

**Celebrating 30 Years  
of Service to  
the Industry**

# **2009 AVEM Resource Guide**

**Products and Services  
Buyers Guide for the Vacuum Industry**

A Publication of:

**AVEM**



Association of Vacuum Equipment Manufacturers

**AVEM**

201 Park Washington Court  
Falls Church, VA 22046 USA

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## AVEM Mission

The Association of Vacuum Equipment Manufacturers promotes member interests and provides services to enhance membership value and understanding of the global market.

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## From the AVEM Chairman

The Association of Vacuum Equipment Manufacturers, celebrating 30 years of service, is a unique trade organization, the only non-profit source for market data across the vacuum industry in North America. Member companies participate in the quarterly collection and confidential reporting of sales to generate a quarterly report distributed back to our members. This report provides a perspective on the overall market trends by the product categories in which they participate as well as by overall market segments.

This resource guide highlights the products and services offered by our member companies, which span the breadth from systems to pumps to instrumentation to hardware and deposition components. In a convenient, quick-reference format, this guide serves potential users by showing at-a-glance where to find the solutions for their vacuum needs. Don't miss our special solar corner on companies supplying the photovoltaic industry on page five! For additional information on the companies listed in the guide, please visit the AVEM Web site, [www.avem.org](http://www.avem.org), where our Membership Directory provides company profiles and descriptions at length of products and services offered by each.

In addition to the resource guide, the association offers numerous marketing and networking opportunities to our members, from banner ads on our Web site, space for literature in our booth at tradeshow, speaker programs, and newsletters. If you have input or ideas for a new program that would provide a benefit to the industry and to our members, please contact us at [aveminfo@avem.org](mailto:aveminfo@avem.org). We are always looking for ways to serve you better.

Sincerely,  
Paul Donovan, AVEM Chairman  
Vice President, Marketing, A & N Corporation

## Benefits of Membership in AVEM

- Quarterly statistics reports demonstrating industry trends
- Representation in the International Statistics on Vacuum Technology (ISVT) Working Group to ensure that the ISVT program operates to the benefit of members participants
- Vacuum industry resource guide that includes a buyers guide of member products and services
- Promotion of member company products and services via the AVEM Web site in the Online Buyers Guide and the Newsroom
- Meetings with provocative and educational speakers
- Online member networking and information exchange via the Ask AVEM ListServ
- Quarterly newsletter with association news; member company news; and informational articles on government programs, standards, international trade, economics and other issues effecting business operations
- Opportunities to steer AVEM in a direction that benefits the industry by participation on AVEM committees (Membership, Marketing, Statistics and Communication)
- Advertising opportunities in the AVEM Resource Guide and on the AVEM Web site
- Online career center to post job opportunities
- Washington alliances allows AVEM to alert members to policies and issues that may shape the business climate
- Discounted access to economic, statistical and research reports developed by The Manufacturers Alliance/MAPI
- Opportunity as an additional activity to become a member of PLP&D to learn about product liability prevention and defense issues for manufacturers

Join AVEM—[www.avem.org](http://www.avem.org)

# Solar Energy Systems—Prospects as a Vacuum Equipment Market

By Angus Rockett, Ph.D., *Professor and Associate Head, Department of Materials Science and Engineering, University of Illinois at Urbana-Champaign*, and William S. Shafarman, Ph.D., *Scientist, Energy Conversion, Institute of Energy Conversion, and Assistant Professor, Materials Science, Department of Materials Science, University of Delaware*

Solar energy is receiving considerable attention due to the sudden increase in oil prices, threats to the environment due to build up of carbon in the atmosphere, and predictions that fossil fuel supplies may be running out. Solar energy may represent a major new market for vacuum equipment manufacturers, although a general feeling exists throughout the community that non-vacuum processes should be less expensive.

Solar energy can be divided into a number of categories but the major ones of interest for this article are solar to electric power converters known as photovoltaics, or “PV” for short, and solar to heat converters known as solar thermal systems. The use of vacuum processing in solar thermal systems is typically limited to conventional glass coating technologies to increase heat capture (for example, transparent conductors on the glass). These systems are widely used for window coatings and computer displays. The market for large-scale glass coaters would likely increase dramatically if demand for solar thermal heating systems increases. However, solar thermal energy conversion systems are not sufficiently common to say how much impact development of this technology might have.

By contrast, many photovoltaic systems require not just simple glass coaters but much more complex vacuum manufacturing methods, although conventional glass coating is often used as well.

Most common solar cells are made from silicon wafers. These are bulk materials rather than thin films. Due to the tendency of silicon to react with air, these materials must be made by vacuum processes. Normally, this involves a slow method forming large single crystals (the “Czochralski” process) or simple casting in molds in vacuum. In the latter case, the molds are cooled very slowly to yield a multicrystalline silicon block, which is then sawed to produce the final materials. The remainder of the processing of

silicon solar cells generally involves non-vacuum processes such as screen printing of contacts and the addition of impurity atoms to the silicon wafers.

Increasingly “thin film” PV is of interest. It includes a substrate, usually glass or a metal foil, coated with a metal or in some cases a transparent conductor. Both of these are normally produced by sputtering. The active layer is usually deposited in vacuum by evaporation, sputtering or chemical vapor deposition. Finally the material is finished with a vacuum-deposited top electrode. The majority of the deposition steps in thin film PV are vacuum based, although

some companies are working on non-vacuum processes.

One device, the Sanyo “HIT” solar cell combines bulk silicon and thin film materials. This product has the potential to provide both high efficiencies (approaching 20 percent conversion of solar energy to electricity) and relatively low costs, especially as the volume of manufacturing increases. Whether it can compete in the long run with the thin film products is unclear as their costs are very low and scale-up is possible.

The PV industry has been expanding at roughly 40 percent per year during the past five years. Most of this has been in silicon devices, although recently a thin film technology manufactured by First Solar has been announced that has the potential to greatly reduce the cost of PV per kilowatt hour of power

produced. Manufacturing of thin film vacuum processing equipment for facilities based on this technology could represent a major new opportunity for the industry.

The ultimate scale of a PV manufacturing industry can be estimated based on the typical device performances. It would be reasonable to expect that solar PV systems can reach efficiencies of 15 percent or higher. Some products already exceed this level although at a cost per Watt of capacity well above the First Solar announced cost. At this level of efficiency a one square meter solar module would



produce roughly 240 kilowatt hours of power per year in Illinois and perhaps double this in the desert southwest. By contrast, the United States consumes roughly one terawatt year of electric power per year or roughly nine trillion kilowatt hours per year. To generate this with solar cells would therefore require roughly 36,000 square kilometers of device taking the Illinois power production as typical. A well-designed product might ultimately reach an average lifetime of 36 years, making it necessary to manufacture roughly 1000 square kilometers per year of device.

In short, to meet the current U.S. electric power demand by solar cells one might expect to require 1000 full-scale glass coating plants operating continuously. This is the magnitude of the potential for a thin film solar cell vacuum coating industry. If it comes to pass, this will require a dramatic expansion of the vacuum coating capability in the United States.

## Companies Supplying the Photovoltaic Industry



Inficon

✧ [www.inficon.com](http://www.inficon.com)



Vacuum Research Corporation

✧ [www.vacuumresearch.com](http://www.vacuumresearch.com)

**oerlikon**  
leybold vacuum

Oerlikon Leybold Vacuum USA Inc.

✧ [www.oerlikon.com](http://www.oerlikon.com)



A & N Corporation

✧ [www.ancorp.com](http://www.ancorp.com)



Brooks Automation

✧ [www.brooks.com](http://www.brooks.com)



VAT, Inc.

✧ [www.vatvalve.com](http://www.vatvalve.com)



**thermionics**  
vacuum products

Thermionics Vacuum Products

✧ [www.thermionics.com](http://www.thermionics.com)



Transfer Engineering and Manufacturing, Inc.

✧ [www.transferengineering.com](http://www.transferengineering.com)



MKS Instruments

✧ [www.mksinst.com](http://www.mksinst.com)

# Deposition Supplies, Gas Control, Ion/Plasma Sources, Plasma/Sputtering/Arc Components, Reclamation Services

Companies	Products and Services	Alicat Scientific, Inc. www.alicatscientific.com	Brooks Automation, Inc. www.brooks.com	Control Process Apparatus, Inc. www.sputteringneeds.com	Denton Vacuum, LLC www.dentonvacuum.com	Edwards www.edwardsvacuum.com	Huntington Mechanical Laboratories, Inc. www.huntvac.com	INFICON www.inficon.com	IonBond AG www.ionbond.com	Kurt J. Lesker Company www.lesker.com	Mass-Vac, Inc. www.massvac.com	MDC Vacuum Products, LLC www.mdvaccum.com	MKS Instruments, Inc. www.mksinst.com	Mustang Vacuum Systems, LLC www.mustangvac.com	Nor-Cal Products, Inc. www.n-c.com	Oerlikon Leybold Vacuum USA Inc. www.oerlikon.com	Pfeiffer Vacuum www.pfeiffer-vacuum.com	Protoflex Corporation www.proflexcorp.com	Rocky Brook Associates, Inc. 800/547-8934	Teledyne Hastings Instruments www.teledyne-hi.com	Thermionics Vacuum Products www.thermionics.com	Torr International, Inc. www.torr.com
<b>Deposition Supplies</b>																						
1.1 Arc cathode materials									●	●												
1.2 Evaporation filaments & crucibles										●		●							●		●	
1.3 Evaporation materials					●					●									●		●	
1.4 Sputtering target materials			●	●					●	●								●	●		●	
1.5 Substrate materials										●												
<b>Gas Control</b>																						
2.1 Exhaust conditioning systems						●							●									
2.2 Gas manifolds			●				●			●			●									
2.3 Gas purifiers																						
2.4 Gas storage																						
2.5 Mass flow meters	●		●							●		●								●		
2.6 Pressure controllers	●	●	●			●	●			●		●				●						
2.7 Variable leaks		●				●			●						●	●						
<b>Ion/Plasma Sources</b>																						
3.1 Cold cathode sources			●	●						●				●								
3.2 ECR sources													●									
3.3 End Hall sources												●										
3.4 Inductive coupled plasma																						
3.5 Kaufman ion guns										●				●								
3.6 RF sources			●										●									
<b>Plasma/Sputtering/Arc Components</b>																						
4.1 Arc power supplies									●													
4.2 DC power supplies			●						●	●			●	●							●	
4.3 Microwave power supplies										●			●									
4.4 RF power supplies			●						●				●								●	
<b>Reclamation Services</b>																						
5.1 Evaporation/sputtering materials			●							●									●			
5.2 Vacuum pump oil			●						●	●						●						

Note: Only the companies who sell the products on these two pages are listed.

						Associate Members	
						↓	
<b>Varian, Inc., Vacuum Technologies</b> <a href="http://www.varianinc.com/vacuum">www.varianinc.com/vacuum</a>							
<b>VAT, Inc.</b> <a href="http://www.vatvalve.com">www.vatvalve.com</a>							
<b>Vergason Technology, Inc.</b> <a href="http://www.vergason.com">www.vergason.com</a>							
<b>A-VAC Industries</b> <a href="http://www.avac.com">www.avac.com</a>							
<b>Vacuum Solutions Group, Inc.</b> <a href="http://www.vacuumsolutions.com">www.vacuumsolutions.com</a>							
Deposition Supplies							
1.1				●			
1.2							
1.3				●			
1.4				●			
1.5							
Gas Control							
2.1							
2.2							
2.3							
2.4							
2.5				●			
2.6		●					
2.7	●	●					
Ion/Plasma Source							
3.1							
3.2							
3.3							
3.4							
3.5							●
3.6							
Plasma/Sputtering/Arc Components							
4.1				●			
4.2				●			
4.3							
4.4							
Reclamation Services							
5.1							
5.2					●		

## Members

### A & N Corporation

352-520-4100 • [www.ancorp.com](http://www.ancorp.com)

### Alicat Vacuum Products, Inc.

781-331-42008 • [www.adixen-usa.com](http://www.adixen-usa.com)

### Alicat Scientific, Inc.

520-290-6060n • [www.alicatscientific.com](http://www.alicatscientific.com)

### Ametek, Inc.

412-828-9050 • [www.ametekpi.com](http://www.ametekpi.com)

### BellowsTech, LLC

386-677-4221 • [www.bellowstechinc.com](http://www.bellowstechinc.com)

### Brooks Automation, Inc.

978-262-2400 • [www.brooks.com](http://www.brooks.com)

### CeramTec North America

864-682-3215 • [www2.ceramtec.com](http://www2.ceramtec.com)

### Control Process Apparatus, Inc.

510-252-9900 • [www.sputteringneeds.com](http://www.sputteringneeds.com)

### Denton Vacuum, LLC

856-439-9100 • [www.dentonvacuum.com](http://www.dentonvacuum.com)

### DRIVAC, Inc.

215-345-7044 • [www.drivac.com](http://www.drivac.com)

### Edwards

978-753-6110 • [www.edwardsvacuum.com](http://www.edwardsvacuum.com)

### Gardner Denver Welch Vacuum Technology

847-676-8800 • [www.welchvacuum.com](http://www.welchvacuum.com)

### GNB Corporation

916-395-3003 • [www.gnbvalves.com](http://www.gnbvalves.com)

### Huntington Mechanical Laboratories, Inc.

650-964-3323 • [www.huntvac.com](http://www.huntvac.com)

### HVA, LLC

775-359-4442 • [www.highvac.com](http://www.highvac.com)

### INFICON

315-434-1100 • [www.inficon.com](http://www.inficon.com)

### InstruTech, Inc.

303-651-0551 • [www.instrutechinc.com](http://www.instrutechinc.com)

### Insulator Seal

941-751-2880 • [www.insulatorseal.com](http://www.insulatorseal.com)

### IonBond AG

416-918-6565 • [www.ionbond.com](http://www.ionbond.com)

### Johnsen Ultravac, Inc.

800-268-4980 • [www.ultrahivac.com](http://www.ultrahivac.com)

### Kurt J. Lesker Company

412-387-9200 • [www.lesker.com](http://www.lesker.com)

### Mass-Vac, Inc.

978-667-2393 • [www.massvac.com](http://www.massvac.com)

### MDC Vacuum Products, LLC

510-265-3500 • [www.mdcvacuum.com](http://www.mdcvacuum.com)

### MKS Instruments, Inc. HPS® Products

510-265-3500 • [www.mksinst.com](http://www.mksinst.com)

### Mustang Vacuum Systems, LLC

941-377-1440 • [www.mustangvac.com](http://www.mustangvac.com)

### Nor-Cal Products, Inc.

800-824-4166 • [www.n-c.com](http://www.n-c.com)

### Oerlikon Leybold Vacuum USA Inc.

800-764-5369 • [www.oerlikon.com](http://www.oerlikon.com)

### Osaka Vacuum U.S.A., Inc.

510-770-0100 • [www.osakavacuum.com](http://www.osakavacuum.com)

### Pfeiffer Vacuum

603-578-6500 • [www.pfeiffer-vacuum.com](http://www.pfeiffer-vacuum.com)

### PHPK Technologies

614-486-4750 • [www.phpk.com](http://www.phpk.com)

### Precision Metal Works Ltd.

506-363-3066 • [www.precisionmetalworks.com](http://www.precisionmetalworks.com)

### Protoflex Corporation

303-771-0809 • [www.protoflexcorp.com](http://www.protoflexcorp.com)

### Ricor Cryogenic & Vacuum Systems

972-4 6530 800 • [www.ricor.com](http://www.ricor.com)

### Rigaku Innovative Technologies

603-890-6001 • [www.rigaku.com](http://www.rigaku.com)

### Rocky Brook Associates, Inc.

401-789-0259

### Sumitomo (SHI) Cryogenics of America, Inc.

610-791-6700 • [www.shicryogenics.com](http://www.shicryogenics.com)

### Teledyne Hastings Instruments

757-723-6351 • [www.teledyne-hi.com](http://www.teledyne-hi.com)

### Televac, A Fredericks Company

215-947-2500 • [www.televac.com](http://www.televac.com)

### Thermionics Vacuum Products

800-962-2310 • [www.thermionics.com](http://www.thermionics.com)

### Torr International, Inc.

845-565-4027 • [www.torr.com](http://www.torr.com)

### Transfer Engineering & Manufacturing, Inc.

510-651-3000 • [www.transferengineering.com](http://www.transferengineering.com)

### Tuthill Vacuum & Blower Systems

417-865-8715 • [www.vacuum.tuthill.com](http://www.vacuum.tuthill.com)

### U-C Components, Inc.

408-782-1929 • [www.ucomponents.com](http://www.ucomponents.com)

### Vacuum Research Corporation

800-426-9340 • [www.vacuumresearch.com](http://www.vacuumresearch.com)

### Varian, Inc., Vacuum Technologies

781-861-7200 • [www.varianinc.com](http://www.varianinc.com)

### VAT, Inc.

781-935-1446 • [www.vatvalve.com](http://www.vatvalve.com)

### Vergason Technology, Inc.

607-589-4429 • [www.vergason.com](http://www.vergason.com)

### Verity Instruments, Inc.

972-446-9990 • [www.verityinst.com](http://www.verityinst.com)

### XEI Scientific, Inc.

650-369-0133 • [www.evactron.com](http://www.evactron.com)

## Associate Members

### A-VAC Industries

714-938-1300 • [www.avac.com](http://www.avac.com)

### Advanced Vacuum Company, Inc.

410-876-8200 • [www.advaco.com](http://www.advaco.com)

### Omley Industries, Inc.

800-541-3355 • [www.omley.com](http://www.omley.com)

### Trelleborg Sealing Solutions

260-749-9631 • [www.tss.trelleborg.com/us](http://www.tss.trelleborg.com/us)

### Vacuum Solutions Groups, Inc.

201-692-7924 • [www.vacuumsolutions.com](http://www.vacuumsolutions.com)

# Repair/Rebuild Equipment, Supplies/Accessories, System Monitoring and Control

Companies	Products and Services	A&N Corporation www.ancorp.com	Alcatel Vacuum Products, Inc. www.adixen-usa.com	AMETEK, Inc. www.ametekpi.com	BellowsTech, LLC www.bellowstech.com	Brooks Automation, Inc. www.brooks.com	Control Process Apparatus, Inc. www.sputteringneeds.com	Drivac www.drivac.com	Edwards www.edwardsvacuum.com	Gardner Denver Welch Vacuum Technology www.welchvacuum.com	Huntington Mechanical Laboratories, Inc. www.huntvac.com	INFICON www.inficon.com	InstruTech, Inc. www.instrutechinc.com	IonBond AG www.ionbond.com	Kurt J. Lesker Company www.lesker.com	Mass-Vac, Inc. www.massvac.com	MDC Vacuum Products, LLC www.mdvvacuum.com	MKS Instruments, Inc. www.mksinst.com	Mustang Vacuum Systems, LLC www.mustangvac.com	Nor-Cal Products, Inc. www.n-c.com	Oerlikon Leybold Vacuum USA Inc. www.oerlikon.com	Pfeiffer Vacuum www.pfeiffer-vacuum.com	Ricor Cryogenic & Vacuum Systems www.ricor.com	Rigaku Innovative Technologies www.rigaku.com
<b>Repair/Rebuild Equipment</b>																								
6.1 Replacement parts					●	●	●	●	●	●	●				●	●	●		●	●	●			●
6.2 Used vacuum equipment							●		●	●						●	●				●		●	
6.3 Refurbished equipment						●	●	●		●					●				●		●	●		
6.4 Repair/maintenance at user's site						●	●		●					●	●	●		●	●		●	●		
<b>Supplies/Accessories</b>																								
7.1 Adhesives											●				●									
7.2 Cleaning and handling supplies																								
7.3 Exhaust scrubbers																								
7.4 Fluid flow switches															●									
7.5 Gaskets - polymer, metal	●			●							●				●	●	●	●			●			
7.6 Heating mantles																		●						
7.7 Oil filters															●	●					●			
7.8 Radiant heaters											●				●									
7.9 Sealants											●				●						●			
7.10 Vacuum lubricants	●	●							●		●				●	●	●				●	●		
7.11 Vacuum pump oils		●					●		●	●					●	●					●	●		
7.12 Vacuum switches							●		●						●			●			●			
<b>System Monitoring and Control</b>																								
8.1 Calibrated leaks							●								●						●	●		
8.2 Capacitance diaphragm gauges	●								●			●			●			●		●	●	●		
8.3 Gauge calibration services					●	●									●			●						
8.4 Ionization gauges	●				●			●		●	●	●			●		●	●			●	●		
8.5 Leak detectors - halogen												●												
8.6 Leak detectors - helium		●	●				●					●			●			●			●	●		
8.7 Microprocessor controls															●									
8.8 Plasma characterization												●							●					
8.9 Residual gas analyzers			●				●					●						●					●	
8.10 Thermocouple/Pirani gauges	●	●			●	●		●	●	●	●	●	●		●		●	●			●	●		
8.11 Optical Spectrometry												●							●					
8.12 PC-PLC Control of Vacuum Systems															●									



Note: Only the companies who sell the products on these two pages are listed.

	Sumitomo (SHI) Cryogenics of America, Inc. www.shicyogenics.com	Teledyne Hastings Instruments www.teledyne-hi.com	Televac www.televac.com	Thermionics Vacuum Products www.thermionics.com	Tuthill Vacuum & Blower Systems http://vacuum.tuthill.com	UC Components, Inc. www.ucomponents.com	Vacuum Research Corporation www.vacuumresearch.com	Varian, Inc., Vacuum Technologies www.varianinc.com/vacuum	Vergason Technology, Inc. www.vergason.com	Verity Instruments, Inc. www.verityinst.com	Associate Members ↓ ↓			
	A-VAC Industries www.avac.com	Advanced Vacuum Company, Inc. www.advaco.com	Trelleborg Sealing Solutions www.tss.trelleborg.com/us	Vacuum Solutions Group, Inc. www.vacuum-solutions.com										
<b>Repair/Rebuild Equipment</b>														
6.1	●			●	●	●		●	●		●	●	●	
6.2				●	●			●	●		●	●		
6.3					●			●	●		●	●		
6.4	●				●			●	●		●			
<b>Supplies/Accessories</b>														
7.1														
7.2														
7.3														
7.4				●										
7.5				●				●	●				●	
7.6														
7.7					●				●					
7.8				●										
7.9					●	●		●						●
7.10					●	●		●	●		●			
7.11					●			●	●		●	●		
7.12	●	●			●		●							
<b>System Monitoring and Control</b>														
8.1			●					●			●			
8.2			●				●		●					●
8.3	●	●						●	●		●			
8.4	●	●	●					●	●					●
8.5														
8.6								●	●		●			
8.7		●												
8.8										●				
8.9														●
8.10	●	●	●				●	●	●		●			●
8.11										●				●
8.12														

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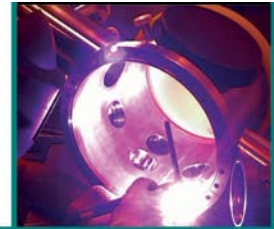


# Vacuum Deposition Components, Vacuum Systems

Note: Only the companies who sell the products on this pages are listed.

Companies Products and Services	Brooks Automation, Inc. www.brooks.com	Control Process Apparatus, Inc. www.sputteringneeds.com	Denton Vacuum, LLC www.dentonvacuum.com	INFICON www.inficon.com	IonBond AG www.ionbond.com	Johnsen Ultravac Inc. www.ultrahivac.com	Kurt J. Lesker Company www.lesker.com	MDC Vacuum Products, LLC www.mdvacuum.com	MKS Instruments, Inc. www.mksinst.com	Mustang Vacuum Systems, LLC www.mustangvac.com	Nor-Cal Products, Inc. www.n-c.com	PHPK Technologies www.phpk.com	Precision Metal Works Ltd. www.precisionmetalworks.com	Protoflex Corporation www.proflexcorp.com	Rocky Brook Associates, Inc. 800/547-8934	Thermionics Vacuum Products www.thermionics.com	Torr International, Inc. www.torr.com	Transfer Engineering & Manufacturing, Inc. www.transferengineering.com	Vergason Technology, Inc. www.vergason.com	Verify Instruments, Inc. www.verifyinst.com	Vacuum Solutions Group, Inc. www.vacuumsolutions.com
<b>Vacuum Deposition Components</b>																					
9.1 Arc vaporization fixtures					●																●
9.2 Deposition rate monitors/controllers				●			●	●	●		●										
9.3 Electron beam power supplies							●	●								●					●
9.4 Electron beam sources							●	●							●	●					●
9.5 Optical property monitors									●											●	
9.6 Resistive evaporation fixtures							●	●								●				●	
9.7 Sputtering target fixtures		●					●								●					●	
9.8 Substrate heaters		●				●	●							●		●	●	●			●
9.9 Substrate temperature controllers		●				●	●									●					
<b>Vacuum Systems</b>																					
10.1 Air-to-Air (no load lock)		●	●				●			●			●			●					
10.2 Arc melting/vaporization					●					●											
10.3 Batch (common in & out load lock)	●	●	●			●	●	●		●			●			●		●	●		
10.4 Batch (one chamber)	●	●	●		●	●	●			●			●			●				●	
10.5 Cluster tool	●	●	●			●	●			●			●	●							
10.6 Electron beam melting						●		●		●						●					
10.7 Equipment design services					●	●	●			●		●	●	●		●				●	
10.8 In-line (separate in & out load lock)		●					●			●			●	●					●		
10.9 Ion Beam Assisted Deposition (IBAD)			●			●	●			●						●					
10.10 Ion implantation										●											
10.11 Ion milling/etching			●							●											
10.12 Ion plating			●							●										●	
10.13 Laboratory coaters			●		●		●	●		●			●			●	●			●	
10.14 Laser ablation						●	●			●						●					
10.15 Low Pressure CVD (LPCVD)					●					●											
10.16 Low Pressure Plasma Spray (LPPS)																					
10.17 Metalorganic CVD (MOCVD)										●											
10.18 Molecular Beam Epitaxy (MBE)						●	●														

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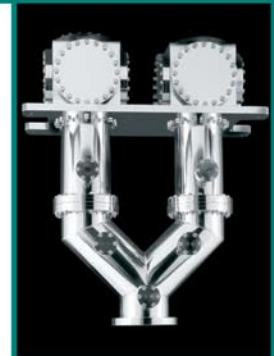


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# Requirements and Challenges for Vacuum Solutions Used in Deposition Processes in the Manufacture of Photovoltaic Modules

Dr. Monika Kuhn Oerlikon *Leybold Vacuum Cologne, Germany*

Vacuum technology is one enabler in the production process for photovoltaic panels.

Along the whole production chain of solar modules, vacuum pumping equipment is required in order to produce silicon wafers, to deposit thin film layers and for the final step of encapsulation. Additionally, an optimized vacuum solution is essential for thin film technologies using glass or organic substrates. This article will outline the specific vacuum system requirements for different deposition processes used in today's production of photovoltaic modules.

## Module Types

Photovoltaic modules can be divided into wafer based technology and thin film technology. Most common are wafer based crystalline Silicon modules.

Thin film technology modules are based on multi layer composites made from a-Silicon/  $\mu$ -Silicon; CdTe ; CIS (CuInSe) or CIGS (CuInGaSe )

Characteristic features of Photovoltaic modules:

	<b>Crystalline Silicon / wafer based</b>	<b>Thin film on glass</b>
Efficiency (%)	14-20	5-13
Contact layer	Printing or electro plating	Vacuum deposition processes
Absorber	Chemical and thermal processes	Vacuum deposition processes
Passivation- and Anti reflective coating (ARC)	Vacuum deposition processes	n.a.

## Process Types

In the production of photovoltaic modules there are different methods used to produce the layers on the glass or silicon wafer.

Contacts: Sputtering; evaporation; LPCVD

Absorber: PECVD; MOCVD; Evaporation; Sputtering

Passivation/ARC: PECVD; Sputtering

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## General Requirements for Vacuum Solutions

Vacuum pumps used in photovoltaic manufacturing tools must meet the following design criteria and their importance may vary by tool type, process step, and process technology:

- Handling of toxic, corrosive, explosive and self igniting gases
- Handling of particles, dust or layers created by process gases and their reaction products
- High pumping speeds for Argon, Helium and Hydrogen
- Short pump down cycle for Load lock and transfer chambers
- High up-time and high reliability
- Small foot print
- Low maintenance
- Low cost of ownership

Due to these different requirements it is important to develop customized solutions for different applications.

## Sputter Processes

Machines used for sputtering of glass consist of several different chambers. The vacuum pumps are a key factor

for the tool up-time and a good understanding of the application specific needs is required to guarantee excellent production yield.

Products used in such processes must comply with specific requirements such as:

- Sufficient pumping speed for fast chamber pump down
- Simple product integration
- Handling of process gases
- High up-time and low cost of ownership
- Robust design and construction
- Designed for industrial ambient conditions e.g. dust in the air or high ambient temperature at high humidity levels

In most coating systems, the carrier material (substrate) for the solar cells is transferred through load locks into the actual coating chambers. Modern systems offer extremely short cycle times with relatively large volumes so as to optimize plant efficiency.

The challenge to the vacuum technology aspect is evacuating the load lock chamber to the required transfer pressure within the short period of time demanded. The experience of well-known manufacturers of solar cells and/or display

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[www.oerlikon.com](http://www.oerlikon.com)



# Vacuum Systems (continued), Vacuum System Components

Companies		A&N Corporation www.ancorp.com	Bellows Tech, LLC www.bellowstech.com	Brooks Automation, Inc. www.brooks.com	Ceramtec North America www2.ceramtec.com	Control Process Apparatus, Inc. www.sputteringneeds.com	Denton Vacuum, LLC www.dentonvacuum.com	Edwards www.edwardsvacuum.com	GNB Corporation www.gnbvalves.com	Huntington Mechanical Laboratories, Inc. www.huntvac.com	Inifcon www.inifcon.com	Insulator Seal www.insulatorseal.com	IonBond AG www.ionbond.com	Johnsen Ultravac Inc. www.ultrahivac.com	Kurt J. Lesker Company www.lesker.com	Mass-Vac, Inc. www.massvac.com	MDC Vacuum Products, LLC www.mdcvacuum.com	MKS Instruments, Inc. www.mksinst.com	Mustang Vacuum Systems, LLC www.mustangvac.com	Nor-Cal Products, Inc. www.n-c.com	Oerlikon Leybold Vacuum USA Inc. www.oerlikon.com	Pfeiffer Vacuum www.pfeiffer-vacuum.com	PPPK Technologies www.phpk.com	
<b>Vacuum Systems (continued)</b>																								
10.19	Plasma Enhanced CVD (PECVD)					●							●		●						●			
10.20	Reactive Ion Etching (RIE)					●															●			
10.21	Reactive Plasma Etching (RPE)														●						●			
10.22	Space simulation				●								●	●	●									
10.23	Sputter deposition				●	●							●	●	●						●			
10.24	Surface analysis equipment											●											●	
10.25	Ultrahigh vacuum systems					●					●		●	●	●		●				●	●	●	●
10.26	Vacuum drying & outgassing														●	●								
10.27	Vacuum evaporation					●									●		●				●			
10.28	Vacuum freeze drying																							
10.29	Vacuum furnaces & ovens														●									
10.30	Vacuum - general (no chamber)	●			●				●	●					●		●	●			●	●		
10.31	Vacuum packaging																							
10.32	Web coating				●	●									●									
<b>Vacuum System Components</b>																								
11.1	Chillers & refrigeration systems			●	●																			
11.2	Cryocoolers for traps & baffles		●																					
11.3	Custom fixtures & tooling	●			●			●					●	●										
11.4	Electrical components			●	●						●			●	●	●								
11.5	Feedthrough collars	●		●				●	●					●	●	●				●		●		
11.6	Feedthroughs - electrical	●		●	●			●	●					●	●	●				●	●	●		
11.7	Feedthroughs - fluid	●		●				●	●					●	●	●				●				
11.8	Feedthroughs - linear motion	●	●	●				●					●	●	●	●				●		●		
11.9	Feedthroughs - optical			●	●			●	●					●	●	●								
11.10	Feedthroughs - radio frequency			●	●			●	●					●	●	●	●							
11.11	Feedthroughs - rotary motion	●	●	●	●			●						●	●	●				●	●	●		
11.12	Flanges - blank	●		●	●		●	●	●		●			●	●	●				●	●	●		
11.13	Getter materials																							

Note: Only the companies who sell the products on these two pages are listed.

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<b>Vacuum Systems (continued)</b>															
10.19		●					●								
10.20							●								
10.21															
10.22	●														
10.23	●	●				●	●					●			
10.24				●		●									
10.25	●	●				●	●	●							
10.26															
10.27		●				●	●					●			
10.28															
10.29	●					●									
10.30						●	●	●	●		●				
10.31															
10.32		●													
<b>Vacuum System Components</b>															
11.1			●									●		●	
11.2			●											●	
11.3					●	●		●				●			
11.4												●	●		
11.5						●									●
11.6						●					●		●	●	
11.7						●							●	●	
11.8						●		●		●			●	●	
11.9						●							●		
11.10						●							●	●	
11.11				●		●		●		●		●		●	
11.12						●					●				●
11.13															

## Requirements and Challenges for Vacuum Solutions ... continued from page 13

coating plants indicates that many pump systems offer an inadequate service life under these process conditions and require comprehensive maintenance work.

For fast pump down of large volume chambers, parallel operation of several pump system is needed in order to achieve short tact time which has a major influence on production output. For such applications multi stage systems of blowers in combination with dry vacuum pumps guarantee the highest performance and long up time.

### PECVD Processes

Deposition of a-Si and a-Si/μ-Si is one key process in the production of photovoltaic panels based on thin film technology. Due to the large glass substrate size which is processed in cluster tools, the design of the vacuum system plays an important role. The process gases used include Hydrogen and Helium and the pumping performance for such “light” gases can differ greatly by technology and supplier.

Specific requirements for PECVD processes are:

- Optimized pumping speed for light gases like Hydrogen
- Safe pumping of Silane and Hydrogen
- Ability to handle highly toxic gases
- Corrosion resistance against SF6, NF3 and byproducts created in the process chamber
- Robust design to handle large amounts of particulates
- High reliability and up-time

Regular leak checks of the complete system are required to avoid any safety risk. The design of the pipe work with respect to material, geometry and sealing flanges must be considered carefully to ensure leak tightness under all operating conditions.

The reactive and toxic gases leaving the pump at the exhaust are afterwards treated in abatement equipment. The exhaust line needs to be adapted to the process requirement to avoid blocking and corrosion.

### Summary

Vacuum is an important enabler for the production of photovoltaic modules. Customized products for the individual needs of the different production steps are mandatory in order to achieve high up-time and to avoid any safety risks.

# Vacuum System Components (continued)

Companies	Products and Services	Vacuum System Components (continued)																				
A&N Corporation www.ancorp.com	Alcatel Vacuum Products, Inc. www.adixen-usa.com	Alicat Scientific, Inc. www.alicatscientific.com	BellowsTech, LLC www.bellowstech.com	Brooks Automation, Inc. www.brooks.com	Ceramtec North America www2.ceramtec.com	Control Process Apparatus, Inc. www.sputteringneeds.com	Drivac www.drivac.com	Edwards www.edwardsvacuum.com	Gardner Denver Welch Vacuum Technology www.welchvacuum.com	GNB Corporation www.gnbvalves.com	Huntington Mechanical Laboratories, Inc. www.huntvac.com	HVA, LLC www.highvac.com	INFICON www.inficon.com	Insulator Seal www.insulatorseal.com	Johnsen Ultrahvac Inc. www.ultrahvac.com	Kurt J. Lesker Company www.lesker.com	Mass-Vac, Inc. www.massvac.com	MDC Vacuum Products, LLC www.mdvacuum.com	MKS Instruments, Inc. www.mksinst.com	Mustang Vacuum Systems, LLC www.mustangvac.com	Nor-Cal Products, Inc. www.n-c.com	
11.14 Heat exchangers																						
11.15 Mechanical components - bearings											●					●					●	
11.16 Pumps - aspiration																						
11.17 Pumps - booster		●				●										●						
11.18 Pumps - cryo, colder than -160C				●		●										●						
11.19 Pumps - cryo, warmer than -160C				●																		
11.20 Pumps - diaphragm							●		●							●						
11.21 Pumps - diffusion		●				●		●								●						
11.22 Pumps - getter																●						
11.23 Pumps - ion																●						
11.24 Pumps - mechanical, oil-sealed		●				●		●	●							●	●					
11.25 Pumps - mechanical, oil-free		●				●	●	●	●							●	●					
11.26 Pumps - sorption											●							●				
11.27 Pumps - turbomolecular		●				●	●	●								●						
11.28 Traps & baffles - diffusion pumps	●			●					●		●					●		●			●	
11.29 Traps & baffles - mechanical pumps	●	●		●		●			●		●					●	●	●			●	
11.30 Traps & baffles - exhaust	●					●			●							●	●		●		●	
11.31 Tubing, flanges, fittings & seals	●	●		●		●			●		●					●	●	●	●		●	
11.32 Vacuum chambers	●					●				●	●				●	●		●	●		●	
11.33 Valves (<2 inches)	●					●					●	●				●		●	●		●	
11.34 Valves (>2 inches)	●		●			●				●	●	●				●		●	●		●	
11.35 Valves - soft pump/let-up								●			●					●		●	●		●	
11.36 Valves - ultrahigh vacuum	●	●	●		●	●					●	●	●			●		●	●		●	
11.37 Valves - variable conductance		●		●						●	●	●				●			●		●	
11.38 Windows	●				●	●				●	●			●		●		●			●	



Note: Only the companies who sell the products on these two pages are listed.

Vacuum System Components (continued)																	
11.14																	●
11.15									●								●
11.16																	
11.17	●	●	●							●	●					●	
11.18	●			●					●	●						●	●
11.19	●								●	●							●
11.20	●		●													●	
11.21	●	●	●							●						●	●
11.22										●						●	
11.23	●									●							●
11.24	●	●	●							●	●				●	●	●
11.25	●		●							●	●					●	●
11.26										●							●
11.27	●	●	●							●						●	●
11.28	●		●							●							●
11.29	●	●	●							●						●	
11.30	●		●							●	●					●	
11.31	●		●							●	●	●					●
11.32			●	●	●	●				●	●					●	●
11.33	●									●	●	●					●
11.34	●		●							●	●	●	●				●
11.35	●									●							
11.36	●		●							●	●	●					●
11.37	●									●		●					●
11.38	●									●	●				●		●

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Understanding industry trends in the global marketplace is critical for a company's sales and operations planning. In order to help our member companies fulfill this requirement, the Association of Vacuum Equipment Manufacturers (AVEM) is a participating association in the International Statistics on Vacuum Technology (ISVT) program. The ISVT program was developed through the cooperation of the AVEM, the Japan Vacuum Industry Association (JVIA), the European Vacuum Technology Association (EVTA), and the Semiconductor Equipment and Materials International (SEMI).

Quarterly sales data collected for the ISVT program is divided into three main product groupings: vacuum pumps, vacuum instrumentation, and vacuum hardware. Each grouping is broken down into several product types and the aggregate sales of these products types are reported for

the geographical regions of North America, Japan, Europe, China/Korea/Taiwan and Rest of World. Product and regional data is also reported according market segmentation (see chart below).

The ISVT Working Group, comprised of representatives from each participating association, continually works to improve the quality of the program and the accuracy of the data collected. Each association also follows strict rules for maintaining the confidentiality of individual member company's data through the services of regional notaries and a certified public accounting firm. Data submitted by a specific company cannot be identified in the final reporting.

To learn more about the ISVT program, or to become a participating member, visit the Resources Section of the AVEM Web site ([www.avem.org](http://www.avem.org)).

## VACUUM MARKET SEGMENTATION

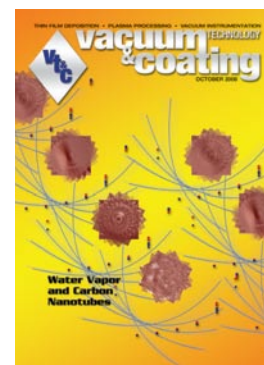
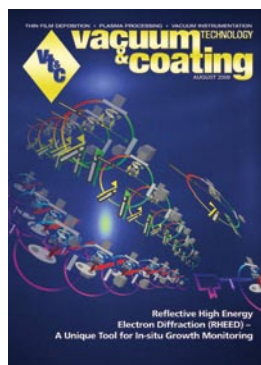
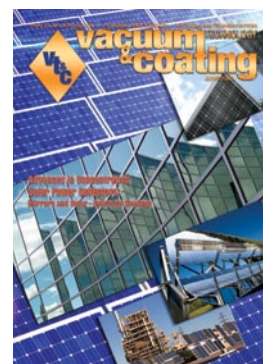
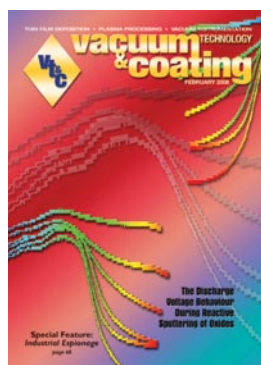
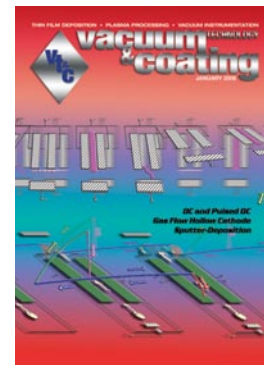
<i>Rough Vacuum</i>	<i>Process Vacuum</i>	<i>Industrial Vacuum</i>	<i>Semiconductor Process Vacuum</i>	<i>Thin-Film Deposition (non-Semiconductor)</i>	<i>Instrumentation Manufacturers</i>	<i>R &amp; D</i>
<u>Markets</u>	<u>Markets</u>	<u>Markets</u>	<u>Markets</u>	<u>Markets</u>	<u>Markets</u>	<u>Markets</u>
Packaging (except Food)	Chemical	Vacuum Metallurgy	Silicon Semiconductor	Glass/Web/Optical Coating	Mass Spectrometers	Universities
Central Vacuum	Petrochemical	Vacuum Heat Treatment	Compound Semiconductor	Data storage (CD, DVD, ..)	Electron Microscopes	Government Labs
Printing and Paper handling	Pharmaceutical	Laser Technology	TFT-LCD Displays	Thin Film Heads	Leak Detectors	Scientific Research Laboratories
Pick-up and Conveying	Plastics	Electron Tubes	MEMS	Surface Coating (wear protection, decorative, ..)	Surface Analysis	Laboratories
Medical	Food	TV Tubes	Process Equipment	Display Coatings (OLED, FED, PDP..)	Gas Analysis	Space Simulation
	Beverage	Lamps and Bulbs	Manufacturers and End Users for PVD, CVD,	Solar (Photovoltaics, Thermal)	Metrology/ Inspection/ Defect Review systems for Semiconductor	
	Textile	Industrial leak detection	Etching, Ion Implantation, MBE, Crystal Pulling, etc		Focused Ion Beam systems	
	Paper	Refrigeration and Air Conditioning			Electron Beam systems	
	Ceramics	Automotive (Dehydration Charging and Test)			X-Ray Analysis	
	Freeze drying				MRI and NMR	
	Power					
<b>Typical Operating Pressure (mbar)</b>						
> 1	> 10 <sup>-2</sup>	10 <sup>-2</sup> - 10 <sup>-8</sup>	1 - 10 <sup>-8</sup>	10 <sup>-3</sup> - 10 <sup>-8</sup>	10 <sup>-6</sup> - 10 <sup>-10</sup>	10 <sup>-2</sup> - 10 <sup>-11</sup>

- |       |                                  |          |   |
|-------|----------------------------------|----------|---|
| CD:   | Compact Disk                     | MRI:     | Magnetic Resonance Imaging  |
| CVD:  | Chemical Vapour Deposition       | NMR:     | Nuclear Magnetic Resonance  |
| DVD:  | Digital Video Disk               | OLED:    | Organic Light Emitting Diode( or OLED: Organic Electro Luminescent Display) |
| FED:  | Field Emission Display           | PDP:     | Plasma Display Panel  |
| MBE:  | Molecular Beam Epitaxy           | PVD:     | Physical Vapour Deposition  |
| MEMS: | Micro Electro Mechanical Systems | TFT-LCD: | Thin-Film Transistor Liquid Crystal Display                                 |

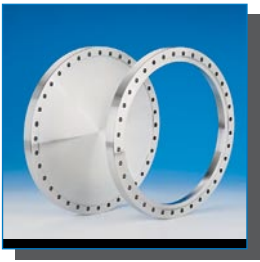
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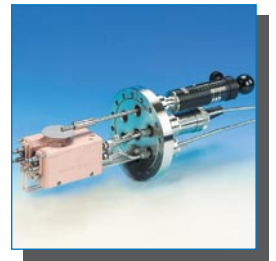
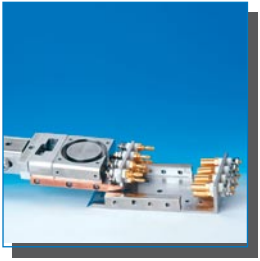
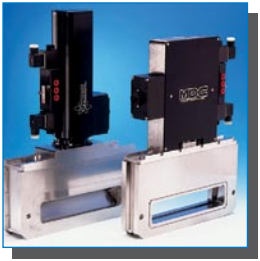
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