NANO-COATINGS FOR IMPROVED PRODUCT PERFORMANCE

S.R Coulson*, D.R Evans
P2i Ltd, 127 North, Milton Park, Abingdon, Oxfordshire, OX14 4SA UK

1. Introduction

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

2. Experimental details

An example of a standard process, pre commercial optimization, the product in question was placed into a plasma chamber with a processing volume of ~ 300 litres. The chamber was connected to a supply of the required gases and vapours via a mass flow controller, liquid mass flow meter and a mixing injector. The chamber was evacuated to a base pressure between 3 and 10 mtorr before allowing helium into the chamber at 20 sccm until a pressure of 80 mtorr was reached.

A continuous power plasma was then struck for 4 minutes using RF at 13.56 MHz at 300 W. After this period, 1H,1H,2H,2H-heptadecafluorodecylacylate (CAS # 27905-45-9) was brought into the chamber at a rate of 120 milligrams per minute and the plasma switched to a pulsed plasma at 30 microseconds on-time and 20 milliseconds off-time at a peak power of 100 W for 40 minutes. On completion of the 40 minutes the plasma power was turned off along with the processing gases and vapours and the chamber evacuated back down to base pressure. The chamber was then vented to atmospheric pressure and the product samples removed for analysis. The products can then be tested using a variety of industry specific tests:

<u>General liquid repellency:</u>

'3M Test Methods' - 3M oil repellency Test I, 3M Test Methods Oct. 1 1988). As a water repellency test, the 3M water repellency Test II, water/alcohol drop test, 3M Test Methods, Oct. 1 1998 was used. These tests are designed to detect a fluorochemical finish by measuring: (a) aqueous stain resistance using mixtures of water and isopropyl alcohol where water 0 (W0) corresponds to pure distilled water, water 6 (W6) corresponds to 60% isopropyl alcohol and 40% water and water 10 (W10) is pure isopropyl alcohol, (b) the resistance to wetting by a selected series of hydrocarbon liquids of different surface tensions where oil 3 (O3) is hexadecane and oil 8 (O8) is heptane. These tests serve as an objective way to benchmark the untreated samples and other liquid repellent technologies. The water repellency tests comprise placing 3 drops of a standard test liquid consisting of specified proportions of water and isopropyl alcohol by volume onto the surface. The surface is considered to repel this liquid if after 10 seconds, 2 of the 3 drops do not wet the material. From this, the water repellency rating is taken as being the test liquid with the greater proportion of isopropyl alcohol which passes the test. In the case of the oil repellency test, 3 drops of hydrocarbon liquid selected from an homologous series are placed on the coated surface. If after 30 seconds no penetration or wetting of the material at the liquid-material interface occurs around 2 of the 3 drops, then the test is passed.

<u>Sweat drop test</u>

This common industry test exposes a hearing instrument placed on a prosthetic ear to continual drops of a sweat solution for several days. Following this the amount of corrosion was determined visually and various diagnostic tests were run. The specifics of the tests are confidential to the manufacturer.

3. Results & Discussion

<u>3.1 Experiment 1</u>

To baseline the technology the 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 don't appear to repel the highest rating liquids, they do in fact support the droplet, however due to the specific definitions of the test, it is classed as a fail due to slight surface wetting. Fig. 1 demonstrates the water repellency rating before and after processing on a wide variety of materials.

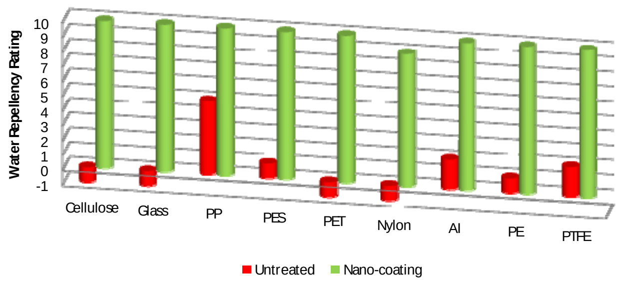

Fig. 1: 3M Water repellency of a variety of uncoated and nano-coated materials

Fig. 2 demonstrates the oil repellency rating before and after processing on a wide variety of materials.

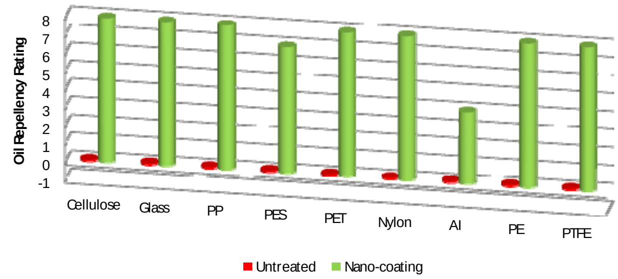

Fig. 2: 3M oil repellency of a variety of uncoated and nano-coated materials

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

3.2 Experiment 2 - Electronics

Following the sweat drop test the level of corrosion is assessed visually. As can be seen in Fig. 3, and 4, following the nano-coating process, no visible corrosion occurs due to the ability of the process to readily penetrate the complex structures, assuring maxim protection.

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

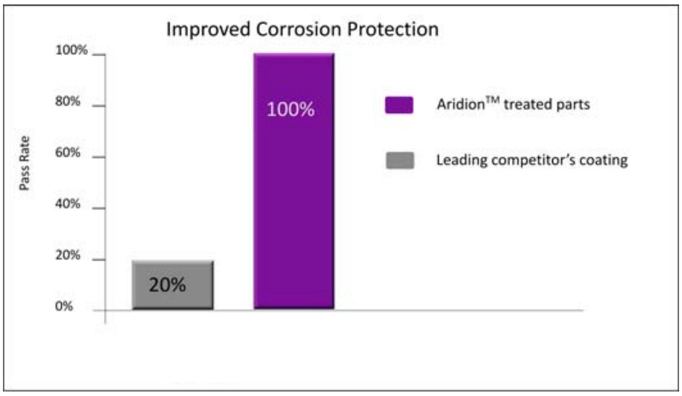

Fig. 4: Improved corrosion protection following Aridion™ treatment is not experienced with other technologies

This leads to longer lived products, consumer confidence that the instrument is working correctly and 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.

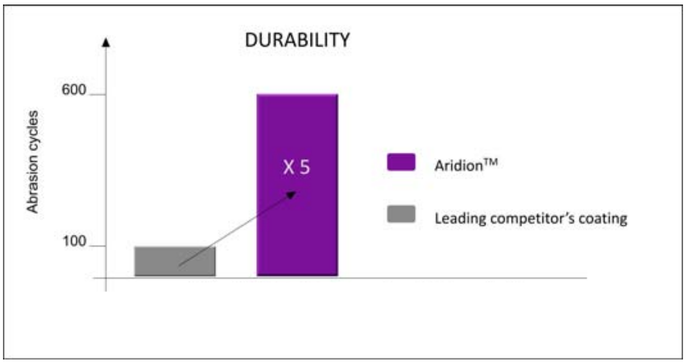

Fig. 5: Aridion™ demonstrates 5 times the durability then competitor surface coatings

Further work in the area of electronics has focused on mobile phones, which has demonstrated 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 can be readily penetrated ensuring not only the outer casing has an increased protection to water ingress but 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. As this can only realistically be delivered by a fully sealable box using an o-ring or gasket seal, this does not provide a market acceptable solution as the look and feel of the device is 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 they suffer from poor adhesion, but this approach cannot stop water getting into the device in the first place. By having available a cost effective industrial process that can protect the fully constructed end device, the vast majority of the water does not enter the phone in the first place and therefore there is minimal exposure to water; translating 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.
Just importantly the process does not affect the look or feel of the device and has passed all the necessary temperature and humidity cycling tests required to demonstrate efficacy in all operating environments.

4. Conclusions

Imparting a highly water and oil repellent nano-coating has been demonstrated to improve the performance of a number of everyday commercial and industrial products. Not only have these been proven at the lab-scale but have gone through production prototyping and are now being used as cost effective industrial processes. By providing protection to fully constructed devices, many of the previously encountered issues are overcome leading to a new opportunity of reducing return rates which impacts costs and brand perception.

References

[1] A. Grill, Cold Plasma Materials Fabrication: From Fundamentals to Applications, Wiley, (1994).
[2] S.R. Coulson, S.A. Brewer, C.R. Willis, J.P.S. Badyal, GB Pat. Patent: WO 98/58117.
[3] S.R. Coulson, I.S. Woodward, J.P.S. Badyal, S.A. Brewer, C.R. Willis 'Ultralow Surface Energy Plasma Polymer Films' Chem. Mater. 104, (2000), 2031-2038