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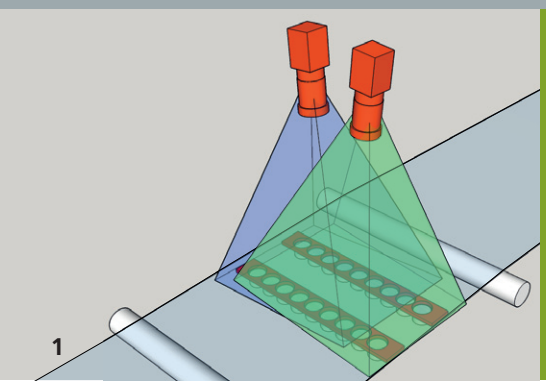

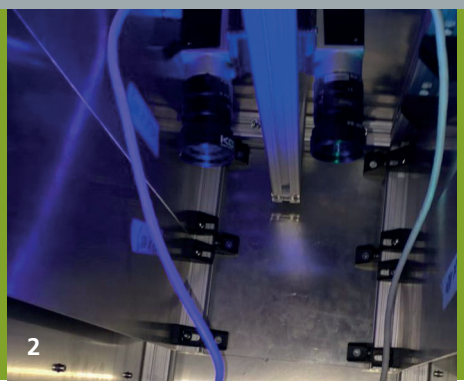

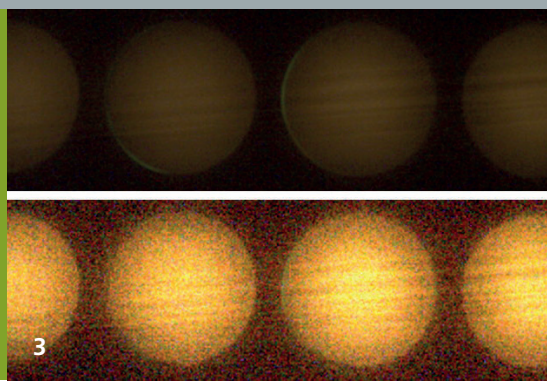

1 *Scheme of the detection system.*
2 *Detection system in a film converting machine.*
3 *Picture taken from a running film showing deliberate smear tracks in the coating (top as recorded, bottom amplified).*
4 *Relative thickness distribution.*
5 *Distribution of curing state of a lacquer coating after running through an oven at 60°C (left) and 120°C (right).*

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PROCESS CONTROLL FOR ORGANIC COATINGS

IN-LINE IMAGING OF THICKNESS AND CURING

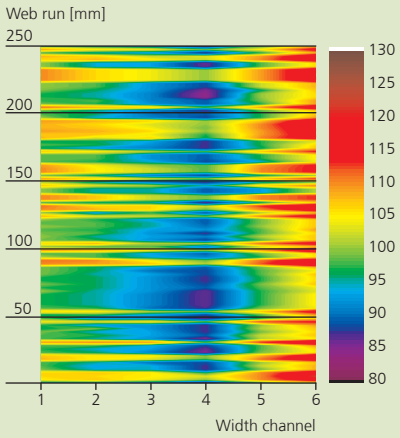
The challenge

Measuring the thickness of a transparent coating on a transparent material both having very similar refractive indices can be tricky, in particular if the coating is rather thin. The challenges even increase if the thickness distribution over an area is to be determined. The next step of sophistication is required when these measurements need to be established as an in-line technique for process control.

These challenges can be encountered with sub-micron lacquer coatings on polymer films or with impregnations such as a siliconization.

The solution

Some organic dyes exhibit a particular optical property called fluorescence. It means that they can absorb light of a particular wavelength (color) and emit light with a longer wavelength (other color). Fluorescence can be measured with an extremely high sensitivity and, therefore, only a very small concentration of a fluorescent dye is sufficient for its detection. For coatings with a thickness of one micron a concentration in the order of some ppm (parts per million) is required to record the fluorescence. Such a small concentration in a thin layer is not visible for the naked eye and it does not affect properties like mechanical strength.



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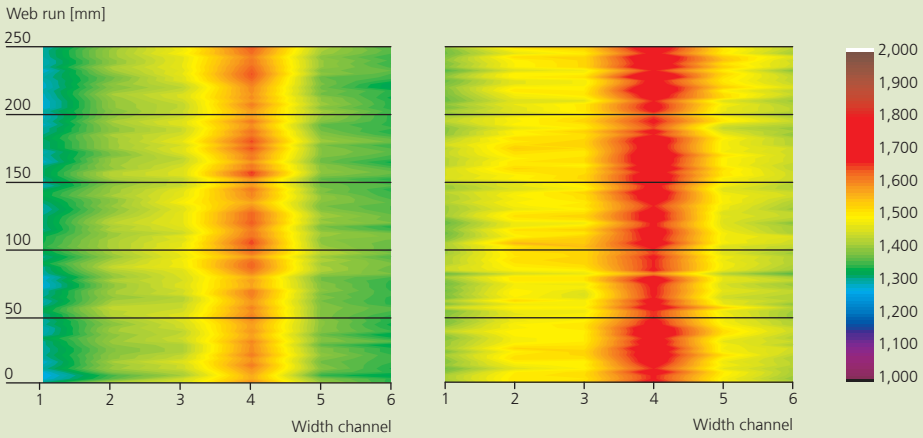

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The curing state

Some dyes show a fluorescence effect which depends on the molecular environment. The surrounding molecules influence the intensity and the wavelength of the fluorescence light. For example, the fluorescence may depend on the pH or the ionic strength of the medium. Other dyes react on the viscosity of the matrix. They show a stronger fluorescence in a solid than in a solution or in a highly cross-linked resin than in a less cross-linked one.

These properties can be used to tag materials and coatings. Then, the fluorescence depends on the curing or the cross-linking density of a resin and it can signal mechanical stress.

In-line imaging

For recording the fluorescence of a dye containing lacquer a source of the illuminating light and optical sensors are required. For the illumination monochromatic light is preferred and LEDs or a laser are perfectly suited. The fluorescence light can be detected by a digital camera. Depending on the details of the dye's optical properties additional components as filters might be necessary. Commercial web inspection systems can be used directly or with modifications.

Demonstration installation

In order to demonstrate the feasibility of an in-line process control by imaging the fluorescence of a lacquer coating, a very simple measurement system was installed in a film converting machine (Fig. 1 and 2). It comprises two types of LED and two cameras for detecting the fluorescence of two dyes. In this very simple system no means were integrated for the homogenization of the illumination. Therefore, the recorded picture shows the light spots illuminated by the LED in dark areas. Due to the intensity distribution of the LED light the spots are brighter in the middle. In a more sophisticated system there will be a correction for these shortcomings. But also the very simple system allows to display failures in the coating (Fig. 3).

The dye A fluorescence is used to image the thickness distribution (Fig. 4). Together with dye B a measure of the curing state can be calculated (Fig. 5).

Application range

The demonstration system was run at a web speed of 3 m/min and exposure times of 5 ms which gave a resolution of 2.5 mm in run direction. Web inspection systems with frame rates in the order of MHz are commercially available which would allow for much higher web speed and higher resolution.

The system parameters depend on many details. The dyes must be selected to be soluble in the coating system and not to be interfered by its optical properties. The selection of the light source, filters etc. is determined by the optical properties of the dye and the coating. The detection system has to comply with the optical properties of the dye and it determines to resolution at a given web speed.

Our service

We offer assistance with the design and the installation of fluorescence-based in-line imaging systems including

- the selection of suitable dyes
- design of the optical system
- feasibility studies
- finding suppliers of the components
- installation of the system in the clients equipment
- troubleshooting