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NEWSLETTER

Nº 1 | September 2016

This is the first newsletter, containing the latest news from the LASER4FUN project.

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Project

(Ultra) short pulsed laser-material processing as a promising technology for structuring surfaces and thus for embedding new functionalities for industrial applications. The project LASER4FUN, where "Fun" stands "Functional Surfaces", pursues to go far beyond the current state through the development of new surface micro/nano-structuring and patterning methods by using emerging these laser technologies. The research focuses on the interaction of laser energy with several materials and on new surface functionalities like tribology, aesthetics and wettability.

Academic partners participating in the project are Fraunhofer-IWS (Germany), the Technical University of Madrid (Spain), the University of Twente (Netherlands), CNR (Italy), the University of Birmingham (United Kingdom) and the Leibniz-Institut für Polymerforschung (Germany). Industrial partners in the project are BSH group (Spain), Alphanov (Fance), Robert Bosch (Germany) and Airbus (Germany). The project will run for four years and started on 1 September 2015.

The 14 Early Stage Researchers (ESRs) at the 1st Annual LASER4FUN meeting in Bordeaux, France (June 23-24, 2016).

14 Early Stage Researchers (ESRs)

LASER4FUN is a Marie Curie "European Training Network" (ETN), receiving a grant of 3.5 million euros from the European Committee. From the grant as many as 14 Early Stage Researchers have been recruited for research positions in the frame of a PhD doctoral program, targeting a PhD degree. The PhD candidates are hosted by ten partners from in and outside academia. The aim is for the researcher to experience different sectors and develop their transferable skills by working on this joint research project. The 14 Early Stage Researchers have started on their respective topics between January 1st and May 2nd 2016. For a biography of each ESR point your internet browser to:
http://www.laser4fun.eu/people

Summer school 2016

The Fraunhofer-Institut für Werkstoff- und Strahltechnik IWS organised and hosted, from August 29 until September 2, 2016, the first Summer school "*Short Pulsed Laser Micro-Nanostructuring of Surfaces*" for (and by) PhD students of the "Laser4Fun" project, supported by the European Commission (Marie Sklodowska-Curie Actions. This summer school was combined with the "*5th International Summer School on Trends and new developments in Laser Technology*", organised by the Fraunhofer-Institut für Werkstoff- und Strahltechnik IWS and the Technical University of Dresden. This one-week International Summer School brought about 40 undergraduate and PhD students together for an intensive programme of study on fundamental and applied aspects of laser technology. The main programme consisted of lectures by renowned experts, supplemented by poster presentations and informal discussion sessions, as well as practices in the laboratory. The course aimed to enable the exchange of new ideas across these fields.

The next summer school will be organized by the University of Twente (The Netherlands) in June 2017. Make sure to check the project's website for updates.

Friction reduction using DLIP

By Alfredo Ismael Aguilar Morales – PhD student at Fraunhofer IWS, Germany

Interference phenomena occur when two or more waves overlap in space and time. In laser processing, this basic phenomenon can be used for producing periodic surface patterns on different materials if high-power laser systems are used. In this case, the method is called Direct Laser Interference Patterning (DLIP) and it permits to fabricate periodic structures up to the sub-micrometer level. The geometrical characteristic of the structures depend on the laser energy density, pulse duration and wavelength used, as well as material properties. In the case of metallic surfaces, this technology has allowed to produce very well defined and homogeneous surface patterns based on local ablation and Marangoni convection. Furthermore, the repetitive distance of the patterns (spatial period) can be changed by controlling the angle between the beams (β, Fig.1)
Since friction and wear of technological materials depend on the contact area between parts as well as on the interaction between lubricant and surfaces, laser microstructured parts can be applied in the automotive industry in order to improve the tribological performance of different parts including mechanical seals, piston rings and thrust bearings. The patterned surfaces should act as a trap for the lubricant, increasing its lifetime as well as friction reduction[1]. So far, DLIP has permitted to reduce the friction coefficient in

steels up to 65% compared to unstructured surfaces. The results also indicate that different geometries might lead to different hydrodynamic pressures[2]. The challenge for the future is employing the micro- or nanostructured materials in existent devices for energy saving and lubricant consumption reduction.

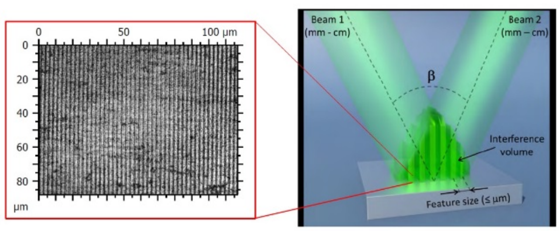

Figure 1 – Pattern resulted from interference of two beams on stainless steel

Anti-biofouling surfaces by DLIP

By Sabri Alamri – PhD student at Fraunhofer IWS, Germany

In our everyday life we are continuously in contact with technical products, from which we require higher and higher performances. Their properties do not rely only on the material composition, but typically on their surface characteristics. Therefore, the fabrication of specific surface topographies is a key for significantly improving their performances or even creating completely new properties.

An application where textured surfaces are nowadays strongly required is to prevent biofouling for example in devices that are in contact with living organisms. Most of the current research in this field is targeted to create surface functional structures in the micro- and nanometer scales. Several techniques are today capable to achieve these dimensions. However, they are typically sequential processes or they require high technical efforts. Direct Laser Interference Patterning (DLIP) is a recent technology becoming one of the most efficient routes for texturing materials up to the sub-micrometer level with high throughput. It relies on the principle of the interference between two or more laser beams for a selective ablation of materials capable to absorb the laser radiation (fig. 2A).

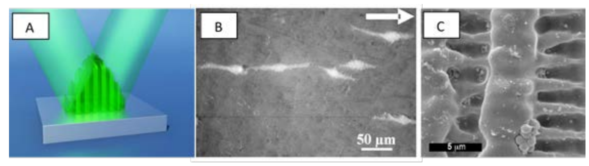

Figure 2 – Interference pattern generation (A), line-like pattern on poly-imide (the arrow indicates the direction of the pattern) with adenocarcinoma cells elongated adhesion (B) and S. aureus bacterial adhesion on lamella-like structures on poly-styrene

As an example of application, line-like structures with special periods of 500 nm on polyimide[3] have shown to force mouse mammalian adenocarcinoma cells to grown parallel to the lines and with a strong elongated morphology (fig. 2B). When in contact with ridges of the microstructures, the cell's filopodia detect the features and force the cell to spread in the other direction. A further study[4] reveals how other morphologies can reduce the bacterial adhesion on patterned polystyrene. In this case lamella-like structures (fig. 2C) are shown to reduce the bacterium S. aureus adhesion both in static and continuous flow culture conditions. Moreover, the same textured surface prevents S. aureus to colonize in presence of human serum proteins in a sub-cutaneous implantation. This preliminary result suggests a possible strategy for decreasing bacteria adhesion and proliferation on biomedical surfaces.

Textures to contrast biofilm adhesion

By Alberto Andrés – PhD student at BSH, Spain

Biofilm adhesion is a potential threat to both industrial processes and human life, enhancing corrosion processes, formation of biofilm on the ships' hulls, making easier the spread on diseases, causing periodontitis or dental caries, etc. This problem is also present in domestic appliances, where it can develop due to a prolonged use or a poor maintenance. For this reason the assessment and control of biofilm adhesion acquires a capital importance. Bacteria can attach to surfaces and develop into the layer known as biofilm. This biofilm is an assembly of bacteria (dead and alive) and other microorganisms, all of them glued together by an extra polymeric substance (EPS) matrix. It is this EPS matrix which provides structural integrity and protection, allowing the biofilm to survive in hostile environments.

Several strategies can be adopted in order to prevent the adhesion of biofilm, acting on the different stages of biofilm formation. The formation process starts with the attachment of bacteria to a surface, which start signaling other bacteria (using a mechanism called Quorum Sense) to increase their numbers. It is at this point when the EPS matrix starts being generated, developing the whole conglomerate into mature biofilm. The last step is the propagation along the substrate via detachment or sloughing.

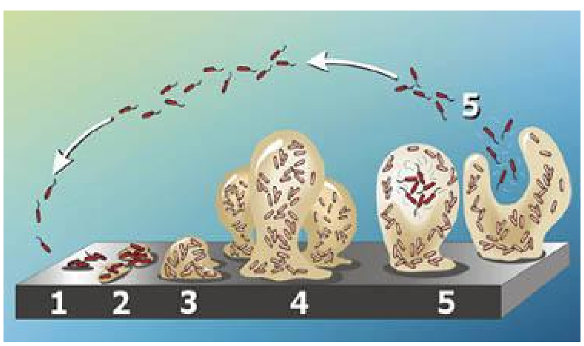

Figure 3 – Biofilm formation stages

The roughness of materials' surfaces plays an important role in bacteria adhesion thus becoming a promising method to fight biofilm adhesion during its early formation stages. Laser patterning is an efficient and versatile method to modify the surface's roughness from the industrial point of view, being able to reach structures in the submicron regime using the DLIP (Direct Laser Interference Patterning) and LIPSS (Laser Induced Periodic Surface Structures) techniques. Considering that bacteria's size varies between 0.5 µm - 5 µm, these techniques will suffice for the purpose of creating anti-biofilm surfaces.

Sapphire for microfluidic devices

By Luigi Capuano – PhD student at University of Twente, Netherlands

Synthetic sapphire, also known as single crystal aluminum oxide, alpha-alumina or simply alumina is a single crystal form of the mineral corundum. Its unique properties makes it a first choice for many high performance applications. Crystalline synthetic sapphire is remarkably transparent to wavelengths between Ultra-Violet and Infrared, and It is the hardest of the oxide crystals. Sapphire is also highly inert and resistant to strong acids and bases, and its chemical and physical properties remain constant even at very high temperatures and pressures. All these singular characteristics make this material perfectly suitable for applications in harsh and hostile environments.

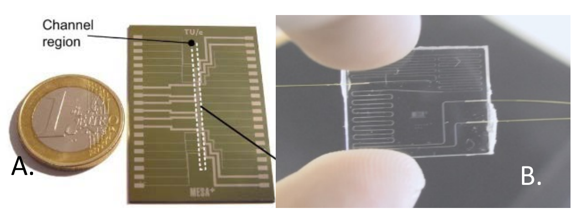

Figure 4 – Examples of Microreactors[5]: A. Microreactor made of silicon and glass, B. Microreactor made of glass

Microreactors (fig. 4) are small-scale instruments usually used for chemical reactions involving very small amounts of fluids (typically micro-, nano-, pico-, femto-liters). Thanks to their reduced size, they have many advantages over traditional macroscale chemical reactors such as the lower use of chemicals, higher reactions speed, fast analysis and modified reaction conditions. Typical used materials for microreactors are: silicon, glass metal, silicones and ceramics.

In 2006 Juodkazis et al.[6] achieved the creation of a pattern of microchannels inside the bulk of a single synthetic sapphire sample, using a two-step method of laser irradiation and selective chemical treatment. By focusing tightly a laser beam inside a sapphire bulk (below the surface), they altered the crystalline structure of the material and subsequently, by selectively etching only the modified part, obtained a complex structure of channels.

The use of sapphire to manufacture microchannels for microfludic devices is a powerful and promising novelty. Because of the material properties, in fact, such devices could be used in extreme conditions in terms of pressure, temperature or pH, conditions that can be found, for example, at great depths within the Earth where oil and other fossil materials are.

Self-cleaning metallic surfaces

By José Cardoso – PhD student at Universidad Politécnica de Madrid, Spain

Nature has a variety of functional surfaces to meet the harsh environments on the day to day life. Recently this field of study has gained considerable interest due to the potential applications in industry as well as in home appliances. Inspired by the "Lotus leaf", one of the LASER4FUN project aims is to study its high degree of water repellence and develop super hydrophobic materials that can also possess anti corrosion and low hydro dynamic friction properties. In super hydrophobic materials a self-cleaning property named the "Lotus effect" has great interest in industry due to its simple mechanic of removing contamination on the surface by rolling or bouncing water droplets. Ultrashort pulsed laser machining is an effective and fast solution to develop these materials, the high resistance of the hard textures created on the materials' surfaces turn laser processing into the most efficient technique to obtain proper roughness and achieve highly hydrophobic materials. Exploring the Cassie-Baxter model, where complex interfaces between solid-liquid-air improve the wetting property on the material's surface, using the UV-laser present at our facilities and taking advantage of the LASER4FUN consortium joint resources, we aim to produce hydrophobic surfaces on Aluminium and Titanium for future integration on AIRBUS aircrafts (Fig. 5) where the anti-icing and self-cleaning properties will increase both safety and performance.

Figure 5 – New generation Airbus 350 XWB[7]

Colouring by laser induced functionalization

By Fotis Fraggelakis – PhD student at ALPhANOV, France

Ultrashort pulse (USP) lasers have been extensively utilized as an effective and reliable tool for fabrication of so-called laser-induced periodic surface structures (LIPSS). LIPSS can be applied in a variety of surfaces resulting in a radical change of surface properties. Nanostructure surface can exhibit altered wetting and optical wetting properties in respect to the morphology of the induced nanostructure.

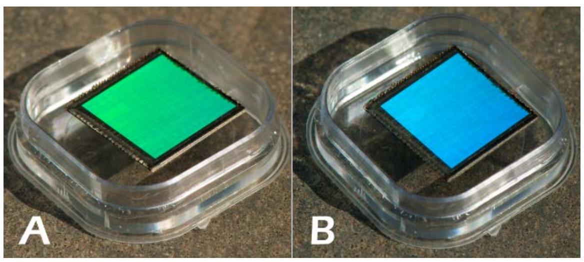

Figure 6 – Laser treated surface iridescence. The surface appears green (A) and blue (B) when observed by different angles

In Figure 6 we present an example of optical property modification using laser texturing.
The surface was processed using a high repetition rate, high average power industrial laser, combined with a high speed and high accuracy beam positioning system called scanner head. The surface becomes iridescent after laser treatment and in figure 6 is showed appearing green (Figure 6 A) and blue (Figure 6 B) under observation by different angles.

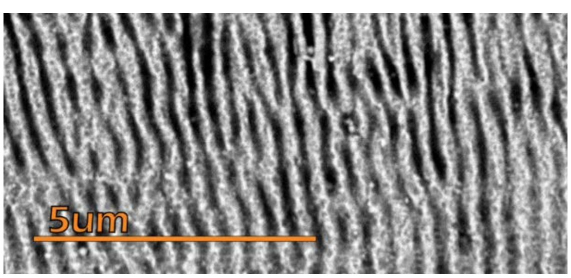

Figure 7 – Ripples induced on stainless steel surface (SEM image)

This optical effect is a result of the induced nanostructure, which consists of periodic nanoscale ripples. An image of the surface is shown in Figure 7 and it was obtained using an SEM microscope.
This periodical structure, when applied homogeneously in a large surface, behaves as a reflecting diffraction grating, reflecting different wavelength on different angles.
The resulting nanostructure is an outcome of a sequence of ultrafast interactions that undergo laser irradiation. Preliminary studies point out, that after an in-deep comprehension and manipulation of these interactions, we could affect the LIPSS morphology and moreover, we will be able to induce new structures on the surface.

Laser writing for hydrophobic surfaces

By Antonio García Girón – PhD at University of Birmingham, England

Surfaces can be classified by their wetting behavior. In particular, the shape of water droplets on surfaces shows whether a given substrate material is hydrophilic (the drops spread) or hydrophobic (the drop stay rounded).
Hydrophobic properties are often related to other interesting phenomena as bacteria repellence, self-cleaning or anti-icing, and that is why such surfaces are of great interest to a range of applications including medical, aeronautics and engineering ones.
Wettability of materials is measured by the contact angle of water drops on surfaces. An angle above 90º, for example, designates a hydrophobic surface, while a smaller angle hydrophilic properties. When the contact angle is higher than 150º, surfaces are considered super-hydrophobic. The contact angle between a liquid and a surface depends on chemical compositions of both and also on the surface roughness. The chemical composi-

tions affect directly the surface energy of the three phases in contact, i.e. liquid, solid and air, and water drops will always take a shape with the minimum energy in the contact area. At the same time, the contact angle increases with the roughness for hydrophobic surfaces. When this roughness is high enough to enable trapping of air between the liquid and the solid, super-hydrophobic properties can be obtained.

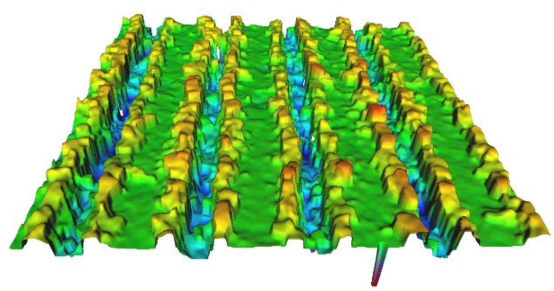

Figure 8 – The topography of a super-hydrophobic surface on a stainless steel plate obtained by laser patterning

Surface topographies of almost any substrate material can be modified by means of laser processing; control movements of a laser beam, i.e. a pulse train, across surfaces vaporizes and melts the material of the substrates and creates sequences of craters or small trenches on the surface. As the molten material is pushed away from the interaction zone it solidifies again and a dual scale pattern can be created. This dual scale topography acts like air pockets and changes the contact angle of water drops on processed surface, and thus leads to super-hydrophobic properties.

Stainless steel plates were patterned using infrared laser pulses in the nanosecond range (220ns) with the following process settings: 30 kHz pulse frequency, 100 mm/s scan speed and 70 J/cm2 fluency (Figure 8). Parallel trenches were formed that were 75 µm apart. The machined surfaces showed super-hydrophobic behavior with contact angles close to 180º.

Laser processing to control wettability

By Daniel Huerta– PhD student at Universidad Politécnica de Madrid, Spain

The concept of hydrophobicity of a surface refers to its ability to repel water, thus avoiding wetting and making the formation of puddles impossible as the droplets roll off the surface. In nature, this hydrophobic property is observed in the surfaces of some plants like the lotus leaf or the rose petal, and it's been show that these hydrophobic surfaces have structures at both micro and nano scale which help to develop this effect.

Figure 9 – Hydrophobicity on a leaf, also known as "Lotus effect"

Thus by creating these hierarchical structures on the surface of some material by artificial means, it's possible then modify the wetting properties of the material. In the research field of laser material processing it's possible to produce this micro and nanostructured surfaces in all kind of solid materials by means of a process of laser pattering. This allow to make hierarchical structures by the use of laser processing to generate micro and nanostructures all over the surface.

By use of nanosecond laser processing it is then possible to create these hierarchical structures and manipulate the wettability of some specifics materials that are vastly used in many industrial applications. Being able to develop large scale surfaces capable of repel water means some advantages when using them in real applications, since some problems that are related to excessive accumulation of water on the surface, such as oxidation, corrosion or wear, to name a few, may be avoided. Through collaboration of companies and research centers of some European universities, we seek to develop a direct connection between scientific research in this field and the industry by implementing the knowledge gained in laboratories and bring it to a more fundamental area in the industry, and that may be reflected into a benefit to the society. The specifics needs that we seek to fulfill are those required by Airbus Group Innovations, who are trying to apply this hydrophobic property on the aeronautic field, like in slats or winglets, to achieve a better performance of these parts. Because of this in the Laser4Fun project, we are working with this method of laser material processing in order to create hierarchical structures and have a good control of the hydrophobic properties of some materials at a large scale.

LIPSS for biomedical applications

By Marek Mezera – PhD student at University of Twente, Netherlands

Laser-induced periodic surface structures AKA LIPSS are very small ripple structures. They look like the wave structures found in sand which are formed by the water at the beach, just in nanometer scale. And just like the name says, they occur by laser processing materials with very specific properties of the laser beam.
They are found on metals, semiconductors and also on some polymers. The periodicity and scale of LIPSS makes them highly interesting for new innovative applications.

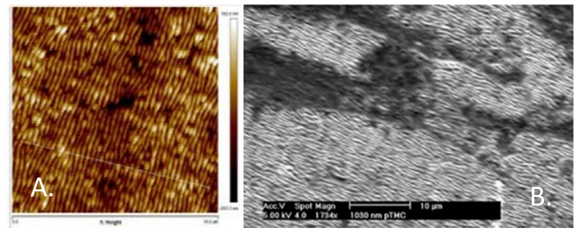

Figure 10 – A. LIPSS in PEG-PTMC; B. Cells on PEG-PTMC

Hendrikson and Masman-Bakker showed that human mesenchymal stromal cells can be transferred successfully to polymers, if the surface of the polymers is covered with LIPSS (Fig. 10). They achieved LIPSS on their polymers with a twostep process. In the first step LIPSS were generated on stainless steel with various laser beam conditions. In the second step they replicated the LIPSS form the stainless steel to the polymers by "hot embossing": the stainless steel samples with the structures are used as stamps to impregnate the LIPSS into the polymer (which is softened by heat) by pressure. The highly organized structure of LIPSS, was shown to be beneficial for direct cellular responses. This leads to a wider range of biomaterials for medical treatments. This approach gives scientists a new tool for stem cell biology and applications in the regenerative medicine field[8].

Mass replication of functional surfaces

By Jean-Michel Romano – PhD student at University of Birmingham, England

Functional surfaces can be fabricated by a range of energy beam-based processes, such as Direct Laser Writing (DLW). Developments in Direct Laser Interference Patterning (DLIP) and Laser Induced Periodic Self Structures (LIPSS) processes allow surface features down to sub-micron scale to be produced. Surfaced functionalized in this way can be used to achieve superhydrophobic, self-cleaning, non-fouling or anti-bacterial properties observed usually in the nature, e.g. plant leaves, animal skins or winglets. However, the cost effective fabrication of such surfaces that is directly related to the processing time is still a limiting factor in utilizing the DLW technology directly for texturing large surfaces. A promising up-scaling of laser structured/textured surfaces could be achieved by using replication technologies, e.g. thermoforming, compression injection molding and hot embossing. However, the gateway for the use of these high-throughput manufacturing processes is the fabrication of highly wear resistant replication masters that could withstand tens to hundreds thousands replication cycles. In this context, Bulk Metallic Glasses (BMG), with their very attractive mechanical properties, can enable the fabrication of such masters. These enhanced properties are due to the fact that, similar to glasses, the BMG has no short-range atomic ordering, i.e. crystallization or phase transformation.

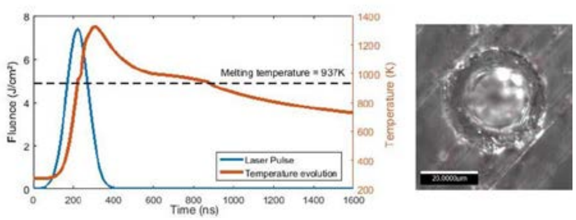

Figure 11 – First results from the temporal modelling of a Gaussian-shape laser pulse (220ns, 7.4J/cm2) and its induced temperature on Vitreloy1b substrates

At the University of Birmingham, we are investigating the use of the DLW technology for fabricating micro-structured masters, made of Zirconium-based BMGs. In particular, Vitreloy1b BMG is two times stronger and two times harder and four time more elastic compared to Stainless Steel. However, the challenge is to retain these attractive material properties by controlling the laser-induced temperature on the processed surfaces. That's why we are currently simulating the temperature response of Vitreloy1b when subjected to nano-second laser pulses and thus to be able to predict the thermal load and avoid any laser-induced crystallization.

Up-scaling of laser omniphobic surfaces

By Melissa Sikosana – PhD student at Leibniz IPF, Germany

A bioinspired textured surface that repels oil, alcohol and water, as well as bacteria was developed by scientists at the Leibniz-Institut für Polymerforschung Dresden in collaboration with the Institute of Botany – TU Dresden. This technology could allow for self-cleaning, antifouling- and drag resistant surfaces that are both mechanically stable and flexible. Today, superhydrophobic surfaces have attracted much attention, with particular interest in lotus-leaf inspired techniques that have the ability to repel water droplets and having self-cleaning as well as antifouling properties. However, these needle like structures have shown various limitations:

- They do not repel low-surface-tension liquids
- These surfaces are not mechanically stable

Researchers at IPF and TU Dresden discovered that the comb-like patterns and overhanging profiles found on the cuticular structures of springtails, can prevent wetting, even for low-surface tension liquids - hence resulting in so called omniphobicity. The commercial appeal of fabricating these overhanging profiles lies in that these structures may exhibit unprecedented level of control over wetting, regardless of surface chemistry. In addition the comb-like structures provide a mechanically stable and self-supporting network.

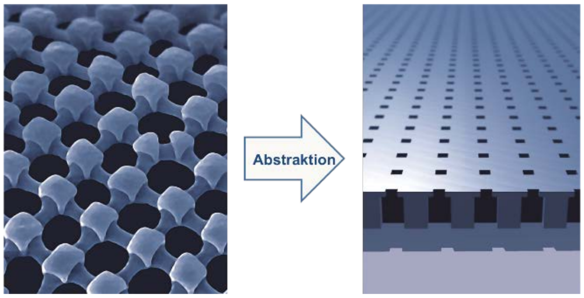

Figure 12 – Comb-like patterns and their replication

As such, a top-down method was devised to produce polymer membranes that mimicked this springtail cuticle morphology. Two-tier silicon master molds consisting of a small pillar centered on larger pillars as shown in figure 12 were fabricated using a lithography-etch approach. The master was used for casting of a first negative mold, which was subsequently casted for a second positive mold. Finally, using the doctor-blade technique, the cavities of the molds were filled with polyethylene gycol dimethacrylate pre-polymer solution to create internal overhangs. The resulting membrane was flexible and transferable onto various substrates. Hence showing promise of a broad spectrum of applications, including biofouling prevention on ship hulls or pipes.

Laser Surface Texturing to reduce friction

By Gagandeep Singh Joshi – PhD student at CNR, Italy

Vehicle emissions are responsible for up to 50 percent of the emissions that form ground-level ozone and up to 90 percent of carbon monoxide in major metropolitan areas, thus significantly contributing to global warming. Minimizing mechanical losses and friction in vehicle engines would have a great impact on reducing fuel consumption and exhaust emissions, to the benefit of environmental protection. Laser surface texturing (LST) with femtosecond pulses, in particular, has emerged as a potential new technology to reduce friction in mechanical components. LST consists of creating an array of high-density microdimples on a metal surface by laser ablation.

If properly designed, the macroscopic effect of such microstructuring is an enhancement of the load capacity, wear resistance, and friction properties of the laser-treated surface. The advantages of using femtosecond laser pulses compared to nanosecond ones reside in the fact that the ablation process is substantially melting free.

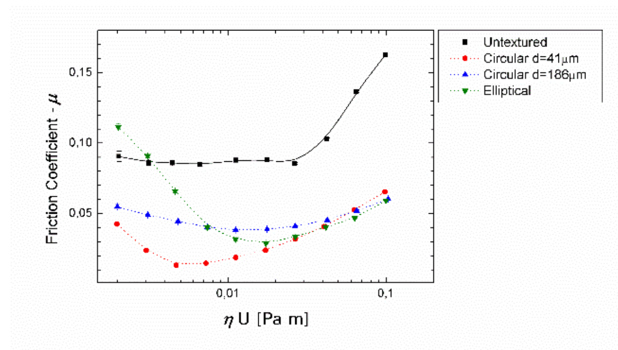

Figure 13 – Stribeck diagram of LST samples with different texture geometries (● circular dimples with diameters d=41μm, depth h~11μm, areal density A[%]=0.21; ▲ circular dimples d=188μm, h~6.8μm, A[%]=0.26; ▼elliptical dimples: major axis a=266μm, minor axis b=128μm depth h~6.2μm, areal density A[%]=0.26) compared to the flat control surface ■

Therefore, no burrs create on the edges of the micro-dimples, which could be detrimental to the desired tribological behavior, and no further polishing of the surfaces is required after LST. Furthermore, femtosecond laser ablation allows finely control the depth and the geometry of the dimples with micrometer precision. We have found that depending on the microgeometry of the surface texture, the coefficient of friction under lubrication regime can be accurately controlled (Fig. 13). In particular, when the texture consists of a square lattice of circular microdimples, the friction values are strongly reduced[9]. The experiments further revealed that an optimal void density and a depth value (depending on the dimple diameter) exist which minimize friction at the interface. Up to 85% of friction reduction has been demonstrated in a wide range from the boundary to the hydrodynamic regime[10]. It was also found that an elliptical texture allows adjusting the friction coefficient by changing its orientation with respect to the sliding direction[11].

Laser structuring to increase durability

By Tobias Stark - PhD student at Robert Bosch GmbH, Germany

The lifetime of mechanical parts is in general limited due to wear, which occurs if two materials rub on each other. In order to counteract wear systems are lubricated e.g. with oil or grease. A distinction is made between full lubrication and deficient lubrication. In this project, the main interest lies in metal-metal or metal-polymers contacts which are in the condition of deficient lubrication. In order to improve these so-called tribological contacts, the surface of the contact will be structured with a laser, e.g. with line- or crosslike structures. A key property for the different structures is the wettability of the surface. The hypothesis is that a high wettability helps to hold the lubricant in the tribological contact. In order to detect which structures have a high wettability simulations are run for different surface structures.
Two different laser methods are available to manufacture the surface structures, namely Direct Laser Writing (DLW) and Direct Laser Interference Patterning (DLIP). The structural period is the key factor to decide which method should be applied. While with DLW the smallest structures are about 10μm, with DLIP it is possible to manufacture structures in the submicrometer regime. Furthermore, the interference of two or more beams allows to parallelize the structuring process for line- or crosslike structures.

Laser texturing for aerospace applications

By Vittorio Vercillo – PhD student at Airbus Group Innovations, Germany

Icing research is a major area of interest of the Airbus Group for several reasons:

- Safety aspects: icing of aircrafts' wings or engines or probes can lead to safety issues during flight
- Environmental aspects: future aircrafts designs with Natural Laminar Flow (NLF) or Hybrid Laminar Flow Control (HLFC) concepts are on the way for reducing fuel burn and emissions by up to 2 - 3% in the next years. Ice on the surfaces disrupts the laminar flow around the profiles and nullifies the benefits of these novel concepts

Figure 14 – A380 flying in inclement weather conditions

It would be advantageous if surfaces could passively prevent ice formation and ease the ice removal.

A promising way to realize this is to tune the surface wettability through a hierarchical nano- and micro-structure, in order to reproduce the lotus effect. By using emerging Short Pulsed/Ultra Short Pulsed laser technologies dual-scale structured surfaces can be achieved. In these techniques the thermal interaction with the material processed is extremely low and its removal takes place directly by breaking the chemical bonds.

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[5] Pictures are by courtesy of Mesoscale Chemical System research group at University of Twente, Netherlands

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