Advanced Techniques for Integrating Brand-Authenticating DNA into Point-of-Sale Packaging Materials

Rory Wolf / ITW Pillar Technologies

Abstract

Today's competitive global marketplace makes brand protection a critical objective for point-of-sale packaging. Impacts of counterfeiting and piracy reached US$1.7 trillion in 2015**,** over 2% of the world's total economic output. Counterfeit deterrence, brand protection technologies, and product authentication tactics help brand owners maintain and build on customer trust as well as protect margins which are eroding under counterfeiting. Knowing the point of origin is also an essential feature of what the customer buys, even if it is an intangible or a difficult-to-verify quality. Among other counterfeiting counter-measures, advanced techniques have been required to provide resilient physical and chemical binding of covert brand-authenticating technologies to packaging material surfaces. This paper examines ground-breaking DNA marker technology, and describes new plasma surface modification techniques and integrative sealant protocols which provide customized and secure chemical binding of brand authenticating markers to polymeric and metallic packaging materials.

Introduction

Due to the complexity and interconnectivity of global supply chains, it is often difficult to police the source of a finished product, and to verify if the product is safe to wear, produced ethically, or environmentally friendly. Consumers trust that the products sold in a store or on-line are sold through legitimate supply chains. Implicit in this inherent trust is that retail merchants ensure products sold at retail, are genuine, as indicated on the packaging and labeling, as well as the product itself.

If we assume that no supply chain is safe from illicit activity, it follows that no consumer is safe from counterfeits. Here are examples of how counterfeits can directly threaten the health, safety and lives of the consuming public:

- According to various studies from the World Health Organization and INTERPOL, 50 percent of medications for malaria and 10 percent for tuberculosis are fake, and an argument can be made that these would kill approximately 700,000 persons per year.
- In one of the largest seafood fraud investigations ever, Oceana found that one-third of all fish samples collected were mislabeled. A total of 1,215 fish samples were collected by Oceana from 674 retail outlets in 21 states. Some key findings:
    - More than half (59 percent) of the 46 fish types tested had mis-labelling.
    - Fish with high mercury content, on the FDA's 'Do Not Eat' list for sensitive groups such as pregnant women and children, were sold to customers who had ordered safer fish.

The long term impacts from counterfeits are multi-faceted. For industry, the negative effects are lost sales and brand value; for consumers, health and safety risks and low quality goods lead to higher cost for replacement; for government, lost tax and customs revenue, increased enforcement cost and risks to national security supply chains.

As products pass through the manufacturing and distribution process, numerous channels are involved – each presenting an opportunity for counterfeit product to enter the supply chain and find its way to consumers who take for granted a level of quality and safety when they buy brands they trust.

While some supply chain paths are more secure than others, industry experts agree that innumerable opportunities for counterfeit product to enter the system exists at every point along the supply chain. Within Figure 1 is an illustration of a legitimate supply chain and the parallel counterfeit supply chain:

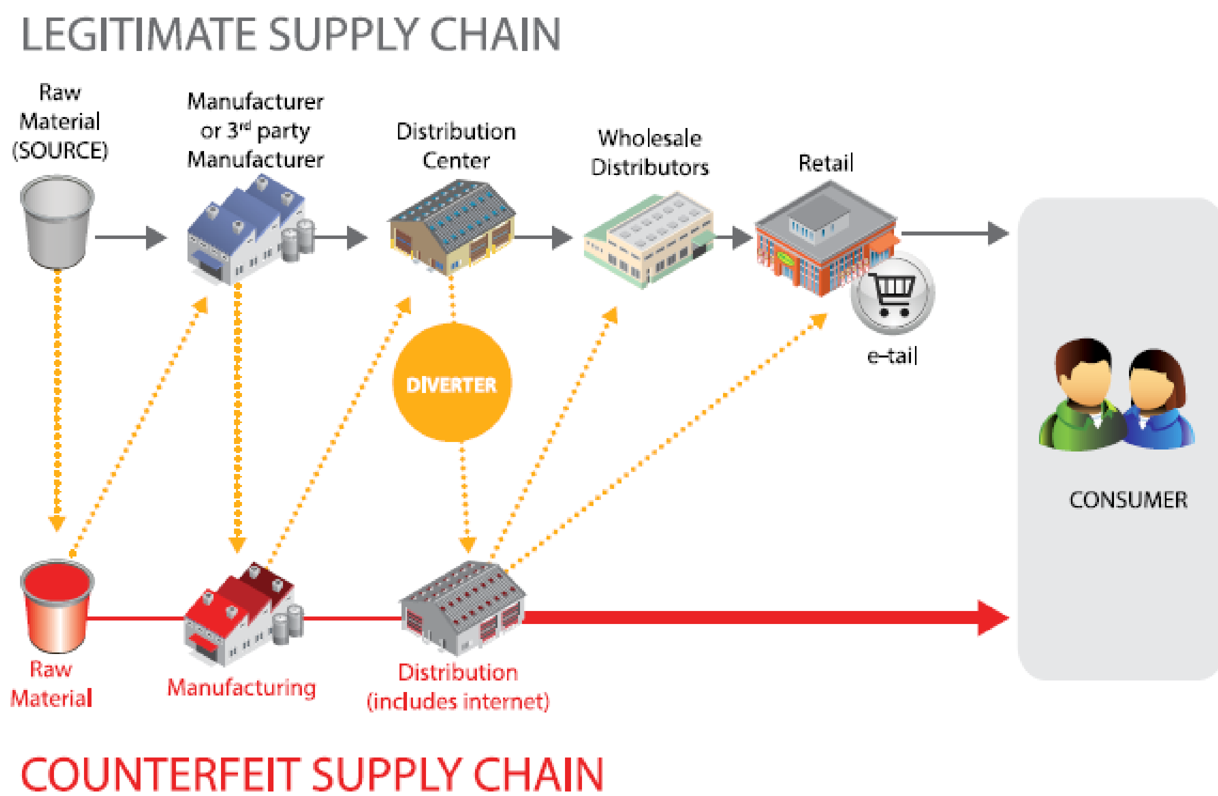

Figure 1. Illustration of Legitimate vs. Illegitimate Supply Chain (Source: Grocery Manufacturers Association)

As illustrated in the above graphic, the fastest route from the counterfeiter to the consumer is direct online sales. E-tailing sites go live and compete for retail dollars every day. Legitimate online retailers are at risk of losing shoppers to e-tailers offering counterfeit product at a lower price. With the power of the internet behind them, counterfeiters can sell illegitimate product virtually across the globe. Depending on the product counterfeited, the practice puts consumers directly at risk, especially if they purchase counterfeit or adulterated products that are applied to or ingested into the body, such as pharmaceuticals, cosmetics and food products.[1]

The reality is that leakage and counterfeit entry can happen at nearly any point. While there are often interactions between the legitimate and the counterfeit supply chain, the two can also be entirely independent of one another. At the same time, aspects of legitimate supply chain can bleed into the counterfeit supply chain. Another reality is that counterfeits can be introduced in the delivery of authentic product. Regardless of method of introduction, the common element remains: all paths lead to the consumer.

As such, a complete solution has been needed which provides:

- Verifiable authentication at each stage of the supply chain
- Real-time transparency of chain of custody transfer
- Court-defendable evidence for internal and external investigations
- Measurable benefits

Driven by the need to help supply chain managers and brand owners with solutions to help with traceability, authenticity and quality, a provider of DNA-based security and product authentication partnered with a provider of atmospheric plasma surface technology to provide a solution that would provide "provenance data" as an essential part of establishing trust and securing reputation with consumers. The DNA utilized is a patented platform technology, developed to help provide provenance, and help protect the integrity of supply chains. It is based on full, double-stranded plant DNA, and the mark is designed with the use of atmospheric plasma surface treatment to not wash off, even in aggressive industrial treatment baths.

Description and Application of Equipment and Processes

Plant-based DNA technology was subjected to testing by Idaho National Laboratory, a U.S. National Laboratory, by CALCE, the largest electronic products and systems research center focused on electronics reliability, and by verified procedures in labs at Applied DNA Sciences. Prior to this experimental protocol, the DNA platform was tested and verified to be highly resistant to UV radiation, heat, cold, vibration, and other extreme environmental conditions across a broad spectrum of materials and had met key military stability standards.

Atmospheric pressure plasma activation technology was provided by ITW Pillar Technologies, consisting of a treatment station, process gasses, electronic gas controls, and power supply.

Combined, both technologies were expected to work synergistically to chemically bind and then authenticate plasma-treated, DNA-marked packaging materials under a commercially-adaptable trial protocol. Because DNA is one of the most dense information carriers known, only minute quantities of DNA were expected to be used for successful analysis and authentication. The theorized ability to strongly bind and then authenticate plasma-treated, DNA-marked packaging materials would enable protection of the products themselves, as well as product labeling and packaging, while providing a multi-layered security solution with little or no change to the existing manufacturing processes.

Atmospheric pressure plasma surface treatment effects include surface activation, fine cleaning, functionalization, coating, and plasma boundary layer processes, and are all based on chemical reactions. One of many prescribable chemical reactions is oxidation, which not only converts organic surface contaminants into volatile compounds that can be exhausted away, but it also contributes to the formation of surface hydroxyl groups. In the case of surface activation of a polymer substrate, an inert gas plasma and its ions and electrons cause polymer bonds to break, thereby creating free radicals on the surface that are able to participate in subsequent reactions. The radicals can also react with one another, giving rise to a particularly highly cross-linked surface layer. The primary chemistries of dyes, coatings, inks and adhesives can bond with a plasma-functionalized surface to promote significant adhesion, higher hydrophilicity and absorption, and lower consumption rates. As such, atmospheric pressure plasma treatment protocols are tailored to specific base materials <u>and</u> what they will ultimately interface with.

This same “pretreatment” principle of delivering functional groups to surfaces by atmospheric pressure plasma treatment to promote adhesion is just as effective, and practiced, as a “post-treatment” approach for delivering and binding DNA to a wide range of materials, including paper, polymer films, fabrics, nonwovens, yarns, filaments, foams, foils, glass, and many other substrates. It was theorized that DNA-rich molecules that are combined with plasma process gases would create resilient chemical binding to these material surfaces.

Experimental and Results

Proprietary DNA marker molecules were provided by Applied DNA Sciences in concentrated form to ITW Pillar Technologies for prescribed dilution within an evaporative process carrier. The process carrier was heated to a prescribed temperature to allow for sweeping of DNA molecules by plasma process gasses into a plasma discharge created between two linear electrodes. The molecules were reacted within the discharge above polyethylene film which was conveyed at 200 feet per minute at a prescribed watt density. The plasma discharge pathway is exemplified in Figure 2. Mixture process gasses included Nitrogen and Oxygen, which were excited under RF power at a defined frequency. XPS spectra in Figure 3 confirmed a post-plasma surface increase in nitrogen and oxygen content on the surface of polyethylene film, while reducing the amount of surface sodium, sulfur, chlorine, potassium, and calcium. In addition, Figure 4 represents data from an electropherogram of a negative control sample without a DNA marker present, a positive control sample confirming the surface presence of a DNA marker (included to ensure assay validity), and a positive DNA peak confirming the deposition and presence of a DNA marker on the polyethylene film following atmospheric plasma deposition.

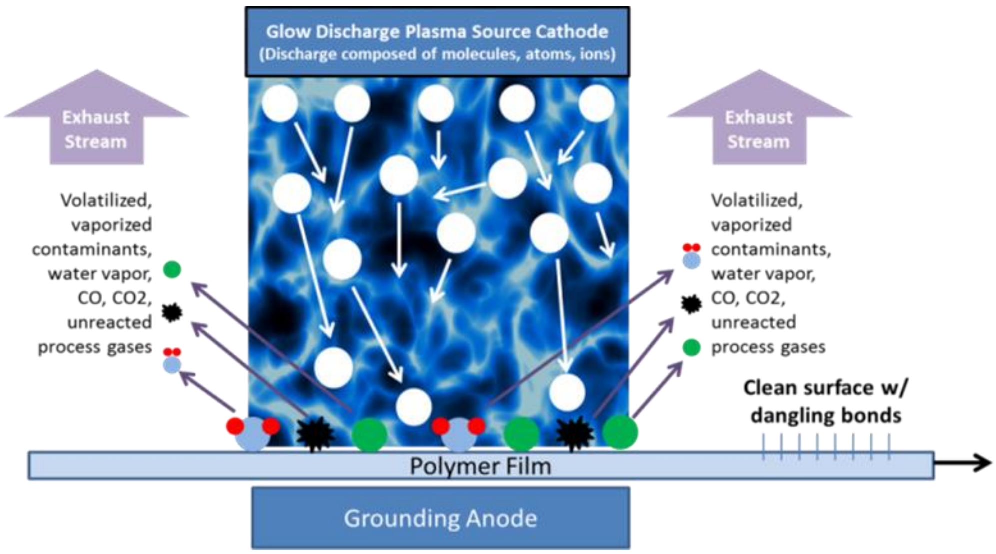

Figure 2. Atmospheric pressure plasma process schematic

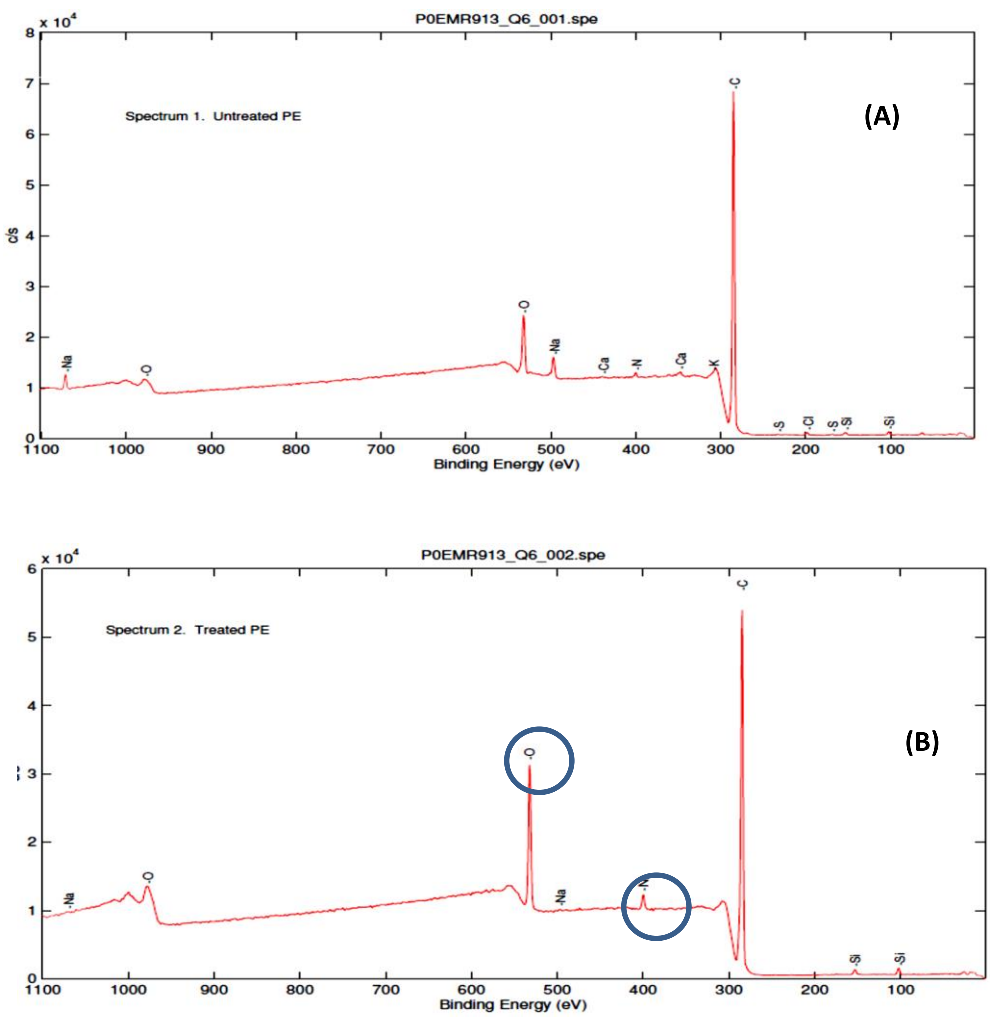

Figure 3. XPS spectra of pre-plasma (A) and post-plasma (B) on polyethylene film.

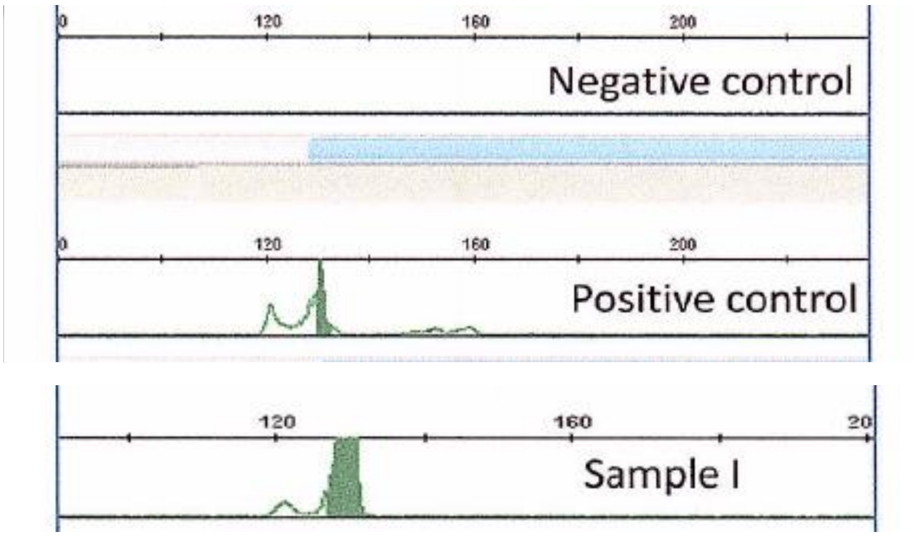

Figure 4. Electropherogram of a DNA marker pertaining to a Negative control sample (no DNA applied), Positive control sample, and DNA deposited on PE film sample following atmospheric plasma grafting process.

Discussion and Conclusion

A DNA marker was provided to ITW Pillar Technologies by Applied DNA Sciences for grafting of the marker to polyethylene film at commercial speed by an RF atmospheric pressure plasma treatment process. The polyethylene film was confirmed by XPS analysis to modify the film in a way in which was chemically consistent with the process gas chemistries applied. Further analysis generated an electropherogram which confirmed the presence the DNA marker following plasma reaction and grafting. The trial confirmed that DNA-based anti-counterfeiting markers can be affixed to point-of-sale packaging materials such as polyethylene film with commercial atmospheric plasma technology for validating the authenticity of branded product packaging.

References

[1] Inmar/Authentix, " Brand Protection and Supply Chain Integrity: Methods for Counterfeit Detection, Prevention and Deterrence - A Best Practices Guide" (2014): p. 5. Grocery Manufacturers Association. Web. 28 December 2015.