# Automation Control for Anti-Reflective Coating Equipment

## Advantages

- **Maximum Flexibility** — Easy synchronization to upstream or downstream equipment
- **Quick Operational Parameter Access** — Select and store operational parameters and set points
- **Faster Development/Troubleshooting** — Pre-built and tested Add-On-Instructions (AOI) with Human Machine Interface (HMI) faceplates provide detailed diagnostics
- **Data Access** — Pre-built information enabled code structures for quicker implementation of data collection needs such as Overall Equipment Effectiveness (OEE), production scheduling and historical process data
- **Integrated Motion** — One development platform for motion and control
- **Modular Code for Batch Processing** – Equipment Modules, Control Modules and State Machine structure offers code re-use and simplifies customization
- **Integrated Drive Control** — Pre-built and tested AOIs and HMI faceplates speeds deployment of networked drives
- **Process Optimization** — Advanced Process Control (APC) and closed loop process control improves process consistency and line stabilization
- **Reduce Raw Material Usage** – Servo motion control reduces gaps between glass panels to limit waste
- **Global Support with Local Resources** – Network of knowledgeable resources offers timely support of hardware and software components

*Photo courtesy of XeroCoat, Inc.*
*www.xerocoat.com*

## Glass AR Overview

Solar panel manufacturing includes the application of an anti-reflective layer or coating to the top sheet protective glass. Light from the sun must pass across the interface between air and the glass, and at this interface 4% or more of the light will be reflected. The anti-reflective layer maximizes the light available to be converted into electrical energy by reducing reflectance. An optimum anti-reflective layer will transmit light from the entire solar spectrum independent of the sun's angle in relationship to the panel. A high quality anti-reflective layer increases the panel's conversion efficiency and can reduce the cost per watt.

In a typical solar photovoltaic (PV) module, whether it is based on crystalline silicon or thin film technologies, sunlight is converted directly into electricity by semiconductor materials ("solar cells"). These cells are electrically connected and encapsulated beneath a protective cover plate, forming the solar PV module. The cover plate serves the dual purposes of providing mechanical strength to the module and protecting the delicate and valuable solar cells from environmental damage. Glass is an ideal material for this role - it is transparent, relatively impenetrable to water and other environmental agents, durable, and most importantly it is economical and broadly available in large quantities.

Most PV modules sold and installed in the world today use a glass cover plate which is laminated onto an assembly of solar cells and a backing material which is typically a polymer film (refer to figure 1). The lamination film material used in PV modules provides the adhesive that holds the module together for 20+ years in the field. Because the lamination material and glass have very similar refractive indices, there is a very low reflective loss at that interface. Only the external, sun-facing, side of the cover glass needs to be coated with an anti-reflection treatment.

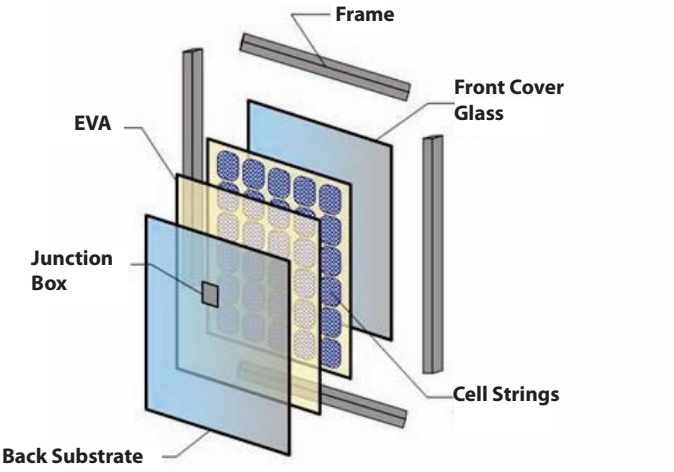



*Figure 1 –For modules based on crystalline silicon cell technologies the glass cover plate is made from low-iron cast or rolled glass often with a texture imparted to the lamination side of the glass, the lamination film is commonly ethylene vinyl acetate (EVA), the PV cells are mono- or poly-crystalline silicon wafers, and the backing film is polyvinyl fluoride.*

Various technologies including Dip, Roll, Spray, PVD and Etch are used to apply an anti-reflective layer to the protective glass. Key features such as transmission over the solar spectrum, angle transmission, aesthetics and durability will vary based on the chosen technology.

For crystalline manufacturing, the cover glass can be purchased with the anti-reflective coating pre-applied. In recent years, advances have been made using new materials and process technology tosimplify the coating application and reduce the need for harmful chemicals or gases. **New technology from XeroCoat allows the equipment to be included in an in-line process for thin film and crystalline manufacturing.** This gives panel manufacturers more options for controlling the quality and efficiency of their finished product.

**Cell AR Overview**

An anti-reflective layer is also placed on cells produced from the crystalline silicon manufacturing process. The coating is applied to the front side of the wafer to increase the solar cells absorption of the sunlight and improve the cell's electrical characteristics. Reflection at both the glass and cell interfaces must be addressed to maximize panel performance.

Anti-reflective layers applied to the silicon wafer cell often use Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD) or Atomic Layer Deposition (ALD) processes. The most common methods used today are the plasma enhanced CVD process and the sputtering process which is a physical vapor deposition process. Factors to consider when selecting the process technology to apply an anti-reflective layer include performance, reliability, manufacturability, and cost.

**XeroCoat**

XeroCoat has developed a unique process for applying a layer of porous $SiO_2$ to glass where the porosity and the thickness of the layer can be tightly and independently, controlled. The patented XeroCoat process starts with an all-liquid solution that is coated onto the glass surface to form a uniform layer with the proper thickness. The coated glass is then exposed to a gaseous catalyst during the curing stage. This drives the coating system to self-assemble into a finished porous $SiO_2$ layer with a low index of refraction that provides excellent optical and mechanical properties.

The entire process takes place at room temperature and at atmospheric pressure, requiring no ovens, vacuum chambers or pressure vessels. The simple chemistry and equipment mean that the XeroCoat process can be performed at low cost. This chemical process results in a covalently bonded coating that exhibits a very high level of durability.

**Hardware and Process Overview**

Material handling equipment is used to load/unload the cell substrates and move them through the process zones and chambers. The same is true for moving the glass through the coating process and curing modules. Measurement and inspection of the deposited anti-reflective layer is also included.

Key process control capabilities differ for each technology but tight process control is required with all of the technologies. Some processes require tightly controlled chamber environments (temperature, pressure, exposure time) while others require tightly controlled substrate temperatures. All require control of chemicals and gases to control for the reactions to yield a high quality, uniform layer. Depending on the toxic or corrosive nature of the chemicals or gases used, special gas detection or leak detection monitoring may be needed.

System control for anti-reflective coating equipment usually includes a Programmable Automation Controller/Programmable Logic Controller (PAC/PLC) and industrial computer running HMI software. Some systems may also include a dedicated operator interface panel. The controller runs a recipe with parameters for critical control including substrate temperature, chamber temperature and pressure, gas flow rates, liquid coating level, roll coating speed, sputtering magnetron spindle speed and power density and frequency.

The main system controller often needs to interface to dedicated gas and chemical distribution panels. These panels are usually equipped with their own control system which includes a small PAC/PLC and a local operator interface panel. The local panel is used when replacing raw materials and purging supply lines.

Communication between the system controller and the distribution panel controller can be implemented via a communication network such as EtherNet/IP or hardwiring the critical control signals between the systems using interposing relays.

The material handling systems used for the cells or glass may include robots to load or unload the material, a servo motion controller to accurately position the material in chambers, and drives to convey the material from one zone to another.

The control system also has the option for real-time level monitoring and tracking of material usage. The operator can easily track the substrate through the system and monitor equipment and process performance through the HMI. The industrial computer handles the recipe storage, historical data logging and reporting functions.

## Solution

Rockwell Automation offers solutions to help monitor and control the equipment used to apply the anti-reflective coating layer. Central to the solution for coating equipment is the Rockwell Automation Integrated Architecture™. Integrated Architecture combines a powerful multi-disciplined control engine, seamless networking, a scalable visualization platform and the information technologies needed to help lower your Total Cost toDesign, Develop and Deliver℠ a machine.

Unlike conventional control architectures, the Integrated Architecture provides fully integrated, scalable solutions using a single control platform and a single development environment. This helps machine builders shorten design cycles and increase their focus on innovations that lead to a competitive advantage.

Subsystem vendors can use their own controllers and easily integrate with the main controller over a network. The main controller coordinates the process as the substrate material moves through the various zones and processing chambers.

The coordination controller can take advantage of the process control capabilities and integrated network drive control within either the Allen-Bradley® CompactLogix™ PAC or ControlLogix® PAC. Material handling systems can either connect to the main coordination controller directly via Kinetix® integrated motion or be delivered with a subsystem controller and Kinetix integrated motion.

Gas and chemical delivery systems can use a CompactLogix PAC or a MicroLogix™ PLC. Connecting a PanelView™ Plus local operator interface panel to either controller provides a view into the raw material distribution system.

Controllers can easily communicate to one another over an EtherNet/IP™ network that uses the Common Industrial Protocol. Data transfers can be implemented on a scheduled periodic rate or on a report by exception basis.

The Rockwell Software® FactoryTalk® Integrated Production and Performance Suite can be used for critical data necessary to monitor and control the anti-reflective coating equipment. Data collection, historical logging of process parameters, real-time trending and enhanced diagnostics are capabilities that can be deployed to help improve equipment operation.

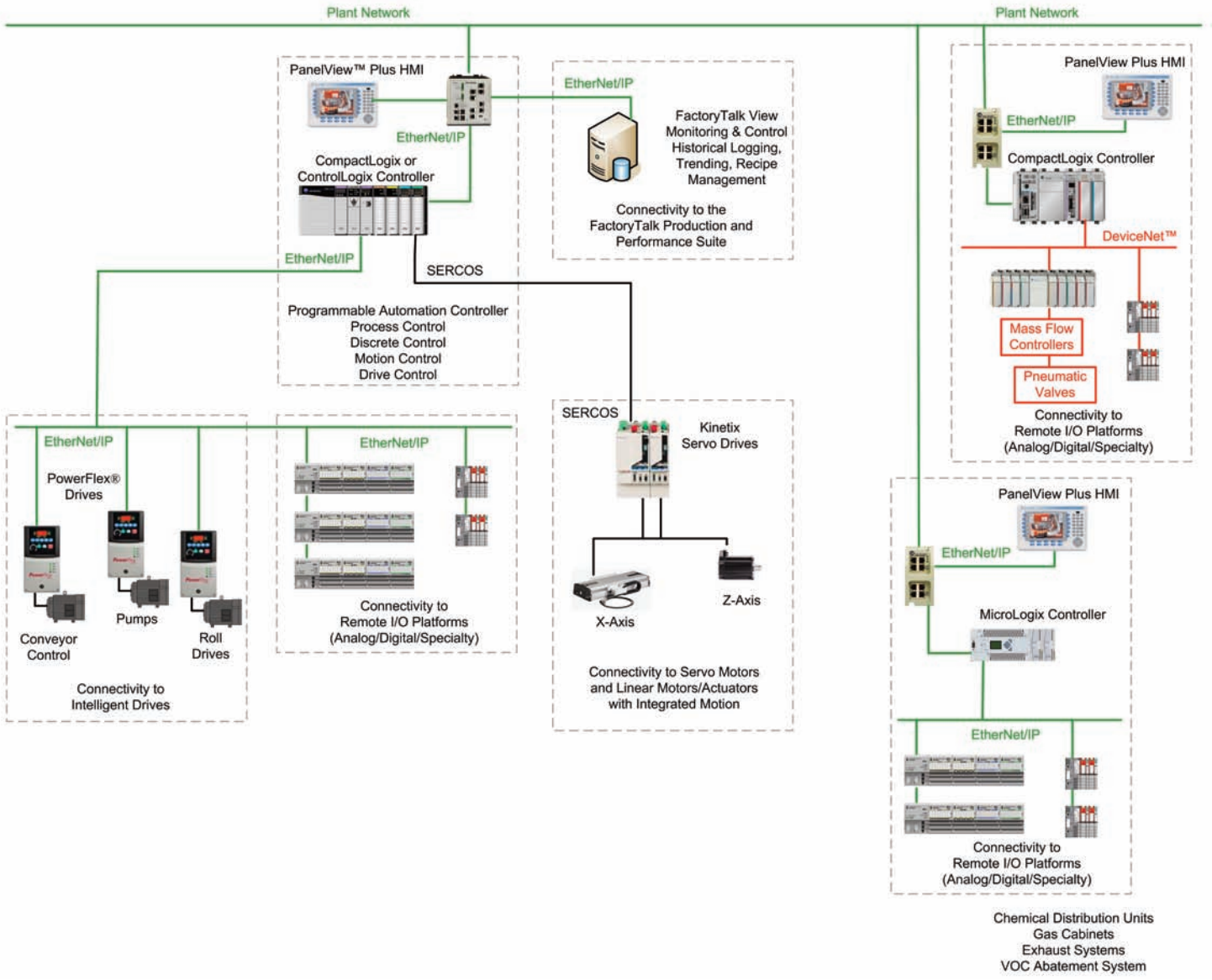
FactoryTalk VantagePoint from Rockwell Automation is a powerful web-based reporting package that brings all data together into a single information management and decision support system.

FactoryTalk VantagePoint can help operators, technicians, and managers visualize the performance of the equipment through reports customized for each. The data can be presented in the context that plant personnel need to make timely decisions.

Premier integration between the Rockwell Automation control and information platforms can help customers provide equipment with standard products integrated to solve specific application requirements. Resources around the globe are available to help support the hardware and software used on the glass coating equipment.

## Typical Architectures

### Coating Equipment with Gas and Chemical Distribution Panels




Rockwell Automation solutions deliver improved production capabilities and help reduce the total cost of ownership by providing unparalleled functionality, flexibility and scalability. Machine builders can respond more quickly to customer or market demands, reduce maintenance costs and downtime and easily gain access to actionable plant and production information for improved management and decision-making.



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