Soft touch waterborne polyurethane coatings.

Control of optic and haptic properties.

covestro

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Introduction

Haptic effect and low gloss coatings are representing a growing share of paints and coatings in the industry. "Look and feel" are core to the added value of these coating systems: by providing distinctive and appealing visual and tactile properties to end consumers, soft touch matting coatings help set a product apart. Next to a pleasant feel, these coatings also offer desirable aesthetic features such as creating contrasting surfaces, reducing sheen and enhancing color depth.

Starting over 15 years ago Covestro introduced a waterbased resin range for these very low gloss and haptic effect (such as soft touch) coatings. This one component technology has grown fast and has become a major product line consisting of a unique portfolio of waterbased (optionally UV curable) resins.

Polyurethane dispersions with micron sized particles

Waterbased Polyurethane Dispersions (PUDs) are a rapidly growing segment of the polyurethane coating industry, partly due to environmental legislations and the pressure to reduce emissions of volatile organic compounds (VOCs) to the environment.

In general, PUDs are small and discrete polymer particles of fully reacted polyurethane/polyureas, stabilized in water. Most common PUDs consist of particles in the typical size range of 10–200 nm. Upon drying of the coating, proper coalescence of particles, results in a smooth and glossy surface.

Covestro has developed a one component technology that enables the synthesis of much larger, yet stable micron-sized polyurethane particles in water. Typical particle sizes range between 1 and 10 micron (Figure 1). These special PUDs can be applied to generate low gloss coatings with a haptic effect, without the use of a second crosslinker. The effect is obtained solely by physical drying of the polyurethane dispersion.

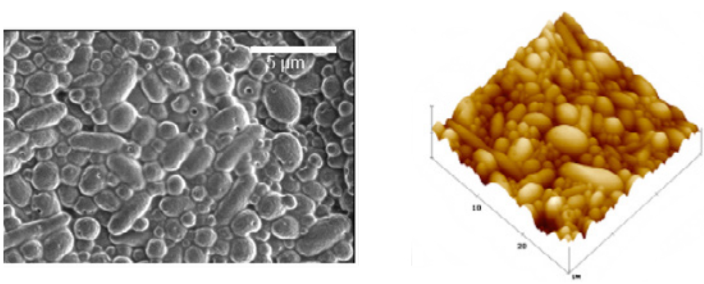


Figure 1: SEM image and a 3D AFM image of a Covestro softfeel coating, illustrating the particles in the size range of approximately 1–10 micrometers.

Due to specific design, these polyurethane particles demonstrate sufficient coalescence during film formation to form a coherent film, but usually retain their original shape, so that a defined surface roughness is obtained. Even though these particles are in the micron size range, this effect can already be obtained in coatings of only a few micrometer thickness.

Optic properties: How does it look?

Traditionally, in the coating industry gloss is controlled with organic or inorganic fillers, which cause surface roughness in the dried coating film thus reducing gloss[1]. In printing and packaging as well as wood finishing it is highly desired to provide matted transparent coatings which enhance the color depth of the underlying substrate. High visual transparency is a key requirement in these markets. This can be difficult when using micron sized fillers, partly due to refractive index mismatching. The alternative approach is to design a polymer, which forms a low gloss rough surface on its own. Such polymers can be cast in thin films, and have high transparency due no internal refractive index mismatching. In order to obtain quantitative data on surface topography, roughness profiles can be analysed by means of white light interferometry.

From the obtained 3D profiles (Figure 2), many different surface parameters can be calculated, such as. the root mean squared roughness (Rq), representing the height differences between valleys and peaks, and the average spacing between the peaks (L).

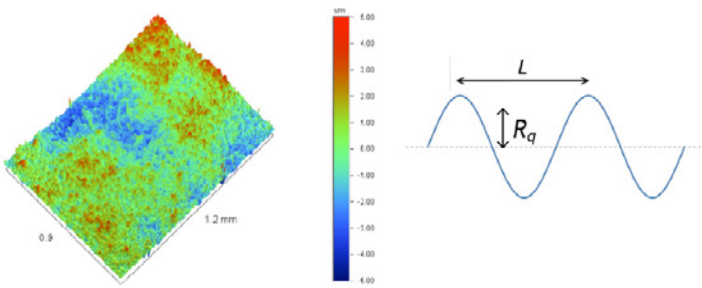


Figure 2: Typical 3D representation of a surface profile (left) and graphic clarification of parameters Rq and L(right), which are used to describe surface roughness.

Haptic properties: How does it feel?

Haptic perception is the outcome of a tribology experiment we perform with our skin: as we move our finger over a surface, the forces and vibrations generated in this frictional contact are detected by several types of neural mechanoreceptors embedded in the skin, whose signals are processed by our brains into our sensory experience of "feel"[2]. The contact mechanics and frictional forces between skin and surface therefore play a key role in haptic perception[3]. During touch, the surface roughness of both skin and surface prevents excellent contact in the entire apparent contact area. Generally, a softer surface deforms more easily, leading to more contact area and thus higher friction[4].

We constructed a finger friction measurement apparatus enabling us to study frictional forces generated on our materials during touch. Inspired by examples in literature[5, 6], the apparatus consists of a triaxial force cell on which the sample surface of interest can be mounted: this force cell simultaneously measures normal and tangential forces exerted on the surface, and this data can be used to calculate a Coefficient of Friction (CoF), by dividing tangential force by normal force.

To evaluate materials, a practiced operator slides his or her finger across a mounted sample (Figure 3). Fresh material is used for each measurement to avoid transfer of finger lipids, which alter the CoF if the same area is touched repeatedly[5].

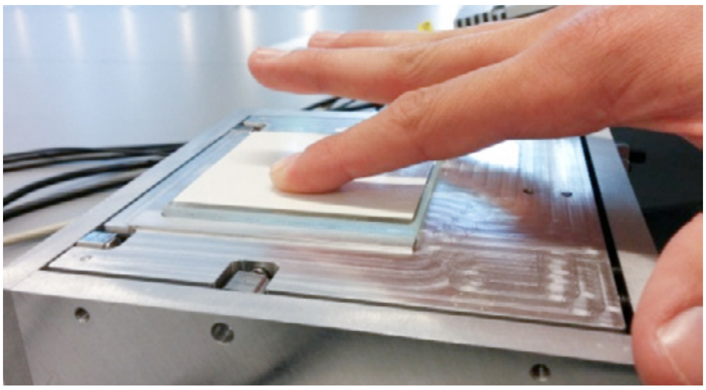
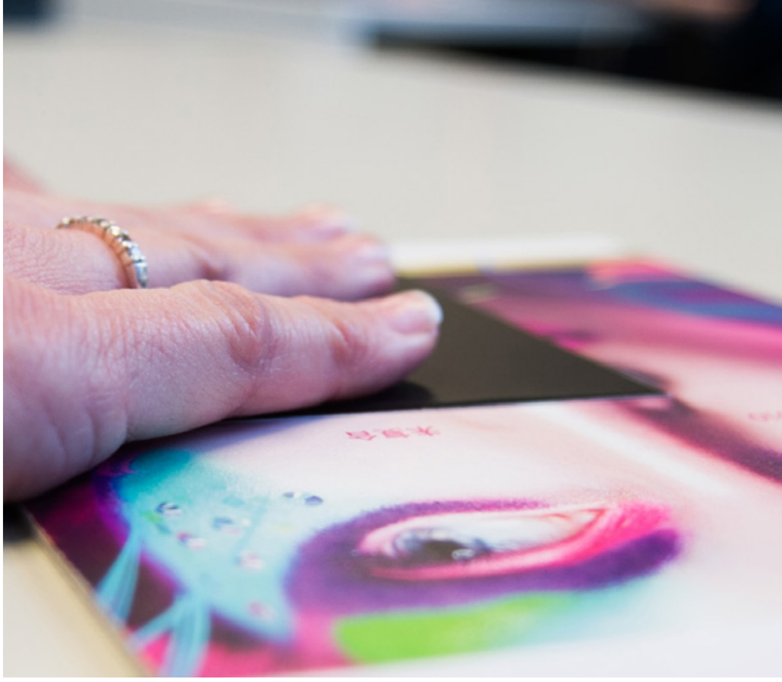


Figure 3: Finger friction measurement in progress using triaxial force measurement apparatus.



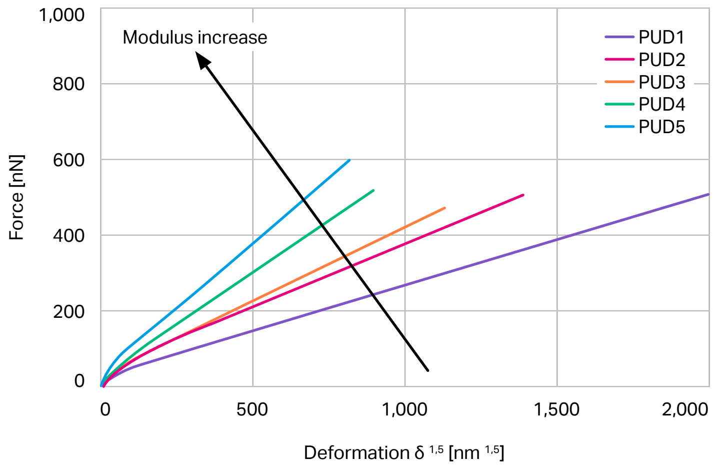


Figure 4: Force deformation curve of the PUD coatings studied in this work.

As an example of how tribological principles can be used to control haptic performance, finger friction data have been collected for a systematic series of five experimental polyurethane dispersions, that were designed to have coatings with similar surface texture, but to have different mechanical stiffness of the coating layer.

The near-identical surface roughness parameters were confirmed by the fact that all coatings showed very similar gloss values[7].

In order to obtain high resolution information on the top surface specifically, Atomic Force Microscopy (AFM) was used to measure the modulus variation[8] in the tested systems (Figure 4); the AFM measurements demonstrate that the coating stiffness has been altered systematically and significantly within this series, PUD5 being the stiffest.

in Figure 5 we present finger coefficient of friction data for this coating series. As expected, the measured finger CoF is observed to decrease with increasing stiffness of the coating. This is in agreement with the theoretical prediction that the lower-stiffness coatings should deform more and create a higher true area of contact at a given load, resulting in higher friction forces. Qualitatively, the softer coatings were also described as having a "rubbery" feel, while the harder coatings are experienced as "smooth." By controlling coating properties and thereby finger tribology, we are thus able to control the haptic properties of the coating.

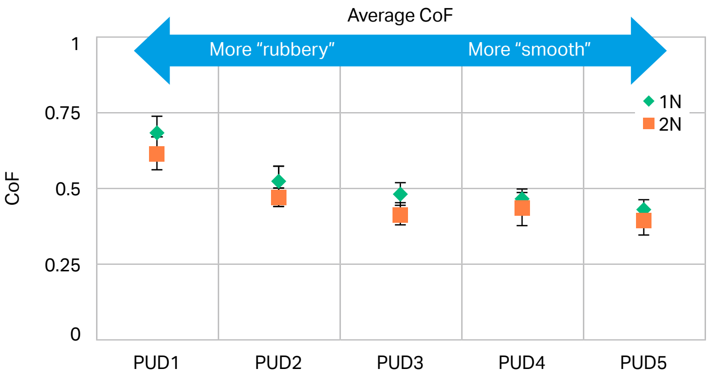


Figure 5: Experimental finger CoF data for the five PUDs.
Higher stiffness coatings are seen to result in lower finger CoF.

Quantifying feel: A human sensory panel as analytical instrument

When describing our haptic perception in daily life, we often refer to concepts like "hard," "soft," "sticky," "slippery," "smooth" or "rough." However, these perceptual experiences do not map one-to-one onto physical properties of the surface; for example, changing the surface texture of molded plastic material can alter the reported perception of "softness" or "hardness" of the surface, even when the mechanical properties of the material are identical[6]. Moreover, it is difficult to use precise language to describe haptic perception, as there is no universal agreement on what, for example, "silky" feels like, or on how to judge which of two surfaces is "more silky." The quantification of sensory experience therefore requires the careful use of a sensory panel of human evaluators[9]. For that reason, Covestro has set up a haptic sensory panel that is used as an analytical instrument as opposed to a qualitative instrument. The goal of this panel will not be to rank coatings for their preference, but to score the coatings on various defined attributes, that together can be used to quantify the haptic perception of coatings. In this way a multidimensional perceptual space can be created in which these (coating) surfaces can be positioned[10].

Our approach is to build the multi-dimensional correlation between the scores of the human panel and the material properties of the coating such as modulus, surface roughness, coefficient of friction and heat conductivity. By doing this, it will be possible to determine which physical measures can be used to tune the haptic perception, which is crucial for new product developments. Additionally, it will assist us to identify which physical parameters can be changed without the influence on the human perception. This can be crucial, as the haptic perception is often not the only important property of a coating. If for example the flexibility of a coating can be increased to improve scratch resistance, without an effect on the way the coating is perceived, it is possible to prepare a coating with better overall properties.

Finally, the sensory panel has been used for quantitative quality control of the Covestro soft feel products. This allows for better control and differentiation of haptic coatings and moves us away from what has been to date a very subjective assessment.

Summary

Covestro has demonstrated the ability to produce one component stable micron sized aqueous polyurethane dispersions that provide coatings with a matt appearance and a haptic perception such as soft touch. This effect is obtained without the use of crosslinkers and can even be achieved at very low film thickness (2 to 3 μm).

The surface roughness is an important parameter for the optic and haptic properties of coatings. White light interferometry was used to quantify the surface roughness and to correlate these with gloss values. For the tactile properties of a coating, next to surface roughness, other parameters such as stiffness of the polymer film are important as well. In a systematic study, a set of experimental coatings were formulated to have similar surface texture, but displaying different mechanical stiffness of the coating layer. The different tactile perception of these coatings were explained by finger friction measurement results and it was conculded that the increase in coating stiffness, results in a reduction of finger coefficient of friction.

Recently Covestro established a haptic sensory panel to quantify the human perception of coatings and to correlate these with physical coating properties. Although Covestro's micron sized polyurethane dispersions have mainly been appreciated in the graphic arts and packaging industry so far, the technology is ready to be expanded to other coating applications.

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Covestro Deutschland AG
Kaiser-Wilhelm-Allee 60
51373 Leverkusen
Germany

www.covestro.com

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