Nano-coating Protection of Medical Devices

S.R. Coulson and D.R. Evans

P2i Ltd, 127 North, Milton Park, Abingdon, Oxfordshire, OX14 4SA, UK

1 Introduction

Consumer and industrial products are manufactured from a range of materials that are selected for specific bulk properties, cost and/or 'look and feel'. However, many 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. Additionally, they should be ultra-thin and well adhered. For commercial success, the desired effect needs to be a cost-effective and robust industrial process.

Plasmas [1] have long been known for their use for modifying the surface properties of materials [2]. It is widely accepted that fluorinated materials are required for maximizing the levels of liquid repellency [3], [4]. A novel, patented liquid-repellent technology, by P2i, can readily apply a functional nano-coating onto the surface of a wide variety of items made from a diverse range of materials [5]. This is created using a pulsed plasma deposition process at low pressure which allows full penetration of complex products [6].

This liquid repellent effect optimizes the surface properties to 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.

This article provides an overview of the technology and examples of its commercial application.

2 Repellency

PTFE is the benchmark low surface energy material with a surface energy of 18 mN/m. It is very good at repelling water, but low surface tension liquids (such as oil) spread out. In order to create high levels of oil repellency, it is necessary to orientate the fluorinated chains normal to the substrate surface. This can lower surface energies to values as low as 6 mN/m. Fluorinated chains with this particular orientation can readily be created using plasmas.

3 What Is a Plasma?

A plasma is an ionised gas, often referred to as the fourth state of matter. The gas becomes ionised through the application of energy. We create our plasmas by applying radio frequency (RF) electro-magnetic radiation. This lets us control the degree of

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ionisation and thus retain key functional groups at the surface, giving rise to the required technical effects.

4 P2i Plasma Process

The process is carried out in a chamber that is pumped to low pressure. The raw materials of gases and vapours are bled into the chamber at this reduced pressure and the plasma is ignited using a RF generator to create the activated state.

As the plasma is a gaseous medium at low pressure, it will readily permeate complex 3D structures and penetrate narrow structures at the sub-micron level. This means a wide range of complex products such as garments and medical devices can be molecularly tailored at the nanometre scale and display desirable properties not shown by the underlying substrate. The technical effect can be applied to a wide range of materials including fibres, plastics, paper, ceramics and glass.

The technology originally used a 0.5 litre chamber, and this has since been scaled through volumes up to 2000 litres. This allows large items or high volumes of small components to be processed.

Plasmas can extensively fragment molecules, but the degree of molecular breakdown can be controlled by reducing the power through pulsing. This creates the required active species to attach to the substrate, and retains the chemical integrity of the starting chemical. This allows specific chemical functionalization at the molecular level.

Critical surface tension of wetting results, on a flat surface, have shown values as low as 4.3 mN/m (cf PTFE ~ 18 mN/m), which explains why high contact angles result with a range of liquids and low liquid retention properties are displayed on a wide number of surfaces.

5 Results and Discussion

Experiment 1: To baseline the liquid repellent technology, 3M repellent test methods were used to determine the level of repellency both before and after processing with the liquid repellent nano-coating technology. Although several materials appear not to repel the highest rating liquids, they do in fact support the droplet due to the specific definitions of the test (it is classed as a fail due to slight surface wetting). Figs. 1 and 2

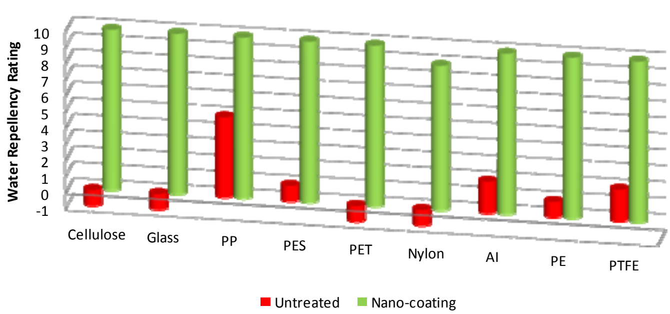

Fig. 1. 3M Water repellency of a variety of uncoated and nano-coated materials

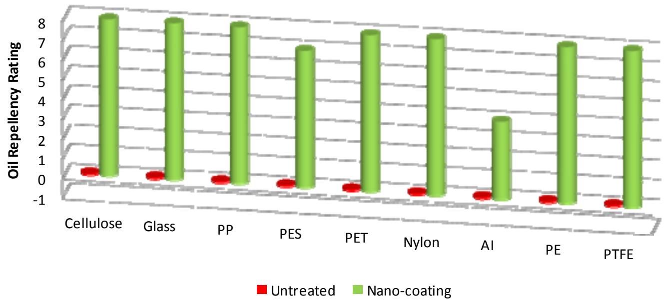

Fig. 2. 3M oil repellency of a variety of uncoated and nano-coated materials

demonstrate the water and oil repellency rating before and after processing on a wide variety of materials.

As can be seen the liquid repellent nano-coating radically improves the liquid repellent performance; no material is inherently oil repellent.

Following the sweat drop test the level of corrosion is assessed visually. As can be seen in Fig. 3, no visible corrosion occurs after the nano-coating process due to its ability to readily penetrate the complex structures.

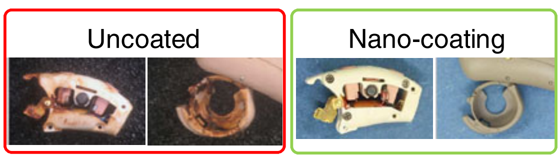

Fig. 3. Uncoated and nano-coated hearing instrument parts after sweat drop testing

Experiment 2– 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.

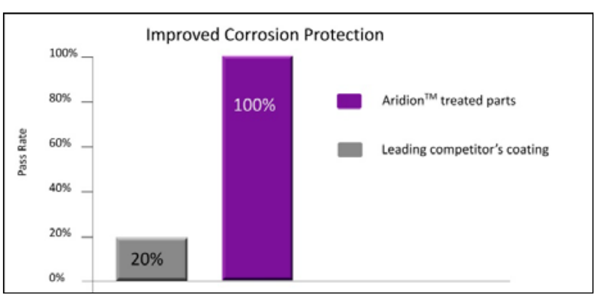

Fig. 4. Improved corrosion protection following Aridion™ treatment is not experienced with other technologies

A much greater proportion of Aridion™ treated products pass corrosion tests (Fig. 4), 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 5). These other technologies can only be applied to the plastic housing and so don't protect the delicate electronics within the device.

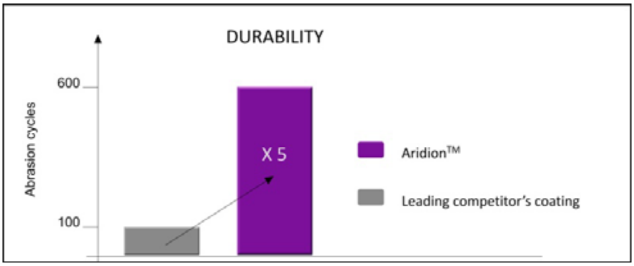

Fig. 5. Aridion™ demonstrates five times higher durability than competitor surface coatings

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 meansthere 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.

Experiment 4 – Life Sciences: Under increased pressure to discover new drugs and therapeutics, ever greater levels of precision are required in routine analysis and day-to-day laboratory work. In addition, chemical cocktails or starting samples can be very expensive or minimally available, putting pressure on liquid handling capabilities to maximize utilization. Low retention technologies are highly valued for many applications to maximize recovery and reduce residues. Fig. 6 demonstrates that the nano-coating out-performs standard, untreated tips and other low-retention technologies.

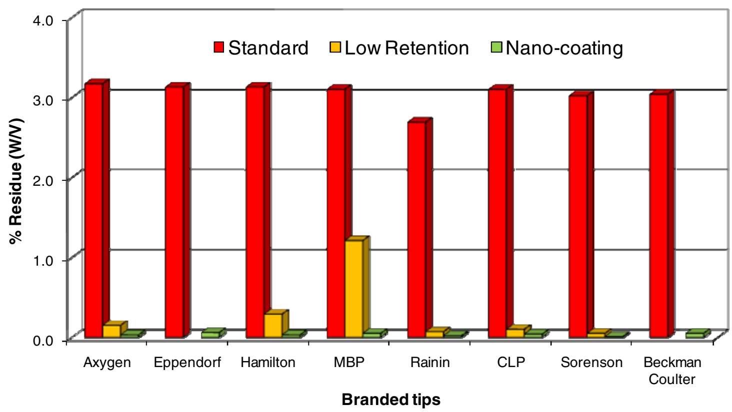

Fig. 6. Nano-coated pipette tips outperform both standard and other low retention tips

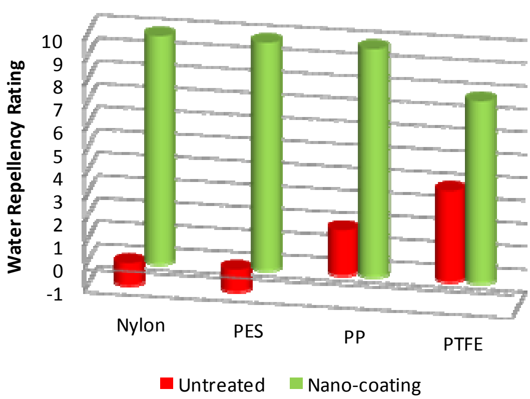

Fig. 7. Common membrane materials made highly hydrophobic using a nano-coating

Experiment 5 – Energy & Filtration: Filtration media rarely display the desired surface properties and will generally benefit from being either highly hydrophilic or highly hydrophobic. Figs. 7 and 8 demonstrate how the liquid repellent nano-coating increases the levels of water and oil repellency allowing the media to perform in harsher environments or out-perform current materials in use.

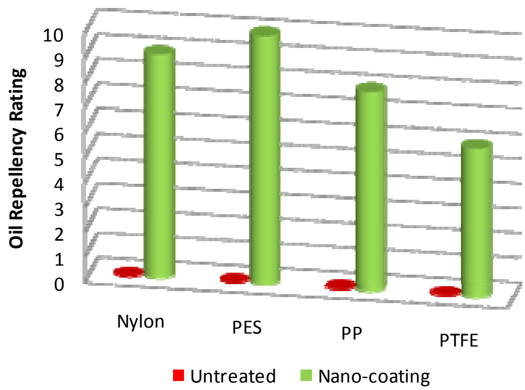

Fig. 8. Common membrane materials made highly oleophobic using a nano-coating

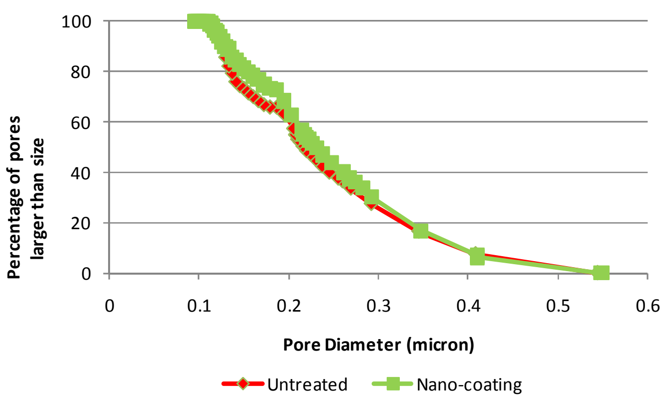

Fig. 9. Common membrane materials made highly oleophobic using a nano-coating

Other technologies can be used to make filtration media more repellent; however, many suffer from an inability to activate inert materials like polypropylene and polytetrafluoroethylene to attach the required chemistry. One other drawback of conventional technologies is that they often apply a thick coating that can block up the pores and change the air-flow and use of the media. Fig. 9 demonstrates how the nano-coating does not alter the pore size distribution, despite the increase in water and oil repellency. This allows it to be used for all intended applications (and many more besides), due to increased performance levels.

6 Conclusions

Imparting a highly water and oil repellent nano-coating has been demonstrated to improve the performance of several everyday commercial and industrial products. The efficacy of the nano-coating has been proven first through laboratory verification, second in production prototyping and third through deployment in cost-effective industrial processes. By providing protection to fully constructed devices, many of the previously encountered issues are overcome, leading to a new opportunity to reduce product return rates, which boosts brand perception and reduces costs.

References

[1] Grill, A.: Cold Plasma Materials Fabrication: From Fundamentals to Applications. Wiley, Chichester (1994)

[2] Biederman, H.: Plasma Polymer Films. Imperial College Press (2004)

[3] Kissa, E.: Fluorinated Surfactants and Repellent. Marcel Dekker, New York (2001)

[4] Kissa, E.: Functional Finishes Part B. In: Lewin, M., Sello, S.B. (eds.) Handbook of Fibre Science', vol. II. Marcel Dekker, New York (1984)

[5] Coulson, S.R., Brewer, S.A., Willis, C.R., Badyal, J.P.S.: GB Pat. Patent: WO 98/58117

[6] Coulson, S.R., Woodward, I.S., Badyal, J.P.S., Brewer, S.A., Willis, C.R.: Ultralow Surface Energy Plasma Polymer Films. Chem. Mater. 104, 2031–2038 (2000)