Faster with Plasma

Inès A. Melamies

Plasmatreat GmbH
Bisamweg 10
D-33803 Steinhagen
Tel. +49 5204 996 00
mail@plasmatreat.de
www.plasmatreat.de

Environment Park S.p.A.
Via Livorno 60
I-10144 Torino
Tel. +39 011 225 72 34
info@envipark.com
www.envipark.com

By using atmospheric plasma a new impregnation process enhances not only the gliding properties and frictional resistance of the running surface of racing skis, but also brings about a sixfold increase in the amount of adsorbable wax.

Ein neues Imprägnierverfahren verbessert mit Hilfe von Atmosphärendruckplasma nicht nur die Gleiteigenschaften und den Reibwiderstand der Lauffläche von Rennskis, sondern erhöht auch die Menge an adsorbierbarem Wachs um das Sechsfache.

Un nouveau procédé d'imprégnation améliore à l'aide du plasma à pression atmosphérique non seulement les propriétés de glissement et la résistance au frottement des semelles des skis de compétitions, mais également de sextupler la quantité de fart pouvant être adsorbée.

Every thousandth of a second counts. Extreme skiers such as Italian Simone Origone hurl down the piste without any protective car bodywork or sophisticated braking systems and safety engineering. When the world champion speed skier clocked up 252.454 km/h in Vars in the French Alps on 31 March 2014, he relied on nothing other than himself and his perfectly prepared skis (Fig. 1). And it's no different for his fellow downhill Olympic skiers. Although they reach top speeds of 'only' 130 km/h to 160 km/h, the courses are three or four times longer and present no less of a challenge to ski base impregnation.

An innovative idea

Modern racing skis are high-tech products. The multi-layered sandwich construction comprises a combination of materials which varies depending on the manufacturer and remains a closely guarded secret. Be it fiberglass or synthetic laminates, rubber, metal inserts or an engineered wooden core - each layer of material is responsible for a specific performance characteristic.

In 2013 Dino Palmi, president of the Italian Association of ski service technicians «Skiman», contacted Plasma Nano-Tech, the in-house research department of Turin-based science and technology center Environment Park S.p.A. (Fig. 2). He asked plasma researchers Dr. Domenico D'Angelo and Elisa Aimo Boot whether plasma might be able to modify the characteristics of ski bases to boost wax adsorption. Palmi is regarded as an expert in his field. He has extensive experience not just in ski preparation but also in the manufacturing process of the sintered UHMWPE (ultra-high-molecular-weight polyethylene) running surfaces of racing skis. He was convinced that plastic residues in the molecular base structure generated during the sintering process have a negative impact on wax

Fig. 1: Speed skiers like Simone Origone have to rely on their perfectly prepared ski bases. (Photo: TamTam-Photo.com)

Fig. 2: Environment Park science and technology center in Turin. (Photo: Environment Park)

adsorption. Palmi hoped that this contamination could be removed by fine cleaning with atmospheric pressure plasma.

A pool of experts

Just about one year before, Giovanni Zambon, director of Plasmatreat's Italian subsidiary, had presented the two Plasmatreat plasma processes «Openair» plasma and «PlasmaPlus» (Fig. 3).The Italian scientists decided now that the research project «PlasmaSki» should be based on these technologies. The aim was to maximize the amount of adsorbable wax and to strengthen the physical structure of the polyethylene ski base by applying a nanocoating in such a way that it would delay friction and heat-induced breakdown of the base structure arising from extreme stresses.

Ski expert Palmi explained to the team that the wax needed to achieve high speeds rubbed off very quickly and the ski base was often worn right down to the substrate. This would cause the ski base microstructure to break down (Fig. 4). When this occurred, the ski could no longer be waxed. The surface of the base would then have to be machine-ground to the point where the pores in the plastic reopened and were able to take up a fresh application of wax. However, the structure of the UHMWPE surface could adsorb wax only up to a certain point. This would be due partly to the production process, and partly the preparation process.

Racing skis are prepared using different layers of wax. Usually a hydrocarbon wax is applied first using a thermal process to create a base layer which penetrates deep into the surface cavities. This is then followed by a second fluorocarbon wax designed to increase speed. During a race, the outer layer of wax wears off after 200 to 300 meters, depending on the frictional characteristics of the piste. As soon as this happens, the base layer of wax kicks in to maintain performance for as long as possible and delay the collapse of micro-cavities in the three-dimensional honeycomb structure of the UHMWPE. This layer of wax eventually wears down too in the end.

The question the experts had to cope with was how to increase wax absorption and delay collapse of the base microstructure without changing the established hot-waxing process itself?

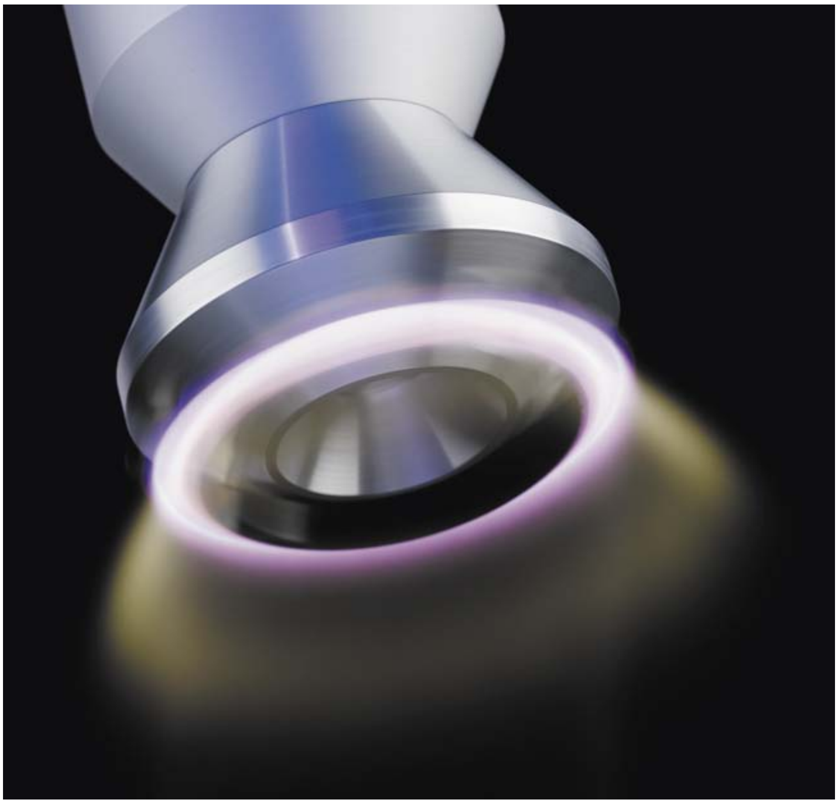

Fig. 3: «Openair» plasma technology allows for ultrafine cleaning and simultaneous activation of material surfaces in one work step only. (Photo: Plasmatreat)

Inside the running surface

The gliding properties, behavior in snow and thus the speed of a ski are determined by its running surface or base. Nowadays the base of high-performance skis is made from sintered UHMWPE. This plastic combines strong wear resistance with water repellence. The non-polar, hydrophobic UHMWPE, characterized by high molecular density, is combined with special additives such as black graphite. Graphite is a good electrical conductor which prevents the base from becoming electrically charged and attracting particles of dirt.

In the sintering process the UHMWPE powder and the additives are combined, heat-fused in a cylindrical mold and then compressed under high pressure. Once

Fig. 4: Micro-cavities in the three-dimensional honeycomb structure have collapsed: At this stage it is no longer possible to apply wax. (Photo: Scuola Skiman)

Fig. 5: The sintered UHMWPE structure of the ski base before treatment. Blockages and dust have accumulated in the micro-cavities. (Photo: Scuola Skiman)

Fig. 6: Base structure after plasma treatment: The micro-cavities are clean and have expanded. (Bild: Scuola Skiman)

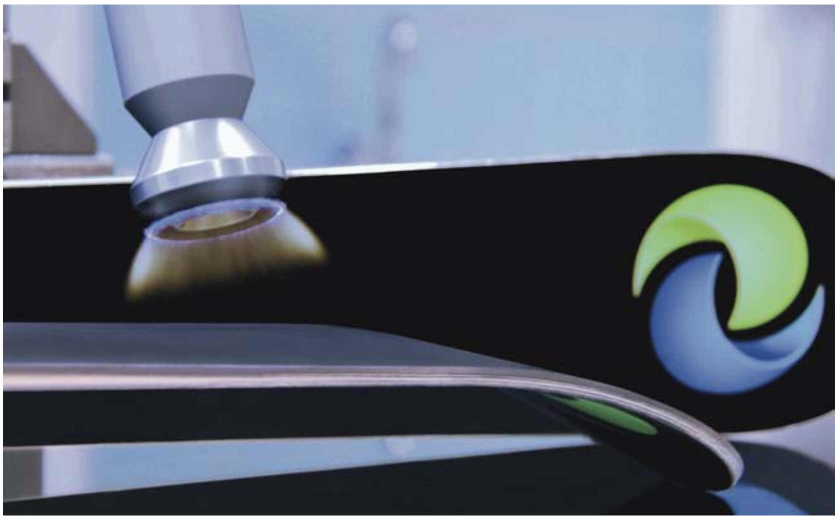

Fig. 7: The AP-plasma technologies «Openair» and «PlasmaPlus» modify and functionalize the UHMWPE base of race skies in such a way that a sixfold increase in the amount of adsorbable wax becomes possible. (Photo: Environment Park)

cool, a slice is cut from the UHMWPE cylinder and molded to the final shape of the running surface using a stripper.

Microscopic analysis of a UHMWPE ski base shows a three-dimensional honeycomb structure which is created by the formation of micro alveoli. This configuration makes the base surface fundamentally receptive to wax. However, the walls of the individual cells have an irregular geometry, culminating in a pointed tip that twists back towards the center of the structure. This significantly impedes wax adsorption. Due to their sensitivity to heat, these tips tend to block the micro-cavities during the hot-waxing process. What limits wax adsorption by the cavities even more is the amount of polymer dust left in the cavities during the sintering process, which is enough to partly obstruct them (Fig. 5). So the aim was to remove these blockages and residues - a task for which atmospheric pressure plasma, which can perform dry, deep-pore microfine cleaning on plastic surfaces in a matter of seconds, was ideally suited.

Once project manager D'Angelo had described in detail the complex chemical-physical interactions of the structural characteristics to those involved, the test series got underway in September 2013.

Fig. 8: Dr. Domenico D'Angelo and Elisa Aimo Boot have turned the PlasmaSki project into a patentable process after just nine months of research. (Photo: Environment Park)

Two-stage test phase

The tests posed a challenge to the researchers. Not only system parameters such as nozzle type, and the plasma jet's spacing, speed and motion sequence had to be configured, the right combination of gases, the configuration of the plasma energy and contact time had to be found as well. Furthermore, functional and operational details had to be tested and established.

The first stage of research focused purely on cleaning. The success was evident: Light microscopy analysis revealed that after plasma cleaning, the cavities in the honeycomb structure of the UHMWPE were not only clean, they had also expanded; in other words their overall volume had increased (Fig. 6).

Plasmatreat's plasma technology

In 1995 Plasmatreat GmbH from Steinhagen in Germany developed a technology called «Openair» plasma, which is now used throughout the world. By developing and using plasma nozzles - contrary to the low pressure plasma process in a vacuum chamber - it became possible for the first time to make plasma usable for large scale pretreatment of material surfaces in normal air conditions and to integrate this atmospheric plasma «in-line» into industrial production flows. The method allows for highly effective cleaning and activation of material surfaces before follow-up processes such as bonding, painting, printing or foaming. The method is environmentally friendly, needing only compressed air and electricity to produce the plasma beam. The dry, contactless plasma treatment enables materials to undergo further processing immediately.

In recent years Plasmatreat, working in partnership with the Fraunhofer IFAM (Institute for Manufacturing Technology and Advanced Materials) in Bremen, has developed a further process based on this technology known as «PlasmaPlus». This was the first time that an atmospheric pressure plasma coating process was implemented in industrial production. Concealed inside the plasma nozzles is an ingenious coating system which enables locally selective layer deposition to modify the functional characteristics of surfaces in a targeted manner. A precursor is added to the plasma to produce a coating. High-energy excitation within the plasma fragments this chemical compound and deposits it on the surface in the form of an ultra-thin vitreous coating. What is essential to a user is the fact that he can vary both precursor and plasma performance himself to define layer functionality. The layer chemistry can be controlled selectively by adjusting the plasma parameters and nozzle geometry.

The aim of the second stage of the test phase was to create a nano protection coating in order to reinforce the three-dimensional honeycomb structure and reduced the friction coefficient. «PlasmaPlus» plasma technology provided all the criteria to implement these requirements (Fig. 7). The first step was to identify the exact chemical and physical mix for the coating. The right precursor had to be found and the plasma parameters for the layer deposition process had to be re-determined. In particular, the layer thickness had to be defined such that it neither blocked the 3D structure nor adversely affected the electrostatic interactions (Van-der-Waals forces) between wax and base.

Ready for patenting

The final result which the researchers D'Angelo and Aimo Boot (Fig. 8) had achieved emerged after just nine months and 40 laboratory tests and a patent application for the PlasmaSki process was filed. «Thanks to microfine plasma cleaning and the plasma coating which we developed specifically for our needs and applied with the aid of Plasmatreat technology, we were able to achieve a sixfold increase in wax adsorption compared with the conventional, but otherwise identical wax impregnation method», D'Angelo declared. The glide test showed that after waxing, not only were the gliding properties greatly enhanced; frictional resistance and adhesion endurance of the wax to the surface of the ski base also improved substantial.

Then, last winter, the «PlasmaSki» had to prove its qualities under real snow conditions. A professional downhill racer tested the ski in the Italian Alps on different slope lengths and under changing snow conditions. The snow test results didn't just confirm the laboratory results - they exceeded them and in March 2015 the patent for the innovative process was granted. ■