No Chance for Dust and Contaminations

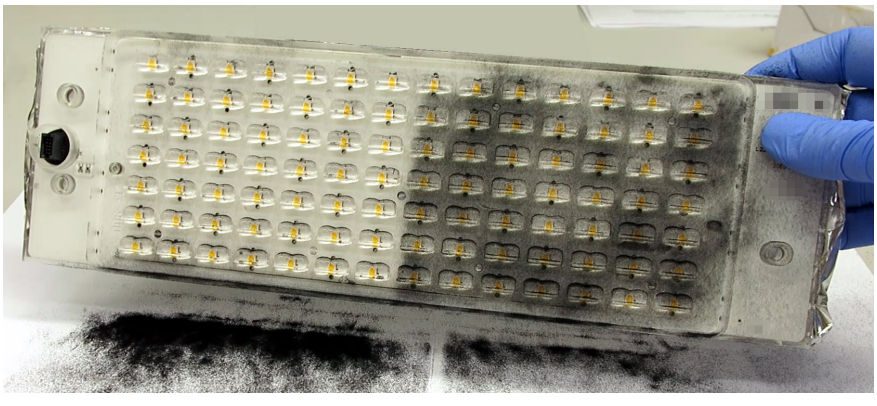
Surface Modification of LSR Components Hinders Adhesion of Dirt

LSR optics offers a wide range of applications due to the optical brilliance, the possibility to produce undercut shapes not to mention the competitive pricing. The adhesive surface which is almost impossible to clean however makes the LSR parts vulnerable against contaminations. This characteristic however limits the possible application fields. To overcome this limitation Wilhelm Weber has partnered with Fraunhofer IFAM in a recent research project.

The numerous advantages explain the large potential of LSR (Liquid Silicone Rubber) for optical applications. Next to the optical quality the high flexibility and the adjustable specifications must be named. In addition, the material is chemically stable, not sensitive against light exposure or natural UV radiation and usable in a temperature range between –60 °C and +250 °C. By overmolding of LED circuit boards it is also possible to seal the electric components and implement the optical lenses in one single step. However, the sensitive, sticky surface which can hardly be cleaned after a contamination is a big drawback. Therefore a special treatment during production is required to ensure a stable process and to avoid rejects. This allows new applications for LSR-parts and components in a non-sealed environment.

To overcome these limitations the company Wilhelm Weber GmbH & Co. KG together with the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) have started a state-supported ZIM project ("Central Innovation Programme for small and medium-sized enterprises"). Aim: develop and implement a chemical-free surface modification (registered under the OpSiLight trademark). For almost 15 years Wilhelm Weber is pioneering in the field of optical LSR applications. Remarkable, recent products are the complex LSR-Optics which are used in recent Matrix LED headlights.

During the research project which is scheduled till September 30th 2021 the overall principle of the process as well as latest results for a potential change in the refraction angle, reflection coefficient and the effect of micro cracks are examined. Furthermore investigation of geometrical effects of the UV treatment like warpage, the long-term behavior of the treated components as well as the influence of a tempering process onto the process are performed. The potentials and limitations both in term of part shapes and process parameters are discussed and representative sample are presented.



Half of the board was treated with VUV while the other half has covered. Afterwards norm dust was applied onto the board uniformly and than knocked off (once) in upright position. The dust sticks to the untreated areas while falls of the treated areas © Wilhelm Weber

Surface Modification to Allow New LSR Applications

For standard LSR parts, it is know that such a surface modification can be achieved by high-energetic UV-photons. However, for optical LSR parts the influence of the treatment on optical and geometrical characteristics is unknown. What is the effect of the UV exposure? To achieve the effect, the surface is irradiated with 200 nm max. typically 185 nm (**Fig. 1**) or 172 nm. The photons have enough energy to crack bonds in the silicon molecules in the surface layer.

As samples for the modification small optical LSR disks with 32 mm diameter were used. To evaluate the influence onto the surface quality both parts from a tool with eroded surface (VDI 24, 1.60 µm Ra) as well as one with a high-polished surface were produced and evaluated. Due to the good molding this results in crystal clear parts for the polished mold and slightly opaque for the first version. With a XPS analysis (X-ray photoelectron spec-

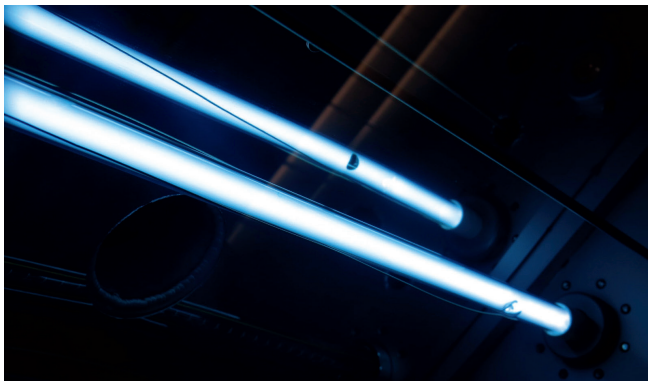


Fig. 1. Surface modification is performed with 185 nm low-pressure mercury lamps © Fraunhofer IFAM

troscopy) of the modified part surfaces it was demonstrated that the oxygen concentration in the molecule structure is more than doubled, while the carbon concentration was reduced up to a factor of 10. Therefore it was proven that the majority of molecules in the surface layer were modified.

By binding oxygen radicals from the surrounding atmosphere onto the silicon molecule fragments a glass-like surface is created. The thickness of the layer in the micrometer range can be modified by the dose and the wavelength of the radiation applied. The whole process can both be performed in normal or an oxygen-reduced atmosphere, additional chemicals are not required. However it must be ensured, that the whole surface which should be modified can be reached by the radiation, as the process is radiation induced. As the process window is pretty large also complex shapes and even areas which are slightly shaded are possible.

Optical Quality Is Not Affected

First experiments have demonstrated, that dust by normed test dust samples of polyamide fibers can be easily blown away by compressed air from the treated samples, while the untreated samples can be cleaned. In addition detailed measurements on transmission and reflection did not show any differences between the treated and the untreated material. However, small micro cracks on the surface may appear which might be reasons for property changes. By a suitable selection of the process parameters these micro cracks can be minimized or even avoided.

To evaluate the process the treatment of the 3 mm thick LSR disk (grade: Silastic MS-1002; manufacturer: Dow Chemical) both the radiation time as well as the surface is varied. Plotting the spectral transmission (**Fig. 2**) demonstrates, that below 450 nm the transmission is not affected »

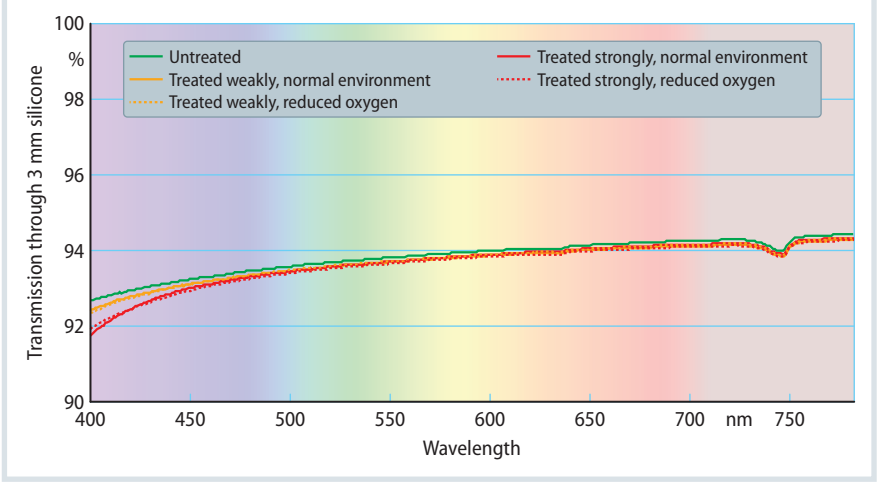


Fig. 2. Influence of the treatment to the spectral transmission, measured trough a 3 mm thick LSR disk. For wavelength > 450 nm no effect could be measured, while below 450 nm there is a slight decrease in transmission which is however not of any effect in most applications Source: Wilhelm Weber; graphic: © Hanser

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Company Profile

Wilhelm Weber GmbH & Co. KG was founded 1925 by Wilhelm Weber and Ernst Eberspächer. It is located in Esslingen am Neckar, near Stuttgart, Germany. Weber portfolio consists of three main branches: the construction of high-quality injection molding tools for multicomponent-, LSR- or high-precision applications, the production of actual injection parts as well as assembly and the production of rotary units. Weber offers the whole value chain of injection molding production, from design and customer support for parts over construction, production, assembly and verification.

Webers main customers are from the medical, electrical and automotive branch, while having a lot of long-term business relations with well-known partners.

The company has a quality management according to DIN EN ISO 9001:2008 and has recently about 120 employees.

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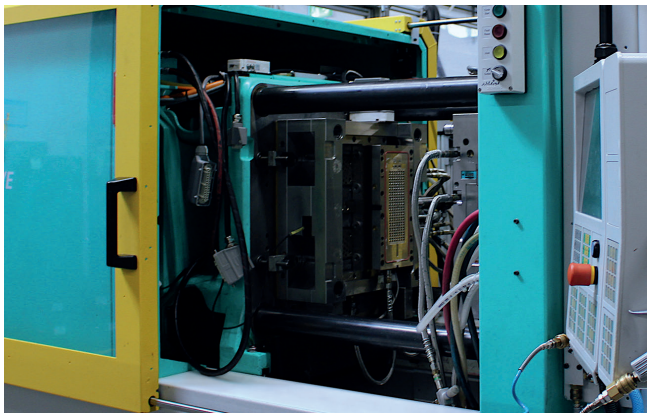

Fig. 3. View into the tool to produce the test boards for the modification
© Wilhelm Weber

at all, while below 450 nm the transmission is slightly reduced, which however is not relevant is almost all applications.

First Successful Application on LED Circuit Board

The advantages of the surface treatment with high-energetic VUV radiation (vacuum-ulta-violation) were shown in some test series. As an example application a LED circuit board with 98 LEDS (**Title figure**) which is overmolded by an optics with a combined sealing (**Fig. 3**) was covered by 50 % and irradiated with UV. After this treatment norm dust – in this case consisting of polyamide fibers of 0.3 mm length – was applied onto the surface. Afterwards the part was shaken and the fibers were blown away with compressed air. While the dusts stick to untreated surface and could not be removed, the treated surface was dust free. (**Fig. 4**). The amount of dust just falling of the board also shows how much dust actually sticks to the surface. In addition, the surface also has an improved surface feel.

In addition optical parameters like the mean intensity, the standard deviation and also a possible color shift were evaluated. It could be shown, that the intensity of the treated area (32.8 x 2.9 AE) and the untreated area (31.9 x 2.0 AE) were the same. Also the recorded intensity patterns and the direct pictures of the boards did not show any difference in light distribution, angle of radiation or spectral distribution.

Additional Advantages of the VUV Treatment

The newly created "glass-like" surface of the LSR is less sensitive to dust as demonstrated. In addition overmolding or gluing is possible in further process steps. Additional benefits oft he VUV treatment are:

- Long-term test cycles (> 18 months) show, that the modification is long-term stable.
- The modification is resistant against climate change, heating, storage in water, chemicals, etc.
- Gluing onto the substrate with typical methods like epoxide resin, polyurethane resins or tapes is possible, overall the surface energy is enhanced significantly.
- Adhesive free bonding onto glass is possible with freshly treated LSR.
- The glass-like surface has a conformable "silk-touch" feeling.
- The treated surface offers a high biocompatibility.

The surface modification also results in an enhancement of the surface hardness. The nano hardness and the elastic modulus was measurement with a nanoindenter. The hardness was measured as a function of the penetration of the measuring tip. The measurements shows, that the hardness and stiffness of the layers close to the surface are significantly enhanced. At a contact depth > 20 mm the value is enhanced by a factor of more than 100 (!), which is the highest value published.

Outlook: Cooperation Partner Requests

Recently, the process window is evaluated exactly. In parallel computer simulations are performed to be able to simulate the perfect process parameters and radiation distributions for specific parts. The process itself is fully ready for operation there Weber is recently looking for actual projects and applications partners which can benefit from the advantages. ■

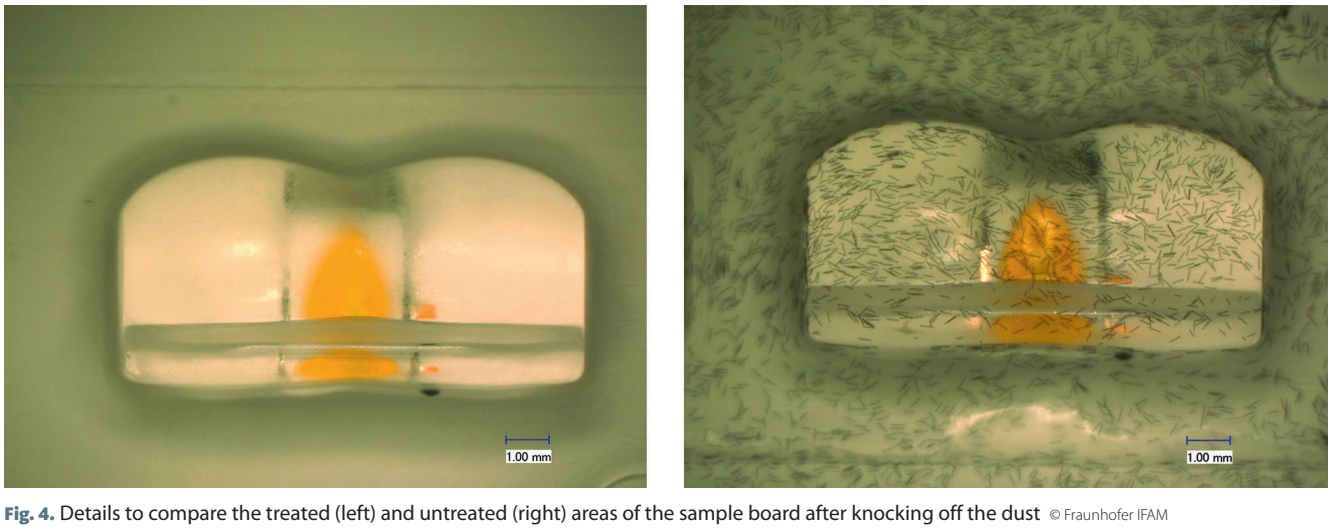

Fig. 4. Details to compare the treated (left) and untreated (right) areas of the sample board after knocking off the dust © Fraunhofer IFAM