NANO-SCALE SURFACE COATINGS

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Introduction

Modern consumer and industrial products are manufactured from a wide range of materials that are selected for specific bulk properties, cost effectiveness and/or 'look and feel'. For example, consumer electronics components may need to deliver specific electronic functionalities at miniature scale, filtration materials may need to be formed into specific shapes, and sportswear materials may be selected for light weight and good ventilation.

However, many of the materials chosen in this way do not display the optimum surface properties. This presents an opportunity for surface modifications to apply desirable properties such as fire retardancy, anti-microbial, protein resistance and, water and oil repellency. It is critical that these modifications do not alter the bulk properties of the product and retain desirable physical attributes.

Products for outdoor use can benefit from hydrophobic surface treatments to repel water. Those for industrial use can be enhanced, or find new applications, by surface treatments that give hydrophobic, hydrophilic or specific chemical functionality. The reliability of electronic products for personal use can be improved by providing protection against aqueous and oily substances.

This paper describes the novel, patented technology from P2i that can readily apply functional nano-coatings onto the surface of a wide variety of items made from a diverse range of materials. It then focuses on the water and oil repellency effect, and details the benefits to electronic products.

The P2i Process

Plasmas [1] have long been known for their use for modifying the surface properties of materials [2]. A plasma is simply an ionised gas, and is often referred to as the fourth state of matter. The gas is ionised through the input of energy such that the gas molecules start to lose their electrons. We create our plasmas at around room temperature by applying radio frequency (RF) electro-magnetic radiation.

Plasmas are used to initiate gas-based polymerisations, but if organic molecules are introduced into a continuous plasma, then they are likely to fragment and deposit on any substrate in the plasma chamber. Consequently, the structure of the starting material is degraded in the process. The patented process used at P2i uses short pulses of plasma and this is sufficient to trigger polymerisations without degrading the starting material. So the key functionality of the starting material, e.g. a hydrophobic or hydrophilic side group, is retained in the final coating. It is this feature that allows us to deliver a range of technical effects from the careful selection of starting substances.

A generic treatment process involves putting a sample into a chamber and applying a vacuum. A continuous delivery of RF power activates the surface of the sample, and then a chemical monomer is introduced into the chamber. The advantage of operating at a low pressure is that the monomer will readily permeate complex 3D structures and penetrate narrow structures at the sub-micron level. The RF power is then pulsed to allow the polymerisation of the coating on the sample to continue. To deliver the required technical properties, the thickness of the coating is typically to the order of 10's of nanometers - this is around one thousandth the width of a human hair. At the end of the process, the chamber is vented to atmosphere and the treated sample is removed.

The process can be applied to products with multiple materials (e.g. high performance footwear) and as it does not require any solvents, it is of particular benefit to electronic devices (e.g. mobile phones, hearing aids)

Over the past few years, P2i have taken the technology from a bench-top 0.5 litre chamber to a range of fully industrialised chambers in a variety of sizes up to 2000 litres.

Oil and Water Repellency

It is widely accepted that fluorinated materials are required for maximizing the levels of liquid repellency [3], [4]. For example, PTFE is the benchmark low surface energy material with a surface energy of 18 mN/m. When a droplet of water is placed on PTFE, it beads up because the water molecules prefer to interact with each other rather than the PTFE surface. However, when liquids with low surface tensions are used (such as oils), then they tend to spread out.

In order to produce surfaces that repel oils, the surface energy needs to be reduced and this can be achieved by orientating the fluorocarbon chains perpendicular to the surface, and presenting CF3 groups on the tops. This can lower surface energies to values as low as 6 mN/m. Fluorinated chains with this particular orientation can readily be created using pulsed-plasma polymerisations.

The application of a coating that delivers this combination of chemistry and orientation can radically improve performance and protect items for extended use, adding considerable value to the product in question both as a suitable differentiator and/or a cost saver.

Applications for Electronics

P2i's nano-coating technology for the electronics sector is Aridion™, which has been optimized to give the highest throughput for fully constructed electronic devices.

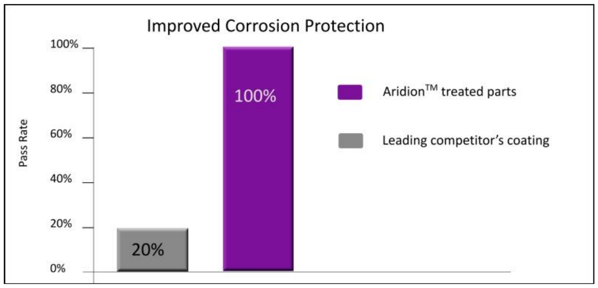

Fig. 1: Improved corrosion protection following Aridion™ treatment is not experienced with other technologies (*)

A much greater proportion of Aridion™ treated products pass corrosion tests (Fig. 1), leading to longer-lived products, consumer confidence that the instrument is working correctly, plus both reduced return rates and warranty costs. Aridion™ also demonstrates superior abrasion resistance properties to other surface coatings used in the industry (Fig 2). These other technologies can only be applied to the plastic housing and so don't protect the delicate electronics within the device.

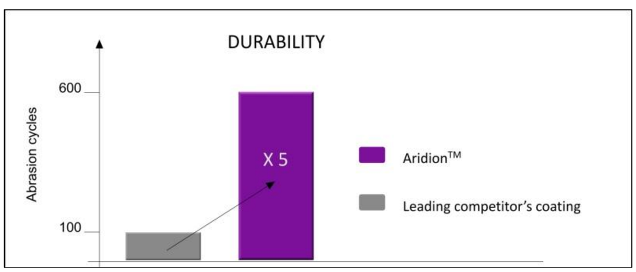

Fig. 2: Aridion™ demonstrates five times higher durability than competitor surface coatings (*)

Further work in electronics has focused on mobile phones, demonstrating the huge benefits from applying a gas phase ionization process to the fully completed unit.

Due to the nature of the low pressure plasma process, the complex construction of a mobile phone handset can be readily penetrated, ensuring not only that the outer casing has an increased protection to water ingress, but also that the water repellent properties are present inside the device, adequately protecting the delicate electronics.

It is well known that the only way to provide compete protection to devices such as mobile phones is to build in a physical barrier with no holes for gas or liquid to penetrate. This can only realistically be delivered by a fully sealable box using an o-ring or gasket seal. That does not provide a market-acceptable solution, since the look and feel of the device are ever more critical in a hugely competitive market.

One of the main failure modes of mobile phones is through water or moisture damage due to ingress of rain water. Incumbent technologies look at providing protection to the internal printed circuit board (PCB) to aid longevity. However, not only can these suffer from poor adhesion, but this approach cannot stop water getting into the device.
By having available a cost effective industrial process that can protect the fully constructed end device, most of the water does not enter the handset in the first place. This means there is minimal exposure to water; which translates into longer operating times.
In-house testing has demonstrated that untreated phones which fail within 2-4 minutes of a spray water challenge, have gone up to and beyond 30 minutes of testing without failure, when treated with Aridion™. Equally importantly, the process does not affect the look or feel of the device, and has passed the temperature and humidity cycling tests required to demonstrate efficacy in all operating environments.

This experience and application is directly relevant for the medical device sector, where electronic devices are used either at point-of-care or in retail environments. There is a strong drive towards miniaturizing these devices for a closer resemblance to 'cool' products such as mobile phones and MP3 players. This makes protection from liquid ingress increasingly difficult to achieve. In addition, corrosion and failure problems associated with liquid ingress of point-of-care devices leads to expensive bureaucracy and negative brand impact, due to the open reporting laws.

Conclusions

A plasma based process has been successfully industrialised to deliver high levels of resistance to water and oils. The tangible benefits for the electronics market have been described here, but it also has numerous commercial applications adapted for high-performance sportswear, bioconsumables, filtration products and more.

References

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