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Atmospheric Plasma Surface Modification for Continuous Manufacturing of Flexible Power Sources

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The advantages for enabling manufacturing of thin flexible sources of power by roll-to-roll processes are evident. In addition to extremely low production costs, the flexible nature of these devices dramatically enables not only their application within a broader range of stationary and remote devices, but also their integration with other flexible materials. Using atmospheric pressure glow discharge plasma technology as an integrated roll-to-roll or continuous production line process for manufacturing power-generating materials can be key to developing continuous, in-line production processes to create inexpensive and flexible item-level power sources.

The use of atmospheric plasma protocols and gas chemistries is commonly used today for cleaning and functionalizing web- and sheet-based materials for fabricating everything from flexible packaging to flexible circuitry. The technology positively modifies the surface properties of these materials, removing organic contaminations, significantly increasing wettability and promoting interfacial adhesions between similar and dissimilar materials.

One emerging beneficiary of atmospheric plasma technologies in the production of flexible power sources is the field of "organic electronics", a fast-growing segment in which circuits are developed with the use of conducting plastics rather than conventional silicon. Given that organic electronics can inherently be less expensive to manufacture, lightweight and flexible, atmospheric plasma technologies generate a homogenous glow discharge that uniformly modifies the surface of both conductive and non-conductive base organic electronic substrates to optimize the adhesion of electrical components which are deposited onto the base plastic using inkjet printing technology and what are referred to as "electronic inks".

Research and developmental work in the use of atmospheric plasmas for continuous processing of flexible organic electronics initially focused on surface and interfacial adhesion characterizations to improve the performance of these organic flexible devices, and found particular success with respect to the atmospheric pressure plasma treatment of ITO films without negatively affecting resistivity.

In the area of semiconductor films, plasma has been applied to modify the surface of a dielectric deposited by PECVD on low cost polymer, foil or glass substrates. The dielectric is effectively plasma treated using inert gases to effectively reduce the surface roughness of the deposited layer, allowing an organic semiconductor film to grow on the dielectric surface with high mobility. Typically plasma oxidation protocols are most effective in creating this surface modification effect.

In-line processing of flexible circuitry is applying atmospheric plasma technologies to remove carbon contamination on the surface of copper and stainless steel foils and other low molecular weight organics which may inhibit the bonding of microcircuits. In-line roll-to-roll processing of flex circuits greatly reduces cycle time and material handling costs.

Flexible solar cells processed by atmospheric plasma holds unique promise in the commercialization of low cost, high efficiency solar cell fabrications which is highly dependent upon fabrication methods which employ continuous processing techniques. One major issue encountered in solar cell construction is the adhesion of thin film solar cells on polyimide substrates. The adhesion promotion potential of variable chemistry atmospheric plasma surface modification against wet primer chemistry on a polyimide-based substrate has defined atmospheric plasma as a promising continuous and environmentally friendly process alternative to batch plasma and surfactant-based surface modification protocols.

In summary, atmospheric-pressure non-thermal plasmas have become one of the key enabling technologies for in-line processing of flexible power sources. As the need for surface cleaning, activation and high adhesion increases with the use of flexible substrates with low polarity or organics-contaminated surface characteristics, atmospheric pressure plasmas are increasingly answering the call in the flexible electronics space.

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