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UV curing systems for automotive refinish applications

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Abstract

The combination of the UV flash equipment, which generates UV flashes in short intervals with a high and homogenous energy density, with UV curing systems for automotive refinish leads to a perfectly suitable procedure especially for spot- and micro-repair applications. The UV curing refinish primer technology is well introduced in the market and the repair process time can be reduced by up to 50% compared to conventional systems. The visualization of the reaction grade and speed of the UV-induced radical polymerization is important for development. The skillful combination of the UV flash equipment with a FTIR instrument enables real-time measurements under application oriented UV curing conditions. The influence of applied UV intensity, oxygen inhibition and effectiveness of the polymerization reaction is investigated.

Keywords: UV curable coating; Automotive refinish application; FTIR; Real-time measurement

1. Introduction

UV curing systems have been successfully introduced into a number of market segments, such as printing inks and wood coatings. Especially for automotive OEM applications UV curable clearcoats will be important to improve scratch resistance. On the other hand UV curing of automotive refinish coatings is a powerful tool to enable a fast curing process and improve the productivity of paint shops.

The development of an UV curing refinish primer system is a new pathway for automotive refinish applications. Combined with UV curing equipment based on flash light technology a high performance is reached. The UV equipment generates UV flashes in a very short time interval with high energy [1]. Also a homogenous UV light distribution is realized to cure three-dimensional objects. This perfected procedure specially designed for spot repair applications enables a UV curing time in less than 60 s. The time of the complete repair process can be reduced by up to 50%.

For the research and development of UV coatings, the visualization of the reaction grade and speed of the UV-induced radical polymerization is important. For these investigations the FTIR real-time method is a powerful tool and is well used [2,3]. The double bond of such UV coatings shows characteristic absorption in the IR-spectrum. The decrease of the double bond content shows the effectiveness of the radical polymerization. To get such data in real-time during the curing it is necessary to measure with a very short scan time. Additionally, a negative influence of the IR radiation also produced by the UV source has to be avoided. With some specially adapted equipment it was even possible to use the very intense UV flash light. By varying the number of UV flashes, it is possible to determine the effectiveness of the polymerization reaction and the influence of the oxygen inhibition as a function of UV-intensity. The results are discussed and shown below.

2. UV curing refinish application

In automotive refinish applications a typical buildup of the paint layers is composed of a putty, primer, base coat and clearcoat system, depending on the type of car damage. Especially for spot-and micro-repair applications a system with high productivity and very short process time is needed. In the case of primer systems a UV curable primer in comparison to conventional 2K urethane or epoxy systems has advantages. First over all a faster and energy efficient curing process within seconds or a few minutes and a reduced process time is achieved with a UV system. Furthermore, with a 1K UV product a ready to use system and unlimited pot life is possible. Also a UV primer system can be formulated with a very high solid content and thereby VOC compliant. This represents an environmen-

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tal friendly and high eco-efficient coating system. Nevertheless, there are some challenges for a UV primer system. In general the through cure of the film depends on the type and amount of extenders and pigments. They have a large effect on the UV light-penetration, -absorption, -scattering and -transmission in the film. If the applied film thickness is too high, it can result in an uncured bottom of the layer. Another important issue for UV curing is the effect of oxygen inhibition, which leads to insufficient surface cure. As a result the surface is smeary and cannot be sanded or coated immediately after UV curing. The consequence is, that the layer usually has to be removed with solvent, increasing the process time.

Therefore, it is very interesting from the research and development point of view to get more information of the reaction grade and speed of the UV-induced radical polymerization. These investigations are done by FTIR real-time measurements.

3. FTIR real-time measurement

The main curing principle of the recent UV-coating developments is the radical polymerization of a double bond containing resin. The reaction is induced by a photoinitiator, which forms radicals by absorbing UV-light. The radicals react with the resin by opening the double bond. Thus, after the reaction the resin molecule again is a radical and the curing propagates as a chain reaction until there are no more initial resin molecules in contact to the radical or the reaction is stopped by oxygen inhibition of the radical. In this investigation different formulations for pigmented coatings with and without solvents were analyzed. Though the structure of UV resins sometimes varies significantly, they all have the double bond as reactive group in common. Such double bonds show characteristic IR-absorption at three spectral regions (810, 1410 and 1650 cm^{-1}). Therefore, the grade of reaction can be monitored by IR-spectroscopy as the decrease of the initial double bond contend due to the polymerization (see Fig. 1). One main task is to identify the potential of different resins with respect to the curing and cross linking and to optimize formulations. Another important task can be to identify the best photoinitiator for a given coating formulation, which is optimized with regard to the properties. Especially for optimizing the UV curing capability of pigmented systems it is necessary to evaluate the influence of the extenders as well as the pigments. For UV curing, the VISIT UV Flash Dry 15/700 equipment is used. This generates a high and homogenous UV energy density within a short time. The UV flash curing equipment can also be combined with an UV-A filter for evaluation and screening tests. But also a conventional and commercial available continuous UV-A handlamp (e.g. Dr. Hönle, uvahand 250) can be used for test evaluations.

3.1. Experimental buildup

In principle, a standard FTIR spectrometer offers the ability to measure an UV-coating at different times, and thus, at different propagating curing states. The requirements for the measurement of flash-induced UV curing in real time, however, are very challenging. On the one hand the UV flash equipment used for curing also produces very intense IR radiation, which would disturb the IR-spectrometer when joining the beam path. The energy of the UV lamp is about 1500 W per flash and the main energy is emitted within a few milliseconds. On the other hand, the UV-induced polymerization proceeds within seconds and the minimal repeat time between two flashes of the lamp is only about 1 s. Therefore, it is necessary to measure with very short scan times to enable monitoring of the progressive reaction and to distinguish between the separated flashes.

The first problem can be overcome by use of Diamond-ATR equipment. The principle of attenuated total reflection (ATR) techniques is the measurement of a sample at the interface to a crystal were the beam path is mirrored under the angle of total refection. During the reflection the sample in contact with the crystal surface attenuate the measurement beam by absorbing IR radiation at frequencies characteristic for that material. The information depth depends on the wavelength/wavenumber and has an amount of about 0.7 μm at 4000 cm^{-1} to 7 μm at 400 cm^{-1} for the diamond crystal. The UV flash lamp is installed above the Diamond-ATR unit with the same distance and operated with comparable radiation and power output like the same as that used in body shops. The IR radiation also produced by the flash lamp penetrates the crystal perpendicular to the surface, and

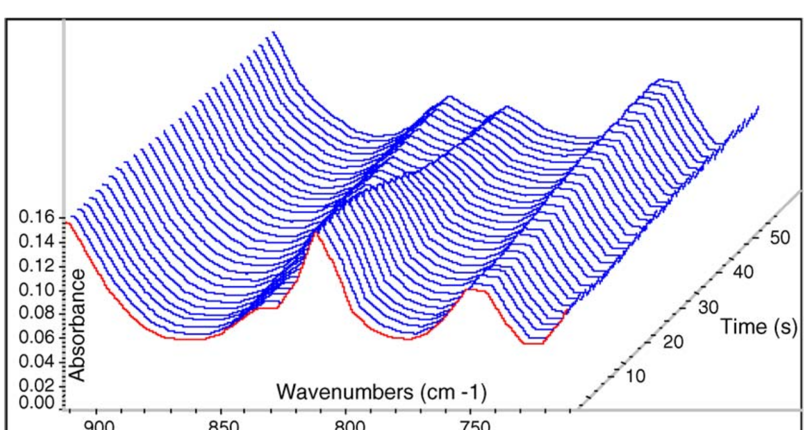

Fig. 1. Changes in the spectral region near 810 cm^{-1} scanned over time and due to the decrease of double bond contend by polymerization.