Surface Treating for Solar-Cell Converting

Enercon Industries

The art of optimizing continuous processing techniques for flexible materials has long been practiced in the converting industry. The accrued benefits range from consistent product quality and waste minimization to lower conversion cost per square meter. And a key component in the optimization of many web converting processes is consistent and uniform surface modification by corona discharge, flame or atmospheric plasma treatment systems to raise surface energy and/or clean web surfaces.

Pages are now being torn from the converting manuals by practitioners in the solar and optoelectronics industries. In the solar realm, photovoltaic (PV) cell manufacturing processes are evolving quickly. The quest for the most efficient energy conversion design is feverish, and pressures are mounting to minimize the costs of PV cell fabrication.

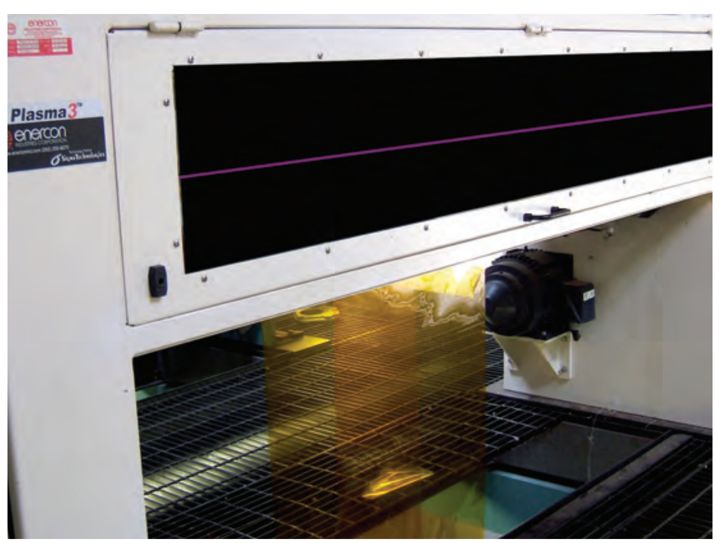
Semi-continuous flow

The prevalent production flows for crystalline silicon and thin film PV solar cell constructions are semi-continuous at best, with a minimum of six processing steps prior to a finished module. With bulk silicon technologies employing wafer-based manufacturing for example, self-supporting wafers between 180 to 240 micrometers thick are conveyed through texturing, diffusion, coating and metallizing processes before they are soldered together to form a solar cell module. Thin film constructions slowly pace through vapor depositions, laser patterning and back contacting processes before a module is completed. However, under development are high-efficiency plastic solar cells to meet for more economically viable alternative energy sources. Polymer-based constructions, such as bulk-heterojunction (BHJ) solar cells are becoming attractive since they can be coated onto flexible substrates by a variety of techniques and therefore enabling inexpensive large-volume manufacturing processes. These constructions demand web optimization techniques to bring these economies of scale to fruition.

Adhesion Issues

Considering the wide range of materials employed to maximize solar efficiencies, adhesion issues are surfacing relative to dissimilarities in surface characteristics and properties. Because the ability to integrate the completely continuous in-line manufacturing of rigid panel and flexible solar cells by utilizing a variable chemistry surface modification technique relative to complex material constructions holds the prospect of significantly reducing in-line continuous manufacturing costs. Atmospheric pressure gas phase plasma technology is therefore becoming an essential enabler for in-line manufacturing of solar cells if major reductions in fabrication costs are to be achieved.

The surface preparation techniques practiced in solar cell manufacturing have fundamentally stemmed from those applied in the past and present for circuit board and related manufacturing processes. Early silicon wafer cleaning processes, for example, have technologically progressed from aqueous, or wet, chemical cleaning and etching approaches to a wide range of alternative dry processes. The latter include gas-phase atmospheric plasma discharges for both two-dimensional and three-dimensional surfaces for removing organic-based layers and residues. These atmospheric plasma regimes are also found being



Atmospheric plasma enhances surface cleanliness, wettability, printability, and adhesion properties.

used in conjunction with supercritical phase carbon dioxide fluid ("snow cleaning") devices for removing particle contaminations where wet chemical approaches can either not be employed or are being reduced due to VOC emission issues.

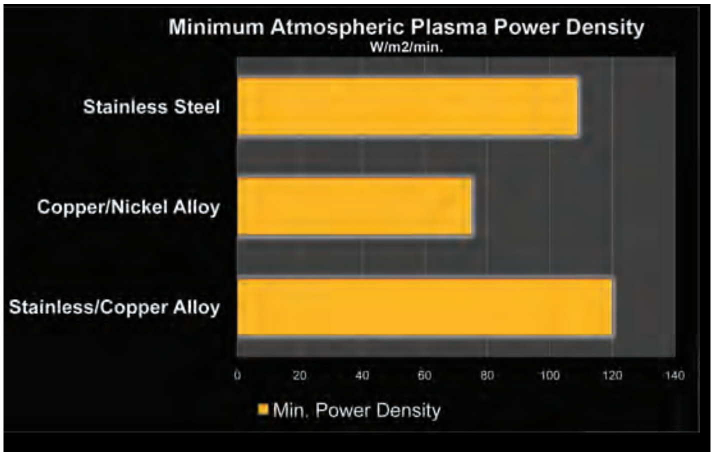
Atmospheric plasma treatment devices allow for completely homogenous surface modification without filamentary discharges (known as streamers), because a uniform and homogenous high-density plasma at atmospheric pressure and low temperature is produced. The atmospheric plasma treatment process modifies material surfaces similarly to vacuum plasma treatment processes - the surface energy of treated materials increases substantially, to enhancements in surface cleanliness, wettability, printability, and adhesion properties.

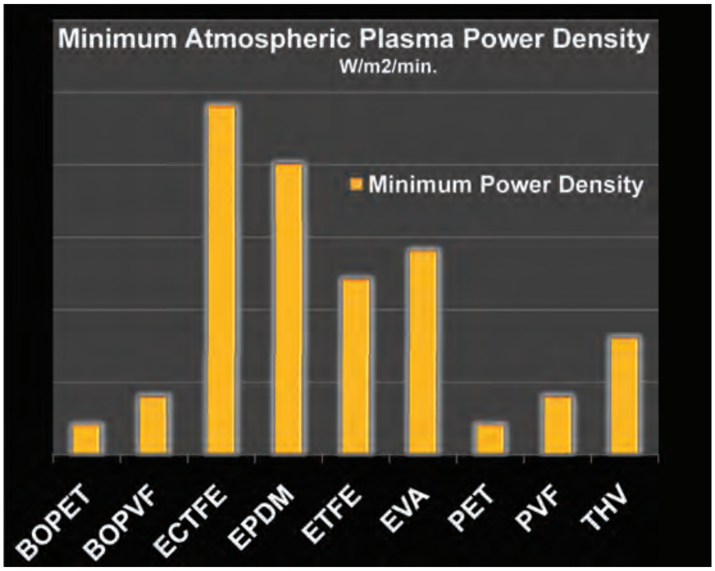
The effect of plasma on a given material is determined by the chemistry of the reactions between the surface and the reactive species present in the plasma. At the low exposure energies typically used for surface treatment, the plasma surface interactions only change the surface of the material; the effects are confined to a region only several molecular layers deep and do not change the bulk properties of the substrate. The surface is subjected to ablation and activation processes. Activation is a process where surface functional groups are replaced with different atoms or chemical groups chosen to react within the plasma.

Process Benefits

The bombardment of solar-related polymer surfaces with energetic particles and radiation of plasma produces the ablation and micro-etching effects. The bombardment by plasma species is able to create a nano-roughness on a polymeric film, for example, that does not modify the mechanical bulk properties of the film but removes low molecular weight surface organics and thereby strongly increases surface adhesion. Where bond strength is required, atmospheric plasma's highly reactive species significantly increase the creation of polar groups on the surface of materials so that strong covalent bonding between the substrate and its immediate interface (i.e., coatings, adhesives) takes place.

Solar cell processes being transferred to atmospheric pressure plasma processes include dry etching, surface cleaning, etching, and activation. Layer reductions using hydrogen-based atmospheric glow discharge plasmas are also an employable aspect of the technology. Solar power is a technology of the future. Successful commercialization of low cost, high efficiency fabrications is highly dependent upon fabrication methods which employ continuous processing techniques. A major issue encountered in solar cell construction is the cleaning and adhesion of many dissimilar materials. The adhesion promotion potential of variable chemistry atmospheric plasma surface modification against wet primer chemistry on a on a polymer-based substrate is just one of many in-line process optimization techniques being adopted by the solar industry.





These two charts show the relative minimum atmospheric plasma power density required to achieve the same end result for a broad range of polymer-based and metal substrates.

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