# AQUEOUS CRITICAL CLEANING: A WHITE PAPER

*THE SIGNIFICANCE IN SOLAR MODULE MANUFACTURING*


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# The Significance of Critical Cleaning for Solar Module Fabrication

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## ABSTRACT

*With increased governmental commitments to support renewable energy initiatives, winners and losers in solar module fabrication will be determined more quickly and by a variety of factors. One factor will be the elimination of defects to increase yields in the manufacturing process. Critical cleaning of substrates and superstrates is an essential component in achieving an optimal solar module fabrication process which reduces the cost per watt. Depending on the material being cleaned and the cleaning process employed, various Alconox products, including ALCONOX, DETOJET, LIQUINOX, CITRANOX and CITRAJET, have already been selected by major manufacturers as the critical cleaners of choice to reduce or eliminate manufacturing defects in solar module fabrication and are being employed in additional emerging processes.*

## THE RACE FOR COMPETITIVE COST

Solar energy production has doubled every two years since 2002. Now, recent political and economic factors augur well for even greater governmental and industry interest and investment in solar energy research, development, and expanded commercial application. And, while this renewed attention is welcomed by many of the various players in the industry, expectations will be correspondingly higher for significant results beyond current growth rates.

The first criteria used to judge the success of solar energy technology is the achievement of competitive costs per watt compared to other technologies. While prices of various mature energy technologies are primarily subject to market forces, current photovoltaic (PV) solar energy costs are more closely related to technological innovation, material choice, and fabrication efficiencies. Achieving lower costs per watt - in concert with the selection of the appropriate technology for a given application as well as the imposition of various national and international tariffs, subsidies, and incentives—will drive increased adoption in the commercial marketplace.

In short, the time may finally have arrived for the solar revolution that many have trumpeted for decades.

## THE IMPORTANCE OF OPTIMIZATION OF THE MANUFACTURING PROCESS

Many technologies currently exist that have achieved significant milestones, from well-established crystalline silicon wafer technologies to super-efficient thin film GaAs-based cells. Numerous emerging technologies, like organic PV, and high-efficiency technologies, like inverted metamorphic multijunction cells, are being accelerated through development and may find more general applications sooner rather than later.

Winners and losers will be chosen based on many criteria, but optimizing the manufacturing process to achieve maximum quality throughput will be essential to all successful solar module fabricators regardless of the underlying materials and technologies selected. And because solar energy modules are produced by employing precise manufacturing processes (e.g. sputtering deposition, spray, or spin) fabrication errors can significantly impact costs.

## THE IMPORTANCE OF CRITICAL CLEANING TO THE MANUFACTURING PROCESS

Currently, according to the National Renewable Energy Laboratory (NREL), a host of potential reliability failures have been identified which can adversely affect manufacturing throughput as well as panel output. These range from delamination, to junction box failures, to busbar adhesion problems, shunt hot spots, scribing errors, and many others. Optimizing the manufacturing process and maximizing quality processes pays immediate dividends by reducing or eliminating fabrication defects and ensuring productivity and lower net costs per panel.

But regardless of fabrication technique, optimization cannot be achieved without ensuring that material surfaces are immaculately prepared for manufacturing techniques like precise scribing or deposition processing.

In order to avoid fabrication errors that compromise efficiencies and performance, substrates must be cleaned at the start of manufacturing as well as after each significant residue-creating process throughout the manufacturing process as a whole.

For this reason, critical cleaning of substrates and superstrates plays an integral role in the optimization of all solar module fabrication approaches.

## SOLAR MODULE CRITICAL CLEANING

Because of the stringent quality parameters associated with solar module critical cleaning, many early manufacturers sought proven products to protect their investment. ALCONOX powdered detergent had an excellent reputation for quality and consistency of products derived from extensive use by laboratory, cleanroom, semiconductor, vacuum processing, and GMP manufacturing customers.

In Europe, Asia and North America, ALCONOX powdered cleaner has now been used to clean original mono-crystalline silicon solar cells in ultrasonic bath batch cleaning for decades. It has been specifically recommended by manufacturers and specified in a number of cleaning processes such as ultrasonic tank cleaning of PV silicon cells.

As new thin film, concentrator and emerging organic photovoltaics have been developed; there have been ALCONOX products developed to meet the needs of various substrates and superstrates of various materials. For example, large glass superstrates of transparent conductive oxide coated glass can be cleaned prior to manufacturing and during manufacturing using large horizontal conveyor washers with DETOJET cleaner. The combination of dispersants and cleaning agents results in excellent particle control and debris free surfaces. The dispersants are able to lift particles into solution by overcoming the electrostatic attractions to the hard surfaces and by reducing the hydrophobic tendency of the surface of the particle, thereby rendering it more water dispersible. The cleaning agents remove hydrophobic oily films that can interfere with the particle removing action of the dispersants.

Because of its track record for effective surface cleaning and ability to rinse freely from hard surfaces without leaving any interfering residues, ALCONOX was selected as the cleaner of choice in the thin film solar module fabrication process that produces the world's largest solar panels. The process has achieved certification for both its single and tandem junction solar PV modules according to International Electrotechnical Commission (IEC) standards 61646 and 61730.

## CRITICAL CLEANING METHODOLOGIES DEPEND ON APPLICATION AND MATERIAL PARAMETERS

Thin film solar module manufacturing requires scrupulously clean substrates in order to optimize the production of efficient photovoltaic components. Thin film photovoltaic cells are typically made by the vapor deposition of silicon (Si) or Cadmium/Telluride (CdTe) layers on transparent metal oxide coated glass superstrates; or by the vapor deposition of copper indium/gallium selenide (CIGS) on thin metal film. In either case, prior to deposition, the glass or metal must be clean and free of particulates and oils that will interfere with proper film deposition and electrically isolated solar cell formation.

Failure to achieve a clean surface affects quality later during the fabrication process when glass superstrates are laser scribed to form isolated cells. Any particulates on the bare glass or oxide coatings can result in poorly formed scribe barriers that cause short circuits and inefficient performance of the resulting cell.

Substrates must be cleaned after laser scribing as well. DETOJET cleaner is commonly used for cleaning glass and coated glass substrates both before and after laser etching. CITRAJET is preferred for metal substrate cleaning. Typically large conveyorized spray and roller brush washing units are used for both surfaces followed by rinsing and drying prior to further processing.

In systems that employ batch ultrasonics for cleaning stainless steel and copper substrates, CITRANOX is the appropriate choice. Even after decades of use, the original ALCONOX powdered detergent is still applicable for ultrasonic cleaning of monocrystaline silicon cells. And for glass and metal substrates cleaned using batch ultrasonics, LIQUINOX is the proper choice. SOLUJET is also an appropriate choice for the removal of oily residues in a variety of cleaning systems.

## THE OPTIMAL CRITICAL CLEANING PRODUCT CAN POSITIVELY IMPACT BOTH PRODUCTION AND PERFORMANCE

As the solar module fabrication marketplace evolves to encompass disparate locations on multiple continents, maintaining quality standards requires reliable products and suppliers.

ALCONOX products have achieved global acceptance in the PV fabrication marketplace because of a reputation built over decades in many demanding applications, consistent manufacturing standards, high purity, knowledge about impurities and comprehensive technical support worldwide.

As technologies mature, emerging technologies stabilize, and future technologies are developed, critical cleaning will continue to play a significant role in the quality and efficiency of PV panels.

One measure of the importance of critical cleaning is the presentation of a recent study by Walker, et al* comparing various critical cleaning detergents used in the solar module fabrication process.

Manufacturers have embraced the challenge of meeting tomorrow's energy needs with innovative solar technologies. No one yet knows which solutions will ultimately triumph in the competition for lowest cost per watt and ease of deployment. But there can be no question that clean technology can only come from a critically clean process.

*Walker B, et al., EFFECTS OF PRE-PECVD GLASS CLEANING ON MODULE PERFORMANCE, 22nd European Photovoltaic Solar Energy Conference and Exhibition – Milan, VISUAL PRESENTATIONS 3BV.4 Amorphous and Microcrystalline Silicon CIS, CdTe and Other (II-VI) Ternary Thin Film Cells, pp 2226-2228

## ABOUT THE AUTHOR

*Malcolm McLaughlin is Vice President of Product & Business Development at Alconox, Inc., a leading developer and manufacturer of critical cleaning detergents. He has over 25 years of detergent formulation and application experience, including consulting on projects to clean semiconductors, photovoltaics and electrical substrates in manufacturing. He earned his M.A. in chemistry from Columbia University. He can be reached at the White Plains, NY, office of Alconox, Inc. at +914-948-4040 or mmclaughlin@alconox.com.*

## HOW TO DEVELOP A CLEANING PROCESS FOR PV MANUFACTURING

An essential component in the development of a new PV manufacturing process is the creation and optimization of critical cleaning procedures. Contacting an experienced cleaning supplier, such as Alconox, Inc., can provide guidance based on familiarity with the challenges and variables inherent to the process.

An experienced partner should be prepared to recommend appropriate cleaners, supply samples for testing, and recommend initial time, temperature, concentration, rinsing and drying conditions for your specific system. Variables they will take into consideration during your initial test phase include your desired cleaning method and your substrates, superstrates and residues.

For example, to clean sheets of conductive coated glass to remove dust, fingerprints and debris at the beginning of the manufacturing process in a conveyorized horizontal washer, you should try using a 1% solution of DETOJET at 45°C at a rate of 1.5 meters per minute, for a total contact time on the order of 30 seconds prior to the rinse station.

Another example would be cleaning copper or stainless steel substrates prior to PV film deposition in batchultrasonic cleaning. In this case, use a 2% CITRANOX solution at 60°C for 5 minutes of dwell time in the tank.

A final example would be cleaning stainless steel substrates in a conveyorized horizontal washer where oily residues are a particular concern. Here, use a 1% SOLUJET solution at 60°C at line rates of 1.5 meters per minute, for a total contact time of roughly 30 seconds prior to the rinse station.

Each of these examples represents a benchmark to determine the optimum cleaning process for a given fabrication methodology. Following these initial trials, you can then run experiments by raising the temperature and increasing the line speed or reducing the dwell time. You might lower the concentration of detergent to determine the minimum required concentration. It is even important to experiment with rinsing methods and timing to determine optimum cleaning conditions. As a rule of thumb, every 10°C you go up in temperature, you can double the line speed or cut the dwell time in half and still get the same cleaning results.

One national laboratory currently employs the following detergent cleaning process for glass (both before and after TCO coating) in thin film processing—ultrasonic cleaning with a 5% solution of ALCONOX in 12 Mohm-cm deionized water at 60°C, followed by rinsing in clean 60°C deionized water, followed by rinsing in cold deionized water.

Whatever your process, there is an ideal combination of method, material, and detergent that will optimize the performance of your fabrication method and the quality of your technology. An experienced partner can help you find it—efficiently and cost-effectively.

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To read more about critical cleaning, request your FREE copy of The Aqueous Cleaning Handbook or Critical Cleaning Guide by clicking here.


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