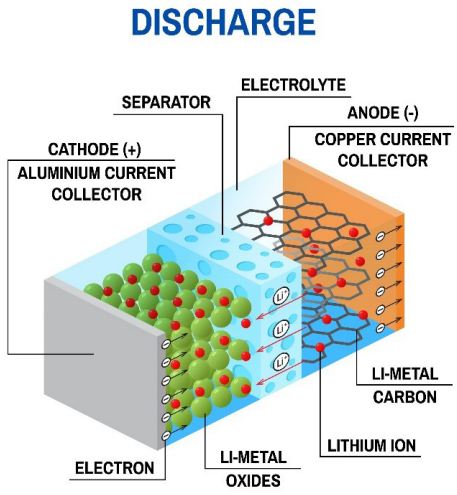
Surface Treating Insights for Substrates Used in Lithium-ion Battery Production

The global demand for high performing Lithium-ion batteries is projected to hit 129.3 billion USD by 2027, at a CAGR of 18% from 2020 to 2027.(1) Critical to supporting this growth is the implementation of efficient technologies that can produce the film and coatings required for these products. Many of the mission critical film substrates used in this market require surface treatment. Surface treatment enables proper coating adhesion which allows the batteries to perform as designed. This article will review important criteria for successful surface treating that enables adhesion without damaging the substrates.

Anatomy of the Lithium-ion Battery

Lithium-ion batteries have four main components: the cathode, anode, electrolyte and separator film. The Cathode determines the capacity of the battery. The Anode enables the passing of currents to an external circuit. The electrolyte facilitates the movement of ions. The separator film provides safety as it prevents contact between the cathode and anode while allowing ions to pass through it.



Within these components, various polymer films and foils are used. The cathode features aluminum, the anode uses copper, and the separator is comprised of an engineered porous polymer film. These substrates are coated and the performance of the battery is heavily dependent on the quality of the coatings.

Surface treating is used to prepare the substrates for bonding by removing contamination, increasing surface energy and enabling wettability. It is critical that surface treating achieves the desired benefit without damaging the films so the applied coatings function as they are intended, without compromising battery performance or safety.

Surface Treating Technology Options

The three main categories of in-line surface treating are corona, plasma and flame. Each method can be highly effective at achieving the results of cleaning organics from the surface and activating surfaces for adhesion. Determining which technology is best for a given application requires a careful review of the proposed application details. It is best practice to always install the surface treater immediately prior to the coating process.

Flame

Flame treaters produce an intense blue flame when flammable gas and atmospheric air are combined and combusted. Treated surfaces are made polar as species in the flame plasma affect the electron distribution and density on the surface. This polarization is made through oxidation. In addition, functional groups are deposited on the surface. Generally speaking, flame is considered for high speed applications and used more for aluminum and copper foils than for polymer films. Thin gauge foils are not a good candidate for flame treating due to the exposure to heat.

Plasma

In-line atmospheric plasma technologies introduce gas chemistries into the treatment process. Carrier (inactive) and reactive gas molecules are diffused toward the surface of the material under the influence of electric and/or magnetic fields. This technology is often recognized as a gentler treatment than flame because its discharge has a lower temperature.

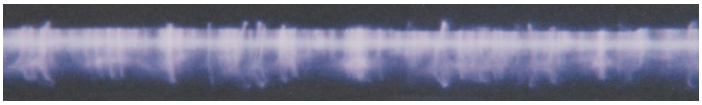
While plasma treaters are relatively easy to use, they are more complex than a corona treater. Sophisticated gas control architecture is required to ensure consistent treatment and there are additional physical dielectric design considerations as well. It's worth noting that there is also an additional operating cost for gas consumption with plasma treaters.

Plasma treaters offer an excellent technology application when desired results cannot be achieved by other treatment methods.

Corona

Corona is essentially the ionization of air. When a substrate passes through a field of corona treatment, the primary goal is to improve surface wettability. Corona is popular because of lower system and operating costs when compared to plasma and flame technologies. Corona can be created in a variety of ways depending on the dielectric materials used in the system design. The properties and combination of these different dielectrics will produce subtle differences in the corona which can make or break the success of an application.

Typical corona treaters produce a highly filamentary discharge (Image 1.) For many applications, this is very effective, but the inconsistency of the corona and the harshness of the discharge is not ideal for many substrates.



Reducing the harshness of a filamentary discharge is important for applications where pinholing and unevenness of treatment are unacceptable. Ceramic electrode systems with a bare ground roll generally produces less of these filamentary discharges; however, they may be limited in the amount of treatment they can provide and be subject to other application issues such as the oxidation of the ground roll.

Many corona treater manufacturers offer a conductive ceramic ground roll coating that protects the ground roll from oxidation. However, the dielectric properties of all ceramic coatings are not the same. When combined with optimized ceramic electrodes, the result is a homogenous smooth corona that meets the sweet spot of all application requirements. It provides effective surface treatment, efficient power requirements, protects against oxidation, and offers insurance against pinholing, backside treatment and film wrinkling.

Enercon's optimizes its ceramic electrodes, its proprietary ceramic ground roll, and airflow to create this "soft corona", also known as High Definition Corona (Image 2). This treatment not only looks better than traditional corona, but it produces better and more efficient treatment results than other dielectric designs.

We have found that this dual-dielectric corona system design does an excellent job of treating separator materials. In fact, it's been confirmed by users that our dual dielectric system enhanced the properties of the separator material far better than their "conventional" corona treater. In this application since the separator material is porous, a corona system using a bare metal or conductive surface ground roll will result in a disproportional amount of energy dispersed in the porous portion of the substrate. This untimely leads to inadequate treatment of the substrate. Whereas, the "High Definition" or dual dielectric system will disperse the energy evenly in the air gap and the substrate will be afforded the full treatment from the corona.

One experienced user of these technologies stated that the High Definition Corona system also yielded better treatment results than a plasma system they had previously used. It's important to note the improved efficiencies gained with this technology. Table 1 shows improvement in substrate wettability (measured in dynes) and is achieved with less power (measured in watt density) than comparable corona configurations (Table 1.)

Table 1: Comparative results show the effectiveness of high definition surface treatment.

Substrate 1	Watt Density		
	2	4	6
Conventional Corona Dyne Results	40	42	44
High Definition Corona Dyne Results	44	48	52
Substrate 2	**Watt Density**		
	2	4	6
Conventional Corona Dyne Results	36	37	37
High Definition Corona Dyne Results	39	40	42

High Definition Corona is ideal for polymer battery separator films, and is also effective on aluminum and copper. As each application is different, the best way to determine which technology is best for your application is to schedule a lab trial. Many corona treater manufacturers offer this service. However, it should be noted that only Enercon offers a full complement of corona, plasma and flame technologies for comparison.

Manufacturing Environments

Dry room production areas are used for lithium-ion battery manufacturing to ensure very low levels of humidity. These rooms also need to support cleanliness to avoid contamination during the manufacturing process. This is a benefit to operating surface treating equipment. Humidity, as well as dirt and debris, can have negative effects on surface treating systems. High levels of humidity are known to lead to high voltage arcing. Enercon's corona treaters utilize a high volume of exhaust air, which helps keep the electrodes and ground rolls cool. If corona treaters are required in areas near solvents, a purged system can be designed to operate safely in those environments.

Conclusion

The race is on as manufacturers of Lithium-ion Batteries look to improve battery performance, keep pace with demand, and increase efficiencies all while reducing scrap. Critical to their success are enabling adhesion between high performance substrates and coatings. The key to optimizing these bonding applications is to work with your suppliers on closely evaluating flame, plasma and variations of corona treaters to determine the perfect balance of economy, efficiency and performance.

(1) Valuates Reports, Lithium Ion Battery Market Report