New impregnation process for race skis

Feeling the rush of speed

By using atmospheric pressure plasma technology a team of Italian researchers succeeded in bringing about a sixfold increase in the amount of adsorbable wax on the running surface of racing skis. The new impregnation offers not only greatly enhanced gliding properties, but also the frictional resistance and adhesion endurance of the wax to the surface of the ski base have improved substantially.

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.

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 Skiman, the Italian Association of ski service technicians, contacted Plasma Nano-Tech, the in-house research department of Turin-based science and technology center Environment Park S.p.A. He suggested to plasma researchers Dr. Domenico D'Angelo and Elisa Aimo Boot that 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 that lies behind the sintered ultra-high-molecular-weight polyethylene (UHMWPE) running surfaces of racing skis. Palmi was convinced that plastic residues in the molecular base structure generated during the sintering process have a negative impact on wax adsorption. He hoped that this contamination could be removed by fine cleaning with atmospheric pressure plasma.

Plasma – the 4th state of matter

In 1995 Plasmatreat GmbH from Steinhagen, Germany, developed a technology called Openair plasma, which is now used throughout the world. Before then, the so-called fourth state of matter could be used only under vacuum, but with the invention of plasma nozzles, it was now possible to use it under normal atmospheric conditions. Consequently, material surfaces could undergo

By using atmospheric pressure plasma the UHMWPE bases of racing skis can be modified to bring about an up to sixfold increase in wax adsorption microfine cleaning and activation on an industrial scale using inline production processes. The process 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 Institute for Manufacturing Technology and Advanced Materials (IFAM) in Bremen, has developed a further process based on this technology known as PlasmaPlus. This was the world's first industrial atmospheric pressure plasma coating process. 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.

A pool of experts

Giovanni Zambon, director of Plasmatreat's Italian subsidiary, presented the two plasma processes to the Environment Park in mid-2012 and the Italian scientists decided that the PlasmaSki research project should be based on this German plasma technology. 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. This, it was hoped, would delay friction and heat-induced breakdown of the base structure arising from extreme stresses.

Speed skiers like Simone Origone have to rely on their perfectly prepared ski bases

Project manager Dr. Domenico D'Angelo inspects the ski's polyethylene running surface

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 could ultimately cause the ski base microstructure to break down. 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 can adsorb wax only up to a certain point. This is 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.

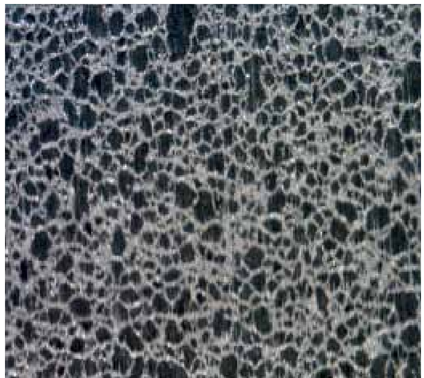
The question the experts had to cope with was how to increase wax absorption and delay collapse of the base microstructure without changing the established hot-waxing process itself?

Inside the running surface

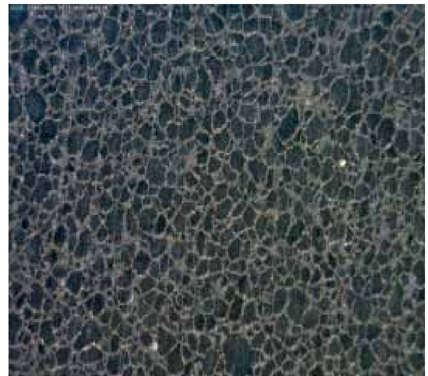
The gliding properties, behavior in snow and thus the speed of a ski is determined by its running surface or base. Nowadays the base of high-performance skis is made from sintered UHMWPE. This plastic combines strong wear resistance with water repellence. The non-polar, hydrophobic UHMWPE, characterized 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 cylindri-

Micro-cavities in the three-dimensional honeycomb structure have collapsed: At this stage it is no longer possible to apply wax



The sintered UHMWPE structure of the ski base before treatment. Blockages and dust have accumulated in the micro-cavities



Base structure after plasma treatment: The micro-cavities are clean and have expanded

cal mold and then compressed under high pressure. Once 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 (hollow micro-cavities). 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. 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 and physical interactions of the structural characteristics to those involved, the test series got underway in September 2013.

Two-stage test phase

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

The first stage of research focused purely on cleaning. The results were impressive: 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. But this outcome was just one of the effects of plasma treatment. Another effect was that the plasma had also activated the previously non-polar plastic, thereby polarizing its surface. Normally this creates the perfect conditions for bonding or coating with polar substances – but not in the case of wax, which is non-polar. In order for the non-polar wax to adhere to a substrate, the mutual electrostatic interaction forces have to be similar, and that only happens if it en-

Dr. Domenico D'Angelo and Elisa Aimo Boot have turned the PlasmaSki project into a patentable process after just nine months of research counters 'its own kind', that is another substance with non-polar molecules.

Plasma Nano-Tech therefore had to generate a new substrate, a layer whose chemical characteristics and surface energy values were again similar to those of the previously non-polar polyethylene. Palmi suggested that at the same time this layer could be functionalized in such a way that it reinforced the three-dimensional honeycomb structure and reduced the friction coefficient. PlasmaPlus plasma technology provided all the criteria to implement these three requirements. The aim of the second stage of the test phase 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 between wax and base.

A sixfold increase in wax adsorption

The final result which the researchers D'Angelo and Aimo Boot 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 at a press conference in June 2014. 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 substantially. ▌

Inès A. Melamies

Contacts:
Environment Park S.p.A., Torino, Italy
info@envipark.com, www.envipark.com

Plasmatreat GmbH, Steinhagen, Germany
mail@plasmatreat.de, www.plasmatreat.de