:	<0.0023 to 1013 mbar <0.0023 to 760 torr
Suction Speed:	2700 to 5700 m^3/h 1589 to 3354 cfm

Key Advantages for Flowserve

SIHI*boost*

Effective Technical Solutions for Inline Coating

Faster pump-down time on load lock chambers as well as the reliable handling of process gas mixtures that can cause buildup in vacuum pumps are growing demands in the coating industry. Multistage combinations of roots-blowers and either oil-sealed or dry backing pumps are currently used in these markets. These combinations struggle to satisfactorily fulfill the increasing demand.

SIHI focused its latest development on precisely those demands and presents a new pump concept: the SIHI*boost*. This unique pump concept:

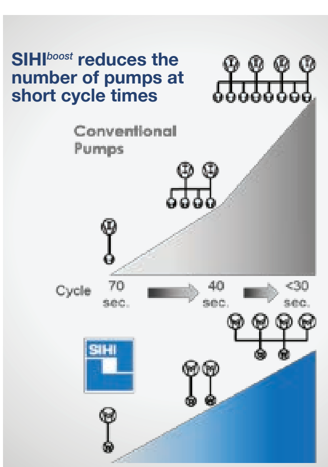
- Reduces the load-lock, pump-down time by half, while utilizing a backing pump, which is downsized by a factor of five
- Utilizes the most rugged backing pump the process industry has known for 1000 years. The liquid ring vacuum pump (LRVP) is legendary for its safe handling of solid carryover.

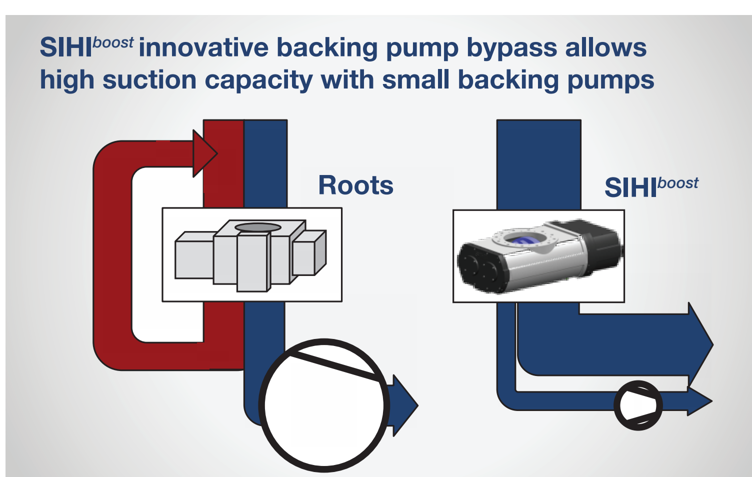
For Short Cycle Load-Locks

Roots-type blowers are designed for operating at low pressure. Higher pressure differential leads to overheating and consequently to seizure of the rotors on the housing. Therefore, passing through the rough vacuum phase during pump-down cycles as required while operating a load-lock can only be handled via a significant performance reduction. This is usually done by a bypass valve that recycles compressed gas back to the inlet, causing massive inefficiency for the sake of protecting the blower from overheating. During that phase, the effective performance on the load-lock is little more than the capacity of the backing pump — an energy waste that does not contribute to cycle time improvement as long as the chamber pressure is higher than 80 torr.

Shortening the cycle time with conventional roots-type blowers results in larger or more backing pumps, which worsen energy efficiency and maintenance costs as well as create a larger footprint. Operating cost increases with extended downtime.

SIHI*boost* enables the direct discharge to the atmosphere from the moment the load-lock valve opens. The backing pump is not needed and is bypassed during the roughing phase. In contradiction to roots-type blowers, SIHI*boost* offers the full capacity and therefore, significantly faster pump-down time. The backing pump is only needed in order to achieve the high vacuum range, which enables the use of a considerably smaller backing pump.





For PECVD Processes

In today's PECVD processes, typical vacuum equipment consists of roots-type blowers in combination with any screw or claw backing pumps.

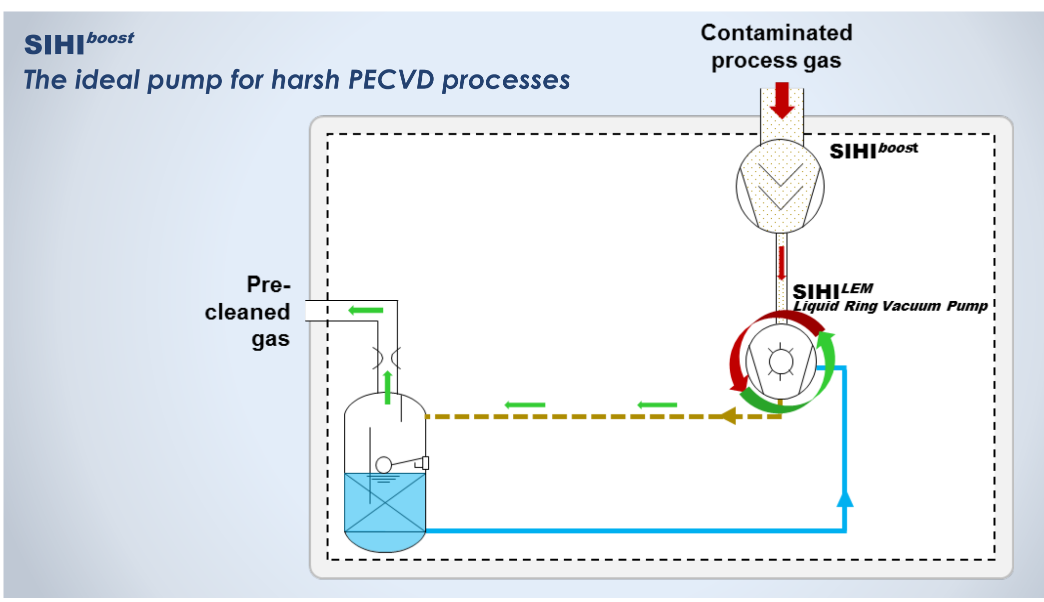
These backing pumps predominantly have been designed for processing non-reactive, particle-free gas loads, suitable for low amounts of dust particles carried over CVD plasma processes. There are many technical issues with these types of pumps which can lead to major maintenance and downtime issues. The mechanical damages typically cannot be completed by an on-site maintenance engineer.

SIHI*boost* is designed to offer features that are ideally suited for process issues, even in PECVD applications. The opportunity to use the SIHI liquid ring vacuum backing pump eliminates the risk of process buildup in the pump. Particles get solubilized, dissolved or suspended.

Consequently, the SIHI liquid ring vacuum pump acts like a discharge scrubber, which allows abatement systems for cleaning the downstream discharge to be downsized significantly, another overall investment cost advantage.

Since the achievable vacuum of an LRVP is only slightly below 100 mbar, the combination with roots-type blowers in high vacuum applications was never an option.

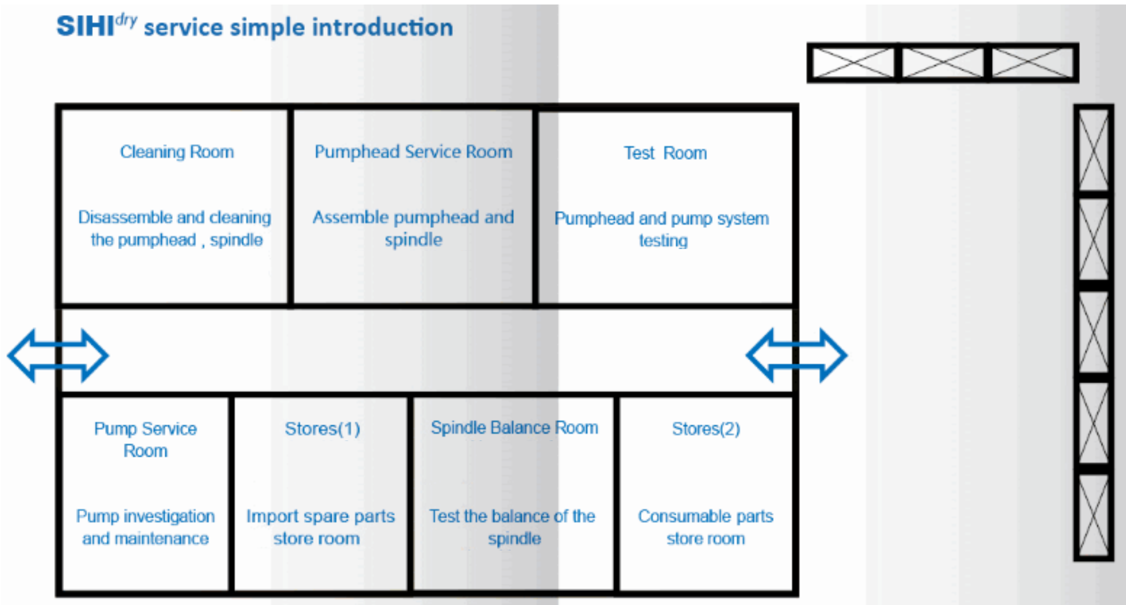
SIHI*boost* allows a much higher compression ratio and therefore the use of LRVP. In case it becomes necessary to clean the SIHI*boost*, its simple design allows it to be serviced on-site by a customer's maintenance personnel. There is no need to call the manufacturer for service. The SIHI*boost* concept therefore is not only the more powerful and efficient vacuum system; it optimizes the entire gas handling vacuum train, including the downstream abatement system.



Aftermarket

Flowserve Quick Response Centers' (QRC) capabilities have been constantly improving as new technologies were developed. With efficiency and reliability improvements, there is a high opportunity for upgrading existing installations to help owners/operators in the following areas:

- Increase plant productivity
- Reduce energy usage
- Reduce footprint



Dry pump repairing steps

1

Pre-Checking & Dismantling

2

Cleaning, Blasting & Ultrasonic

3

Balancing

4

Performance Testing

SIHI^{dry} pump service workflow

COMMUNICATING OUR VALUES

Flowserve Value Proposition

Flowserve	Proposition	Customer Benefit
Ethical Business Practice	Flowserve sets the highest standards in business integrity in its dealings with suppliers and customers.	A trustworthy partner to work toward their project success
Quality	Flowserve manufactures to the most rigorous quality standards to provide reliable products.	Satisfaction in supplier choice, on-time commissioning and project startup
Broad Product Range	Flowserve comprises a list of world-renowned heritage brands and a wide portfolio of products and services.	A product for every service designed by specialists in their respective fields ensures low-cost, high-efficiency solutions.
Project Management	Dedicated project managers certified by IPMA	Professional team to handle documentation and ensure on-time delivery
After-Sales Support	Dedicated after-sales support engineers	Implanted within project management, with the sole objective to resolve warranty issues quickly and painlessly
Aftermarket Solutions	Long-term maintenance	Specialist group capable of maintaining, servicing and upgrading equipment to meet operating goals throughput

GLOSSARY

TERM	DEFINITION
AMOLED	active-matrix organic light-emitting diode
APT	arrested precipitation technique
C-Si	conventional silicon
CBD	chemical bath deposition
CD	chemical deposition; compact disc
CIP	clean-in-place
CSD	chemical solution deposition
CVD	chemical vapor deposition
DRAM	dynamic random access memory
EDI	electronic data interchange
EMES	electrolyte membrane electrolyte semiconductor
FPD	flat-panel display
IAD	ion-assisted deposition
IBAD	ion beam-assisted deposition
ITO	indium tin oxide
IVD	ion vapor deposition
LCD	liquid crystal diode
LED	light-emitting diode
LPCVD	low-pressure CVD
LRVP	liquid ring vacuum pump
MCVD	metalorganic CVD
OEM	original equipment manufacturer
OLED	organic light-emitting diode
PACVD	plasma-assisted CVD
PAM	potential available/addressable market
PECVD	plasma-enhanced CVD
PSG	phosphosilicate glass
PV	photovoltaic
PVD	physical vapor deposition
PVDF	Polyvinylidine fluoride
QRC	Quick Response Center
RF	radio frequency
RFID	radio frequency identification
RTM	route-to-market
SAM	served available/addressable market
SIP	sterilization-in-place
TAM	total available/addressable market
VPE	vapor phase epitaxy

North America

Latin America

Europe

Middle East

Africa

Asia-Pacific

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Experience In Motion