Photonics21 Press Release

Photonics: 'shark skin' surfaces to cut aircraft CO2 emissions

EU Commission invests €5.6 million in new laser system that creates multifunctional film surfaces inspired by smooth shark skin to reduce drag and ice formation on aeroplanes or ships – significantly reducing carbon emissions and lowering fuel consumption.

A new project backed by the European Commission and supported by the Photonics Partnership is developing a new laser system that can create precise, multifunctional patterns from nano to micro scale on polymer films.

Just as the sleek texture of shark skin allows these ocean predators to glide effortlessly through water, advanced films structured by this new laser system are being created to significantly reduce drag on aeroplanes and ships to lower fuel consumption and reduce carbon emissions.

The project, called OPTIMAL, is developing mastering technology to structure polymer films, fundamentally changing how surfaces interact with air or water, and offering a durable solution that outperforms smooth coatings.

The microstructures enable new applications that help to reduce energy, cut waste, and slash production times.

Riblets: Reducing Drag and Ice

Called 'riblets', these microstructures, which mimic the texture of shark skin, are tiny, parallel grooves, often just tens of micrometres deep, that guide the flow of air or water more smoothly over a surface, helping reduce drag.

While plane surfaces might feel smooth to touch, at a microscopic level, they may not be perfectly optimised to reduce drag. More drag creates air resistance, requiring extra fuel to maintain speed and altitude. Similarly, in water, boat surfaces appear smooth but can accumulate algae or barnacles, which increase drag, reduce thrust, and lower fuel efficiency.

Ice formation on the wings, propellers, windshields, or fuselage can be particularly lethal for aeroplanes: incidents like the 2024 turboprop plane crash that killed 62 people near São Paulo, or the American Eagle ATR 72-200, which tragically crashed, killing 68 people on board in 1994, are chilling reminders of the deadly consequences of icing.

Planes already have ice protection systems to remove or prevent moisture from forming on the vital parts of the aircraft, but these new film surfaces structured with functionalities could further mitigate such risks.

Revolutionising Replication

Microstructures such as riblets could have various functionalities like drag reduction, anti-icing or anti-soiling, but currently, the combination of these functionalities can only be obtained on a laboratory scale.

Existing technologies, such as AeroSHARK, developed by Lufthansa Technik and BASF, have already introduced riblet surfaces to enhance aerodynamics and fuel efficiency.

But, the OPTIMAL project focuses on revolutionising the manufacturing of 'masters' — the finely detailed moulds or templates from which high-performance surfaces are replicated.

By integrating multiple laser lithography techniques, quality monitoring systems, and intelligent control algorithms into a single, streamlined platform, the project is enabling the creation of larger, more complex, and more precise master structures than ever before.

For the first time, it becomes possible to combine micro- and nano-structuring on industrially relevant surface areas with high speed and no need for post-processing treatments.

Project coordinator Markus Postl explains, "While 'shark skin films' already exist, the OPTIMAL project is taking this technology to the next level of precision and safety. We are adding extra value by redefining the way advanced manufacturing processes create these surfaces. OPTIMAL has an all-in-one approach: We are bringing together every step of production under one roof."

By integrating laser structuring, quality monitoring, and component production into a seamless workflow, the team is eliminating the need for external treatments or off-site processes, streamlining production and reducing delays.

"At the heart of this innovation is the use of AI and machine learning algorithms, which ensure that every component is manufactured to exact specifications. We have a "first-time-right" ethos to minimise errors, drastically cut waste, reduce costs, and, most importantly, slash energy consumption.

"One of our goals is to create greener, more affordable products. We are combining multiple laser technologies with self-learning algorithms (AI) to optimise designs and speed up production. To reduce errors and material waste, the OPTIMAL technologies include quality monitoring systems which can cut resource consumption by 40% to make manufacturing more sustainable."

Manufacturing and Medical Use Cases

Along with shark skin films, the OPTIMAL team is tackling inefficiencies in existing manufacturing methods by aiming to improve sustainability across a range of applications.

Existing laser-based manufacturing techniques have significant limitations, including being slow and inefficient, consuming a lot of energy, and requiring a long processing time. Conventional laser structuring tools, such as laser interference lithography (LIL) systems or direct laser writing (DLW), often require time-consuming and, therefore, expensive pre-processing for adjustment and calibration or can only create small, shallow structures, which limits their effectiveness compared to OPTIMAL technology.

Elena Turco from Joanneum Research (JOR) and Project Manager at OPTIMAL said: "By integrating advanced laser technologies with AI and inline quality control, the OPTIMAL project

is paving the way for a new era of sustainable industrial manufacturing. Being able to create precise, tiny structures, the OPTIMAL laser can be used to create tools used in high-tech manufacturing, such as moulds for lenses, chips, and multifunctional surfaces. We are making them faster and at a larger scale, which is set to boost efficiency across multiple industries."

"Our new laser system could improve lenses to make clearer visuals and more efficient manufacturing processes. Take, for example, the production of virtual reality lenses. OPTIMAL could make them smaller, which could provide gamers and technology enthusiasts with a more immersive experience at a reduced cost. Similarly, in photography and eyewear, OPTIMAL's advancements could streamline the production of high-quality optical lenses for cameras and glasses."

The medical sector could also benefit from the OPTIMAL system, which is being designed to enhance the production of microfluidic chips for Lab-on-Chip devices – small devices crucial for disease diagnostics and chemical analysis. By enabling faster production at lower costs, these life-saving tools could become more affordable and accessible to healthcare providers worldwide.

The OPTIMAL project is set to conclude in 2026 and brings together a consortium of European and international partners. These include JOANNEUM RESEARCH and Sony DADC Europe in Austria, micro resist Technology GmbH and BASF Coatings in Germany, DeltaPix APS in Denmark, Università degli Studi di Parma in Italy, University of Zilina and Centrum Vedecko Technickych Informacii Slovenskej Republiky in Slovakia, and HyperVision Ltd. in Israel.