



Pall Corporation

# Filtration and Purification Solutions for the Total Photovoltaic Value Chain

*Filtration. Separation. Solution.<sup>SM</sup>*

MEPVCAPENb

# Introduction

## Company Profile

Pall Corporation is the global leader in the rapidly growing field of filtration, separation and purification. Pall is organized into two businesses: Life Sciences and Industrial. These businesses provide leading-edge products to meet the demanding needs of customers in biotechnology, pharmaceutical, transfusion medicine, energy, electronics, municipal and industrial water purification, aerospace, transportation and broad industrial markets. Pall's total revenues are around \$2.5 billion with over 10,000 employees.

The company headquarters is in Port Washington, New York with extensive operations and local companies throughout the world. As consumers we rarely stop to consider how the products we use are made. Whether they are computers or solar panels, a favorite beer or wine, tap water, medicine, electricity, gasoline, or the paint on our cars, we simply expect high quality, reliability and reasonable prices. For the most part, we get them. Pall's highly sophisticated technologies are among the reasons why. These technologies are invisible to consumers, but essential to industry.

Our customers have a common enemy: contamination. It can destroy products, shut down plants, hinder compliance with regulations and slow innovation. We help them to:


- Optimize process efficiency
- Ensure product purity
- Meet stringent regulations
- Remove barriers to innovation
- Develop integrated solutions
- Enable new processes and products

## Pall Microelectronics

Pall Microelectronics is the global leader in filtration, separations and purification technologies for the microelectronics industry. It supports photovoltaics, semiconductor, data storage, fiber optic, advance display, ink jet, and materials markets with a comprehensive suite of contamination control solutions for chemical, gas, water, chemical mechanical polishing (CMP) and photolithography processes. Integrated circuits, which control almost every device and machine in routine use today, simply would not exist without sophisticated purification technologies.

Our strategic diversification into the macro electronics side of the market is enabling us to capitalize on demand for computer gaming consoles, MP3 players, flat panel displays, multimedia cell phones and ink jet printers and cartridges.

Pall's experience in these markets and applications positions Pall to be a valued partner in the photovoltaics industry.



**“Over recent years,  
Pall technologies  
have contributed to the  
rapid growth in the  
manufacturing of solar cells.”**

# Pall Total Filter Value Chain for Photovoltaics

## Filtration for Process Consistency

A manufacturing process consists of many steps, each fraught with potentially costly problems. A dirty fluid stream can decrease productivity and lead to high rejection rates. Pall filtration devices are designed to be deployed in strategic locations in the process stream in order to maximize productivity and profitability. A filtration device, for example, can protect a critical orifice (i.e. a cleaning nozzle) so that the openings do not become clogged and cause downtime. If the fluid in question is re-circulating, bath lifetime can be maximized by placing a filtration device in the line. Removing haze or dust are other reasons for using filtration. This is exemplified by the increase in tool up-times that can be achieved with proper filtration to protect vacuum pumps.

Finally, since gases are fluids, the removal of aerosols or mists can be achieved with high efficiency elements known as coalescers. Vapors can be removed with activated carbon filters and molecular contamination can be removed by purification technology. Cleaner gases lead to reduced defects within thin film layers.

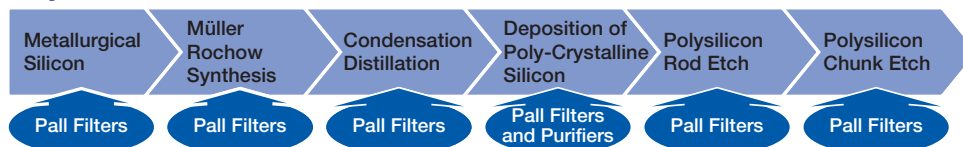
**“Pall filtration devices in the process stream maximize productivity and profitability while minimizing problems.”**

## Pall's Value Chain for Photovoltaics

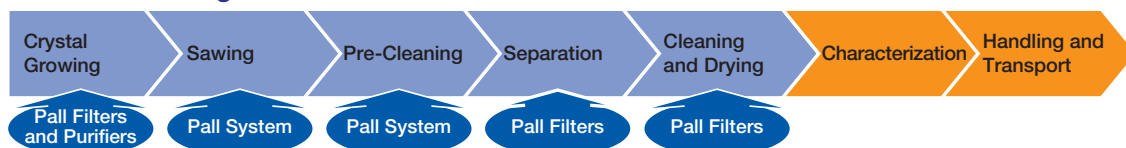
Pall has designed specific filtration technologies for almost all process steps from polysilicon manufacturing, ingot growing and wafering to cell processing. Pall also addresses waste treatment for slicing slurry, water/silicon reclamation in pre-shaping operations and puller exhaust gas dust abatement. There are many steps in thin film processing, however Pall provides filtration, purification and separation solutions for substrate cleaning, chemical bath deposition, thin film deposition and reclaim applications. The following pages show these diverse products.

Pall, through Total Fluid Management<sup>SM</sup> (TFM) filters literally all process fluids. Ask us about our solutions for ultrapure water, process cooling water, bulk gases and bulk chemical filtration.

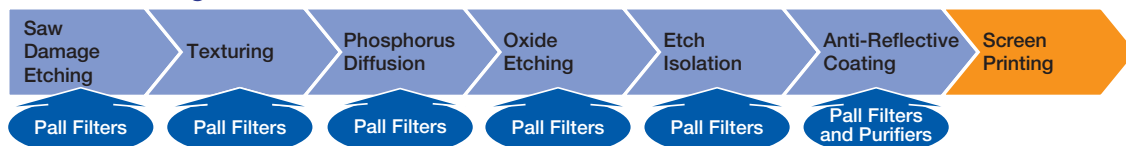
### Polysilicon Material



### Wafer Processing



### Cell Processing



Ultipleat<sup>®</sup> High Flow Housings for large liquid flow rates like process cooling water



Microza<sup>®</sup> OLT Modules for Ultrapure water make up



Pall Advanta<sup>™</sup> Housings for bulk gas filtration



High-Flow Emflon<sup>®</sup> Filters for large gas flow rates

# Polysilicon Material

## Purification and refining of metallurgical silicon

### Process Overview

The process of producing polysilicon (PS) begins with refining quartz or sand into metallurgical grade silicon, which is then purified in a series of chemical reactions. Next, during the Müller Rochow process, purified metallurgical grade silicon reacts with hydrogen chloride at elevated temperatures in the presence of a catalyst, to produce trichlorosilane (TCS).

The TCS gas is cooled and liquified. Impurities with higher or lower boiling points than the TCS liquid are then removed using distillation. The refined TCS is now ready for use in reactors that make PS.

The TCS liquid is vaporized, mixed with hydrogen gas and reduced in either a Chemical Vapor Deposition (CVD) furnace resulting in PS rods; or, Fluid Bed Reactor (FBR) to produce PS granules. Exhaust gases which are released during this process are cooled, liquified and distilled, yielding the co-products silicon tetrachloride (STC) and TCS, which is recycled.

Hydrogen recycle is an important unit operation in PS production. Exhaust gases consisting of hydrogen and chlorosilane from the reduction reaction are recovered. The hydrogen goes through a clean up process and is then recycled back to the reduction plant in a continuous recovery loop.

### Applications for Pall filtration products

- Catalyst fines must be separated from the product stream during the Müller Rochow process. This can be accomplished with Blowback elements made of either ceramic or a special alloy of PSS® filter media.
- Newly produced or recycled liquid as well as gas phase TCS, are filtered before the reduction reaction. The level of filtration will depend on each site's requirements. Rigimesh® metal filters are utilized for coarse applications, with all-fluoropolymer Emflon® PF cartridge filters for submicron requirements.
- Feed gases to the reactor are filtered to submicron levels to protect critical control valves and maintain purity within the reactor. Reactor vent applications capture valuable solid product using cleanable PSS metal filters, with Blowback technology as an option (refer to page 5). Recovering product from vent streams increases process yields, reduces loading to pollution control systems and protects downstream equipment from PS build-up. High capacity filtration systems allow for complete production campaigns.
- Where a recycle hydrogen compressor is used, filtration with Pall metal filters and polishing membrane cartridges protects the compressor from PS deposits and reduces expensive compressor maintenance and associated process downtime.
- Caustic baths followed by water rinsing are used to clean metal filter elements by dissolving off the PS particulate. These baths are filtered with Profile® II and Profile UP filters to recover the PS and keep it from contaminating waste streams.
- Depending on the final product, there may be an etching step on the final ingots, rods or granules using either hydrofluoric and/or nitric acid. These etch baths as well as downstream water rinses are filtered to submicron levels using Emflon PF cartridges.
- Pall provides filtration products and systems for varying grades of water, including ultrapure and wash water, as well as wastewater where there may be a requirement to remove or recover PS fines.

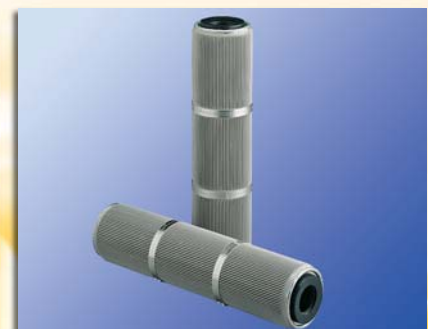
**“Contamination control from the very beginning of the polysilicon manufacturing process has a high impact on final yield.”**



Ceramic Filter Elements for hot gas filtration



Emflon PF Filters for critical chemical filtration



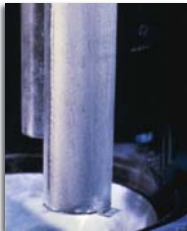
Rigimesh Filters for coarse TCS filtration

# Crystal Growing

## Protection of Vacuum Pumps with PV Blowback Filtration Units

The exhaust gases out of Czochralski pullers used for monocrystalline ingot growing contain dust particles that form by condensation above the silicon melt. This dust needs to be filtered to protect people, the environment and the vacuum pumps. Fine silicon dust is highly reactive and immediately oxidizes to SiO and SiO<sub>2</sub>, an exothermic reaction. Depending on the dopant this dust can be very hazardous.

Pall has extensive experience in this application. Pall PSS stainless steel filter elements and housings in combination with our Blowback technology are the best long-term proven solution in the industry.



Blowback operation - clean cartridge



Blowback operation - cake formation



Blowback operation - gas blow back



Blowback operation - fines removal



PV Blowback filtration unit



PSSPV elements

**“Fine silicon dust needs to be filtered to protect people, environment and the vacuum pumps.”**

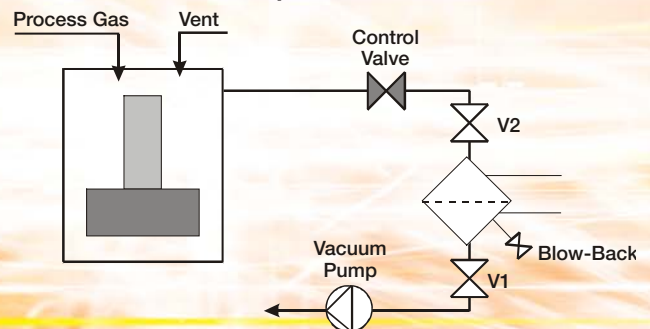
### Traditional filter technology:

- Dust removal with disposable filters requires opening of the filter housing during filter change-out which exposes operators to dust and contaminates the pumps environment
- Oxidation of Si/SiO to SiO<sub>2</sub> is exothermic and traditional filter media typically cannot repeatedly withstand the high temperatures, leading to loss of filter integrity. This results in passage of the abrasive silicon potentially damaging the pump.
- Frequent filter change-outs result in long process downtimes and high cost of ownership.

### PSS Filter Media with Blowback Technology:

- Pall has the most efficient, proven long-term solution on the market
- The filter housing does not need to be opened for dust removal
- Cleaning is quick and automated after each cycle using the Blowback technology
- Oxidation of the Si/SiO to SiO<sub>2</sub> occurs in the filter vessel under well controlled conditions
- Extremely robust PSS filter elements are resistant to high temperatures and provide optimum retention of the silicon dust
- These filtration units are available semi or fully automated
- Blowback units are typically in service for several years without a filter change-out
- Cost of ownership model shows return of investment (RoI) in one to two years
- No leakage, long pump life, low cost of ownership are the hallmarks of the Blowback Units

### PV Blowback Unit Set-up



# Recover Your Waste

## Process Water and Silicon Reclamation

Shaping of silicon ingots prior to wafering comprises several cutting and grinding operations. Large quantities of water must be used to cool tools and silicon surfaces, to act as a lubricant and to remove the resultant silicon fines. The spent process water leaves the tools highly contaminated by silicon particles.

Pall Corporation introduces a new generation of fully automated separation systems for the reclamation of water and silicon sludge from the spent grinding/sawing water. The systems enable PV wafer manufacturers to:

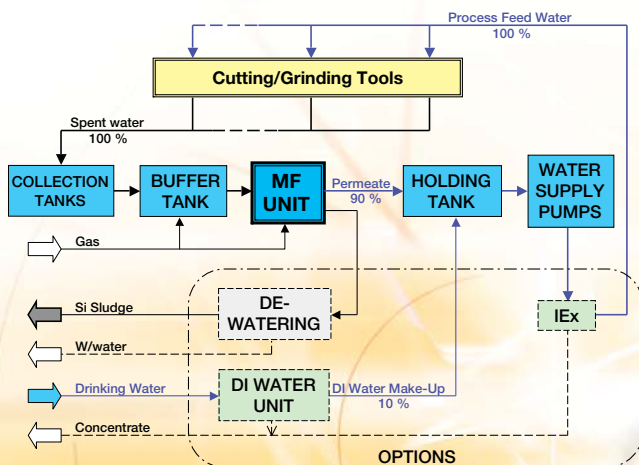
- Re-use up to 95 % of spent process water as high quality water
- Reduce wastewater discharge volumes
- Improve sawing/grinding performance by controlling process water specifications
- Reduce machine fouling and uncontrolled sedimentation in pipes, tanks and sinks
- Reduce chemical hazards due to silicon-water interaction by controlled pre-treatment of spent process water
- Collect de-watered silicon debris having very little chemical contamination, as feedstock for silicon re-use. The heart of such a reclaim system (see diagram below) is a dynamic membrane filtration (MF) unit combined with physico-chemical treatment of the concentrated silicon.

**“Spent process water from saws and grinders are highly laden with silicon fines.”**

The systems clarify the contaminated process water. Typically 90 to 95 % of the contaminated process water is perfectly clarified ready for re-use. The remaining concentrate may be discharged, mixed with other wastewater streams, or subjected to additional treatment to meet discharge regulations or to de-water the silicon debris. Other options are available on request.

Pall has over 20 systems, treating 3 to 33 m<sup>3</sup>/h silicon containing wastewater, operating successfully throughout the world.

The photograph below shows a dynamic filtration unit designed for 30 m<sup>3</sup>/h (7925 usg/h) silicon grinding/sawing wastewater. It provides 2 x 75 % architecture for safe process water supply.



Reclaim of spent grinding/sawing water



Automated microfiltration system for PV silicon grinding/sawing water reclaim

# Purify for Enhanced Efficiency

## Gas Applications

To meet the continuing quest for increased efficiency with ecologically sound technologies, Pall offers a line of purifiers to remove harmful molecular contaminants from process gases.

### CZ Pullers

AresKleen™ INP medium purifies the argon used as a blanket within CZ Puller tools.

- Crystalline defects are minimized during silicon ingot growing
- Additional remelting steps are reduced or eliminated

### Distribution Equipment

Our High-Flow Emflon®, Gaskleen® Light, Ultramet-L® Light and Gasket-Sert™ filters are used to remove particulate throughout the entire gas delivery systems from the bulk supply to the point-of-use (POU).

### Thermal Deposition

AresKleen SIP medium purifies both hydrogen and silane gases used in thermal deposition processes.

- Removes siloxanes, moisture, oxygen and other detrimental contaminants which can lead to defects in the film layers

## Gas Solutions

Pall offers a line of purification and filtration products that deliver the highest purity gases required by the makers of photovoltaic devices.

### Gaskleen Purifier Assemblies

Gaskleen purifiers remove molecular contaminants from process gases used in the production of solar cells:

- Purifiable gases include nitrogen, argon, hydrogen and silane
- Moisture, oxygen and carbon dioxide are removed to < 1 ppb. Siloxanes are also removed from silane gas
- Flow rates up to 1,000 slpm.
- All purifier assemblies contain integral particle filtration

### Gaskleen Light Filter Assemblies

Assemblies are designed to provide high-purity gas filtration for the photovoltaic market:

- All fluoropolymer cartridge in a stainless steel housing
- > 3 nm particle removal
- Broad compatibility with process gases
- Standard and high flow configurations
- Manufactured using less raw material and energy compared with standard products
- Environmentally friendly packaging

### ChamberKleen™ Diffusers

Gas diffusers are ideally suited for vent applications on load lock interfaces or other vacuum chambers where large volumes of gas are flowing for a short period of time:

- Unique design distributes the gas in a 360 degree radius, minimizing turbulence in the chamber.
- Fast vent times are achieved with proprietary, low pressure drop metal media
- Available with NW16, NW25 or NW63 ISO flanges

### Ultramet-L and Gasket-Sert Metal Filter Products

Developed for applications that are particularly sensitive to pressure drop and have limited space:

- All stainless steel construction
- Available in 3 nm and 0.4 µm removal ratings
- 1/4" or 1/2" gasket seal fittings



Gaskleen Purifier Assemblies for gas purification



ChamberKleen Diffusers for load lock interfaces and vacuum chambers



Gaskleen Light Filter Assemblies for gas filtration



Ultramet-L and Gasket-Sert Metal Filter Products for gas filtration

# Filter for Process Consistency

## High Flow Chemical Filtration for Thin Film Solar Module Manufacturing

Ultipleat® PK Filtration products are designed for chemical and DI water processing on large substrates. Fine filtration is especially important for film integrity during thin film processing. Clean substrates are required for consistent high module quality.

### Ultipleat PK Filters

- Can handle flow rates from 200 to over 400 L/min, depending on removal rating
- Reduced system footprint and low change-out costs
- Available in 3 filter media types
- Removal ratings from 0.1 to 40 µm
- Polypropylene (2, 4.5, 10, 20 and 40 µm)
- PTFE (3, 5 and 10 µm)
- Polysulfone (0.1, 0.2, 0.45 and 1 µm)

### Ultipleat PK Housings

- Available in stainless steel and polypropylene
- Operating conditions:
  - PP - 0.4 MPa / 58 psi at 45 °C (113 °F)
  - SST - 1 MPa / 143 psi at 90 °C (194 °F)



Ultipleat PK Filters



Ultipleat PK PP Housing



Ultipleat PK SST Housing

## Chemical Filtration for Recirculating Bath in Crystalline Silicon Cell Processing

Pall filters reduce particulate contamination on the wafer surface in cleaning and etching. Pall filters protect critical orifices (i.e. a cleaning nozzle), preventing openings from becoming clogged and causing downtime. If the fluid in question is re-circulating, reclaim value can be maximized by placing a filtration device in the line. Get the most out of your chemical bath using Pall filters.

Pall offers an enormous choice of suitable filtration products. Depending on compatibility, flow and particle removal rating we offer the best value filter products. Profile A/S filters, for example, are specially designed to provide cost-effective solutions for hot, and/or highly contaminated, aggressive chemicals and are, therefore, ideally suited for alkali texturization.



Megaplast™ Housing



Profile A/S filters



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