# CURING MATT FINISHES INTO UV CURABLE WOOD COATINGS BY DIRECT CONTACTLESS MICROFABRICATION

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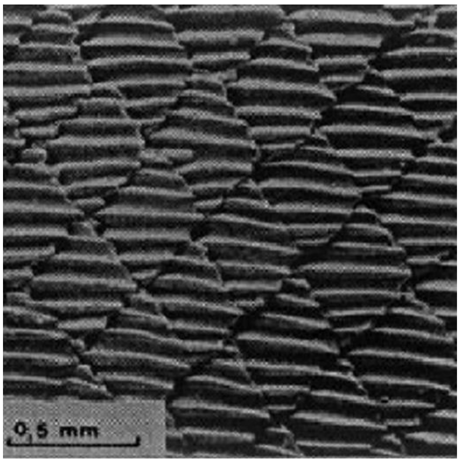
# Summary

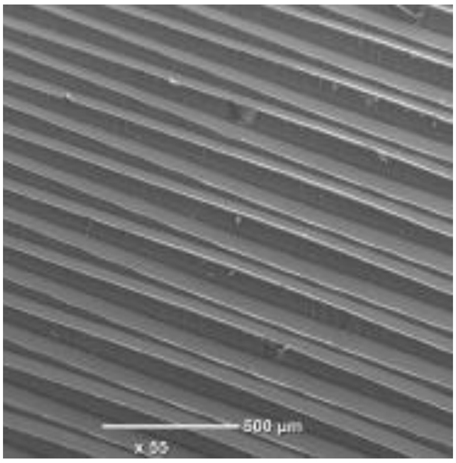
Matt finish for wood coatings are traditionally achieved by the use of matting agents that impose constraints on the application and resistance properties of the coating. This paper reports on a new process to cure matt finishes into UV curable wood coatings without the need for matting agents, by curing a micro-rough structure into the coating. This is a new application of the MicroTau Direct Contactless Microfabrication (DCM) technology originally developed for printing drag-reducing microstructures for aerospace applications. MicroTau and EFSEN UV & EB TECHNOLOGY are working together to integrate this technology into existing wood coating manufacturing lines that utilize UV curing.

## Introduction

Biomimicry is the use of nature as a source of inspiration to find new solutions. There are plenty of examples in nature of structures that gives outstanding functional properties. The technology in this paper creates microstructures in UV coatings to produce functional, visual or haptic effects on UV coated surfaces. The initial goal with the technology was to create a drag-reducing surface pattern in UV coatings, to reduce the friction when air flows over the surface. Inspired by how shark skin microstructures prevent vortexes to be created, the technology has produced this type of microstructures for aerospace coatings, successfully reducing skin friction drag by 7%. This 7 % translates to 2% or greater fuel reduction, and also increases the mileage accordingly.




*Picture 1.* Low drag microstructure of the Galapagos shark.




*Picture 2.* Low drag microstructure produced from a UV coating with the MicroTau's DCM.

EFSEN UV&EB Technology, located in Denmark, has a long history of involvement in wood coating processes, an industry that has been strong locally and in neighbouring countries. The joint venture together with MicroTau was initiated to explore what benefits this microfabrication technology would have in this and similar industries, and how the technology could be transferred and implemented for wood coating applications. This paper will highlight the potential of this technology in the field of wood coatings, and the path forward.

The general purpose of any wood coatings can be divided in two categories; to enhance the appearance of the product and to improve the surface properties. UV coatings in general are known for the resistance properties they bring to the surface, the high productivity due to short drying times and the naturally high gloss of finish. Achieving low gloss surfaces with UV coatings is a challenging task. Enhancing the appearance and properties of the UV coating with this microfabrication technology might open up some new and interesting features.

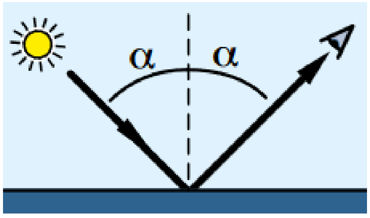
## Microstructures to enhance the appearance of wood coatings

When looking at the appearance impact of microstructures, the gloss level is one of the main things considered. While high gloss coatings have been popular, low gloss coatings seems to have taken over the last few years, at least when it comes to flat wood furniture for interior design. In general, low gloss coatings are perceived as more natural, whilst glossy coatings can have a look and feel reminiscent of plastic surfaces. Whilst glossy coatings are generally easy to clean, as they lack the roughness of a matt surface, they tend to highlight defects due to the high reflectivity. Matt surfaces however, help conceal surface imperfections. A low gloss is also said to give a warmer, more sophisticated look. An example in interior design is the fact that matt furniture surface provides a neutral toned down contrast to polished steel and marble details.

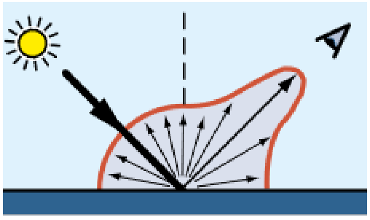
*Picture 3.* An example of matte kitchen fronts, matt parquet flooring and matt walls creating a natural and sophisticated look, providing a good contrast to the gloss of marble and stainless steel.

## The concept of gloss

The sheen of a surface, or the gloss level, is the observers visual impression when looking at a surface. If a lot of direct light is reflected, the surface will be perceived as glossy (*Picture 4*). If instead the surface scatters the light efficiently, it will be perceived as matt (*Picture 5*) or blurred, as only a fraction of the diffused light will reach our eyes. This scattering is measured from 0 to 100%, with 0% being super matt with maximized diffusion and 100% being a mirror-like gloss with maximized reflection. This level is measured at a specific angle, usually 20° for surfaces seen straight on, such as kitchen cabinets, 60° for tabletops or 85 degree for interior ceiling panels. The standard used for wood coating furniture and flooring industries is 60°. A majority of products in the wood furniture industry has a desired gloss level below 25, which is semi-matt, but there has been an increasing interest for lower gloss levels also. There are a number of strategies to reduce the gloss level of a UV coating, which are worth dwelling on a bit in order to understand what benefits the MicroTau DCM method could potentially offer.



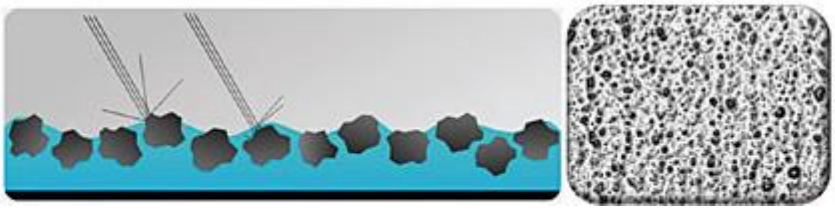

*Picture 4.* Reflection of light from a high gloss surface.



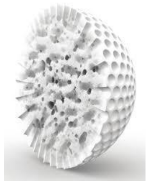
*Picture 5.* Diffusion of light from a low gloss surface.

## Particle based matting

Matt finish for wood coatings are traditionally achieved by incorporating matting agents, usually silicas and waxes, into the coatings. These particles create a rough microstructure, scattering the light that hits the coating, thus providing a matt appearance. This method of creating matt wood coatings has been reasonably successful and widely commercialized. It does however impose some constraints. The relatively high pore volume, and thus the oil absorption, of silicas are generally significantly higher than powder such as mineral fillers, which increases their impact on the viscosity. This is one of the main contributing factors making it increasingly difficult to reduce the gloss level while maintaining a reasonable viscosity and flow. Thus it is a delicate, sometimes impossible balance trying to find the optimal amount of matting agent to reach a target gloss without ruining the application properties. Much due to this, to reliably produce dead matt surfaces (in the 5 gloss region at 60 degrees) with consistent appearance and quality has become a bit like the holy grail in the wood coatings industry. Failures to successfully incorporate matting agents can lead to application issues, resulting in unacceptable surface defects. Even when successfully incorporated, there might be tendencies of these problems. The difficulty to develop and apply these coatings also has a negative impact on the price level.



*Picture 6.* Matting through particle based light scattering.

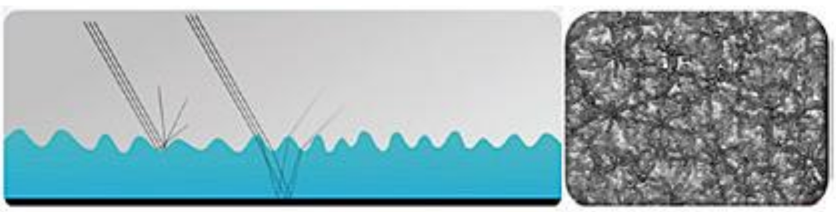


*Picture 7.* Matting agent structure model.

*Picture 8.* Matting through internal reflection, utilizing waxes

## Surface roughness induced by VUV Excimer radiation

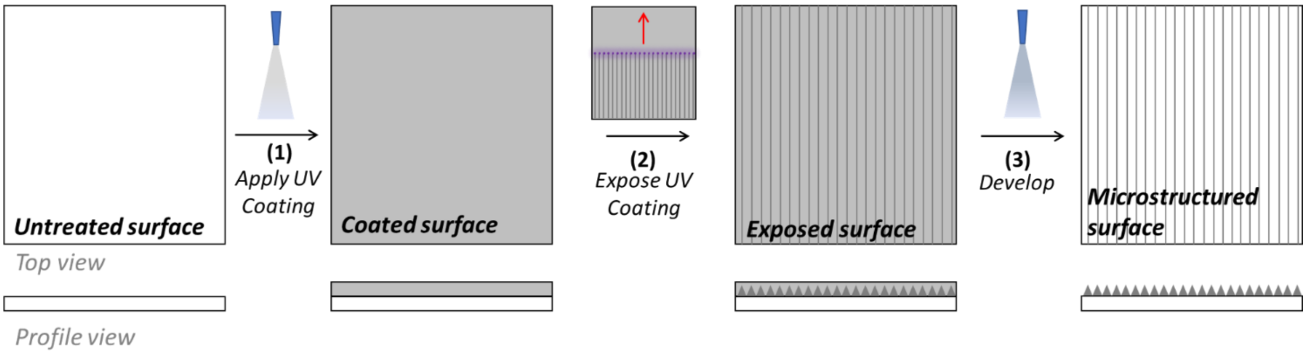
Alternative methods have been explored before, one of the most well-known is probably the excimer technology. This method uses Vacuum UV at 172nm to cure the very top of a coating layer, maintaining a wet layer underneath. As a result, the top layer will curl, forming a microstructure on the surface of the coating. This structure will scatter light efficiently, giving a matt surface, with anti-fingerprint properties. As the highly energetic photons of Vacuum UV is absorbed by oxygen in the air, there is a need for inert conditions. This is usually created with nitrogen, but this adds quite some constraints to the process. If the nitrogen flow is uneven, the gloss level will fluctuate. If oxygen levels are too high, then the technology will not perform as it should. Keeping oxygen levels low, and ensuring a constant nitrogen flow over the whole width of a line, is more convenient in roll to roll applications. There is very little distance between the substrate and the light source, resulting in low oxygen contamination levels, and reduced nitrogen consumption. When it comes to wood coatings, this distance has to be greater, as the substrates are thicker, rigid and may vary in thickness. This distance also creates a safety margin to ensure pieces does not get stuck, or slam into the lamps, thus there will always have to be a gap. This gap, especially at speeds above 10-15 m/min, makes it difficult and significantly increases the cost, to reach a sufficient inerting. Despite having been a reasonably frequent topic of discussion in the last few years, there has been very few adoptions of the technology for wood coatings.



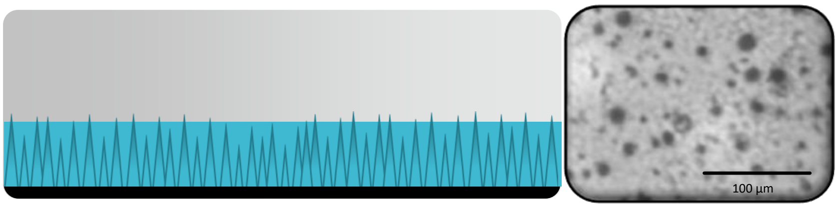
*Picture 9.* Matting through Excimer induced surface wrinkling.

## Surface patterning with the MicroTau DCM technology

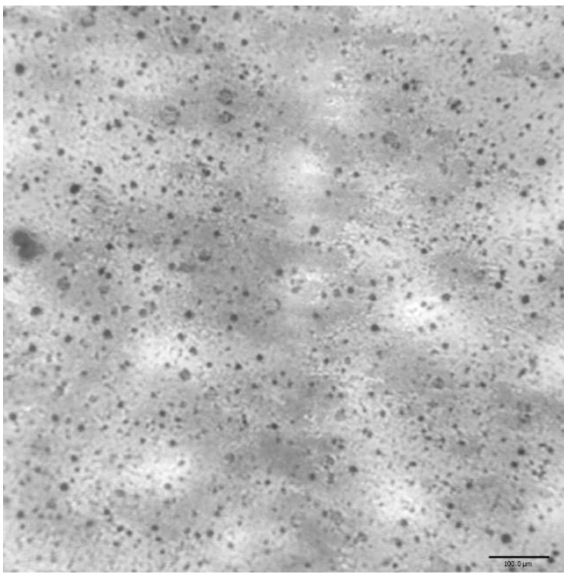
The direct contactless microfabrication technology that MicroTau has developed, offers the possibility to create a rough microstructure in a UV coating. These microstructures are created by applying an UV coating on the surface and expose it with UV utilizing the MicroTau technology. The microstructure will be produced at the bottom of the UV coating. In order to maximize the definition of the microstructure, a development step can be included, removing the unreacted material. The micro structured surface can then be post-cured to ensure that the full properties of the UV coating is obtained.



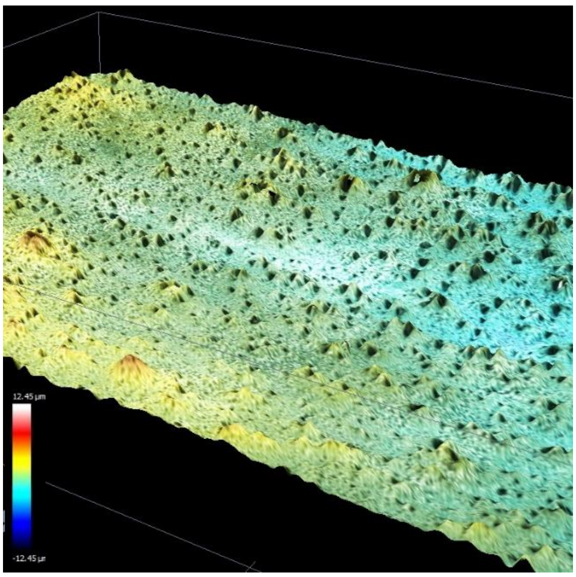

By completely curing the material after microfabrication, the light scattering structure will be embedded within the coating. The matting effect will then come from a combination of internal reflection and direct surface scattering. So far, this produces a matting effect that is not as pronounced, which is to be expected. Further finetuning of the technology is required in order to explore if a low enough gloss can be reached to make the "non-developing" method feasible for matting. If this is indeed possible, that would be an attractive route avoiding the developing step which would otherwise add some complexity to the process.




*Picture 10.* Matting through MicroTau DCM, without the developing step.

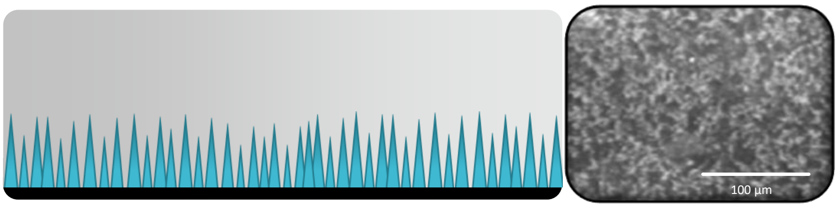


*Picture 11.* Microscopy image of a non developed surface.

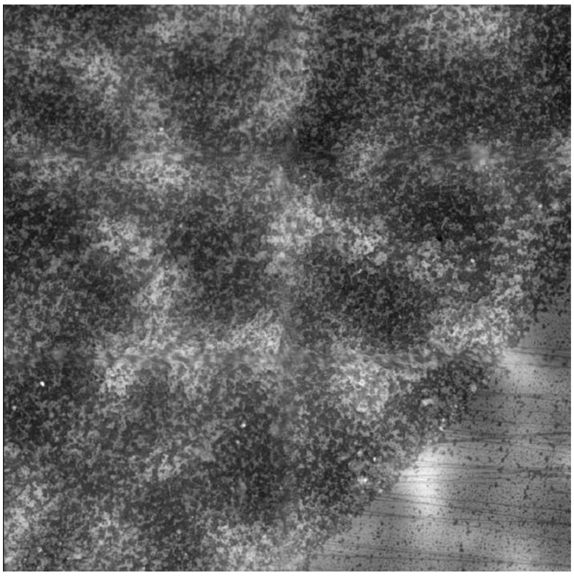


*Picture 12.* Surface topography scan of a non developed surface.

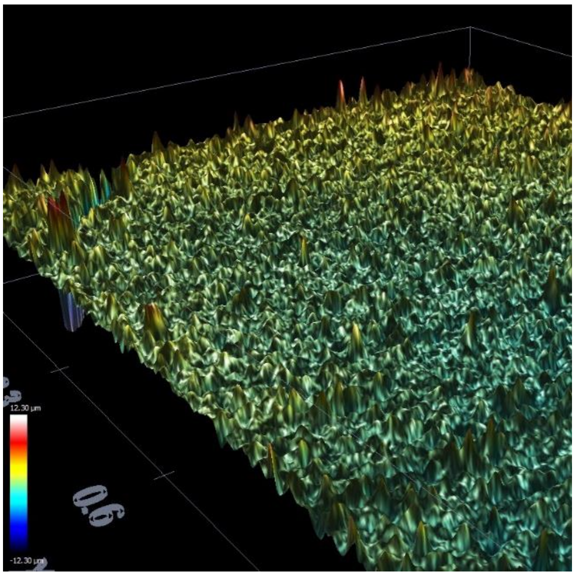
Removing the excess unreacted material with the final process will result in the peaks of the microfabrication being exposed, providing a maximized light scattering effect. The light scattering will work in a similar fashion to that achieved with matting agents, with peak structures rather than particles diffusing the light. While the developing stage requires an addition process step, which introduces some challenges, there are several advantages with a particle free matting methods, as previously discussed.




*Picture 13.* Matting through MicroTau DCM, with developing.



*Picture 14.* Microscopy image of a developed surface, notice the unexposed area in the bottom right.



*Picture 15.* Surface topography scan of a developed surface.

*Picture 16.* A glossy wood coating made matt (gloss 10) with the MicroTau DCM technology, including the developing step.

# Next steps with the Direct Contactless Microfabrication for wood coatings

## Formulating for maximized definition

Achieving a good matting is all about optimizing the structure development. This is true both when using a UV source to develop the matt structure, and when using particles. The efficiency of matting with particles is not only dependant on the particles selected, but are also influenced heavily by the reactive components of the formulation, and of the application and curing parameters. Many studies have been performed to find the answer to how oligomer, monomer and initiator properties impact the matting level. Oligomers with high double bond concentration and linear monomers with high mobility is believed to improve the matting. High initiator levels, high line speeds and high UV dose is known to reduce the matting effect, which stands in contrast to our general desire to have higher line speeds. Heating the coating, or heating the substrate before and/or after the coating application also has a significant positive influence on the matting.

One of the things we are working on with this micropatterning technology is to increase our understanding with regards to how formulations and process parameters impact how these structures develops and performs as the film is cured. As you might realize, this is not something that is done over a week in the lab, but we hope to establish the fundamentals in a timely fashion, to be able to successfully implement the technology in commercial production in the near future.

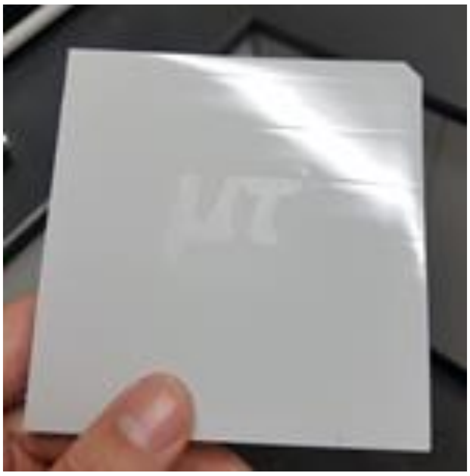
## Adaption of the technology to fit the wood coating industry

The technology was first developed to create drag reducing riblets in a UV coating after spray application to an aircraft, after which the structure could be developed by a spray wash of isopropyl alcohol. When it comes to UV coatings in the wood coatings industry, the most common application method is by roller coater, in flatlines at speeds ranging from 10 to 50 meters per minute. As such an application and process layout is quite different to the original method, there are many things to fine tune transitioning into wood furniture production. The development step in particular requires quite some adaptation, in order to provide a consistent homogeneous removal of uncured UV prior to the post curing. Several solutions are being explored currently.

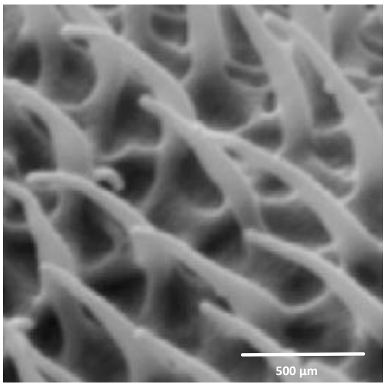
# Advantages and new possibilities with MicroTau's micropatterning technology

While the technology is not yet commercialized, and there are still many things to deal with before it can be implemented in production, there are many promising features that makes the technology of interest.

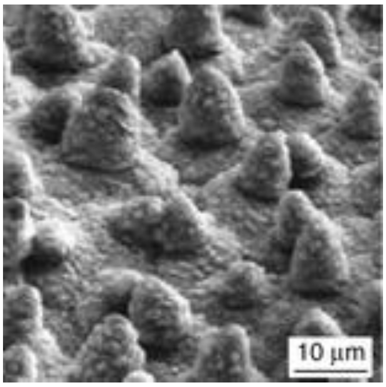
The use of selective exposure and filters can be used to create pictures and macro patterns combining different gloss values and micro patterns. This will give designers more freedom, with the micro patterning offering a new tool to create unique combinations of visual and haptic effect on the same surface. Furthermore, the structures created are not limited to light scattering structures for matting effects. The technology can create different microstructures with the same equipment setup, by adjusting exposure parameters and or utilizing filters.



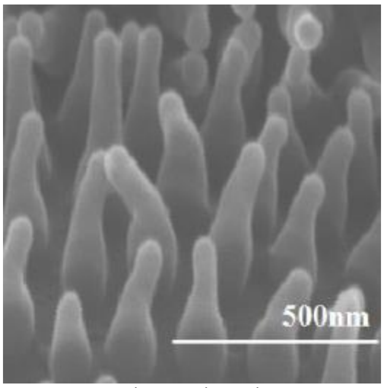
*Picture 17.* High gloss coating with a matt Micro Tau logo




*Picture 18.* Low adhesion Geco skin structure.




*Picture 19.* Hydrophobic Lotus leaf structure.




*Picture 20.* Antibacterial Cicada structure.

Taking inspiration from nature, there are also a wide range of functional microstructures that could be of interest. Antibacterial surfaces for hospitals and sanitary facilities. Hydrophobic structures that are easy to clean. Haptic surfaces, introducing a certain feel, mimicking the surface feel of other materials such as rubber, leather or silk.

## Conclusion

With the increasing demand for matt and functional surfaces, and the never-ending search for ways to increase the freedom of design, there is a high potential for the DCM method discussed in this paper, both for wood coatings and in many other fields. The technology has passed the proof of concept phase for a number of application, and are currently being finetuned for commercial applications. This emerging technology shows a lot of promise as a means to quickly create functional micro scale 3D structures with UV coated surfaces.