The Next Level – Controlled Conformal Coating Processes

Intelligent combination of sensor technologies for calibrated inspection of coating thickness and fault detection – directly integrated into the production line

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Talking about purified assembled printed circuit boards (PCBs), e.g. in automotive industry for control of airbag or anti-lock braking systems (ABS), one of the main issues is the protection against environmental impact. The error-free functionality must be guaranteed even at the North Cape, the Rainforest or in the desert and this warranty has to be provided for even a decade.

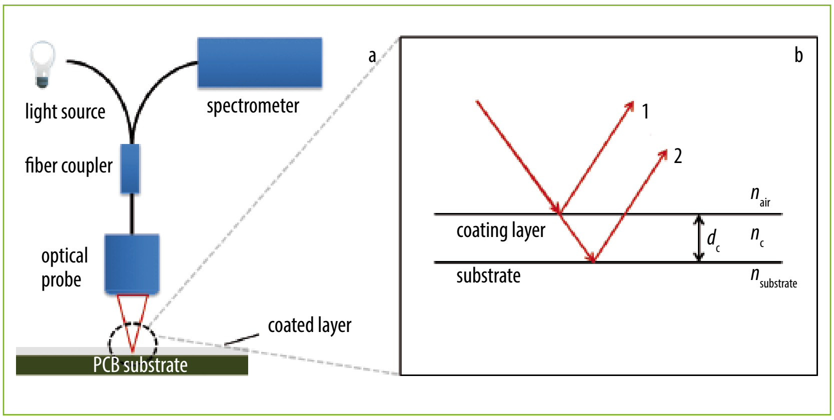

Fig. 1 a) Confocal measuring setup, b) interferometric coating thickness measuring principle (zoom)

The process of conformal coating is not new but nowadays manufacturers of PCBs start to use the conformal coating process not only at selected areas. The full board is going to be protected. To minimize the costs while guaranteeing the required protection on the complete board area it is inevitable in the production to measure and control the absolute thickness of the coatings continuously. An intelligent design of the full process chain implementing the conformal coating process is a perfect condition to integrate sensor technologies for process control.

This article describes the implementation of an optical sensor technology for the inspection of the conformal coating process to illustrate the benefit of optical measurement technology and to accomplish the needs of Industry 4.0 in today's industry.

Principle of conformal coating

Conformal coating is the process of spraying a dielectric material onto a device component to protect it from moisture, fungus, dust, corrosion, abrasion, and other environmental stresses. Common conformal coatings include silicone, acrylic, urethane, epoxy, and parylene. Dielectric conformal coatings are useful, when electrical shorts are a concern, such as when highvoltage components are in close proximity, but need to be insulated, or when conductive contaminants may enter the PCB envelope. Conformal dielectric materials also mitigate the formation of tin whiskers and prevent whiskers from reaching nearby components, which has become increasingly important with the elimination of lead-tin solders.

The simplest means to apply a conformal coating is manually with a brush. It is low-cost and easy to change between compounds. Depending on the operator's skill, little or no masking needs to occur over connectors or sensitive components, and repairs and touch-ups are easily completed. However, this method is usually sufficient only for small production volumes. Brush application is slow and it can be difficult to control the conformal coating thickness. It is also taxing on labor, as it requires a skillful operator as well as an individual to manage quality control.

Dipping of PCBs is a solution that coats all board surfaces simultaneously. It is a simple process that can coat many pieces at once and does not depend on operator proficiency. However, dipping can require significant masking and the conformal coating has a tendency to run off edges or corners. Dipping is typically

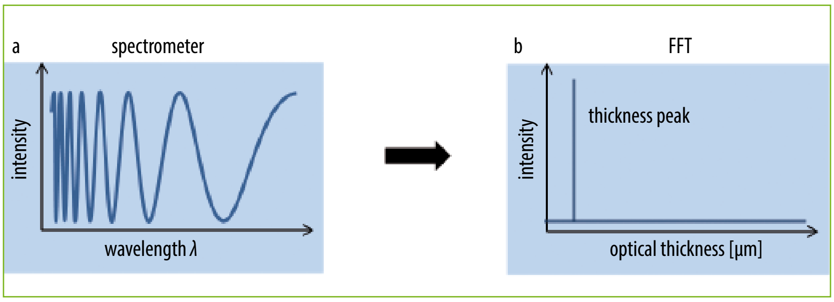

Fig. 2 a) Frequency modulation of the intensity signal. b) Corresponding thickness peak in the Fourier spectrum.

used for heat- or UV-curing materials. The required open conformal coating reservoir is susceptible to contaminants. Dipped conformal coatings also have occasional problems maintaining a uniform viscosity.

Spraying of conformal coatings is often the best option, when manufacturers require rapid throughput and high product volumes – it can be accomplished manually or robotically. Manual PCB spraying requires a skilled operator, but needs less masking than the dipping process. The low investment required for manual spraying equipment and easy conformal coating changes make this an attractive solution. Spray nozzles support a variety of application resolutions and patterns, and there are no edge coverage issues. However, manual spraying can be a slow process as the operator must maneuver the PCB or equipment while also applying the conformal coating. Certain compound viscosities are incompatible with spraying equipment, and the conformal coating spray emitting from a nozzle may not be uniform. Due to these factors, manually sprayed components often need multiple applications (spraying cycles).

Automated conformal coating spraying is the apex of conformal coating technology. It is excellent for high-volume, high-precision applications. It requires little masking as a multi-axis robotic arm or table ensures controllable and repeatable processing. Automated sprayers also can spray around components. Such systems may have significant capital expenses and maintenance needs, but this is the optimal system for speed and efficiency. This process is ideal for implementing sensor technology to measure the thickness of the coated layers to minimize costs while guaranteeing 100 % protection at the same time.

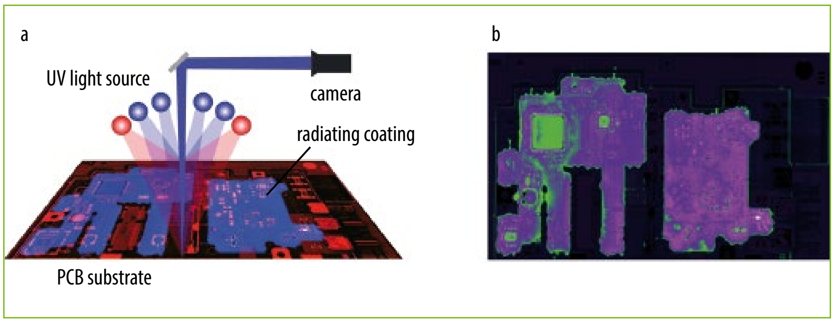

Fig. 3 a) Scanner measuring setup, b) fluorescence image of scanner (top view)

Optical sensor technology for absolute thickness measurement

The sensors of the CHRocodile product line, developed and manufactured by Precitec Optronik, are designed to allow contact-free, fast and precise distance measurements on and thickness measurements of various materials. Due to its small dimensions the absolute thickness measurement of coatings, films or wafers is based on the interferometric measurement principle, which is shortly explained in the following:

Fig. 1a illustrates the confocal measuring setup. The sensor incorporates a light source (white light or infrared), a fiber coupler, spectrometer and evaluation electronics. The light is transmitted via an optical glass fiber to the probe that is mounted perpendicular to the substrate being measured. The probe focusses the light onto the substrate and the reflected light is transmitted via the

Companies

Precitec Optronik

Neu-Isenburg, Germany

Precitec Optronik GmbH is the specialist for optical measuring technologies. We are manufacturer of high-quality products in the form of quality monitoring systems as well as optical measuring systems for distance and layer thickness gauges. Our optical sensors are characterized by highest precision and dynamic even at high measuring speeds.
Our expertise in the area of optical measuring technologies is essential in the glass, electronics and semiconductor industries as well as in coordinate measuring technology. CHRocodile sensor systems of Precitec Optronik are technology and quality leaders on distance and layer gouge measurement in the preferred range of nanometer to centimeter, even “inline” during production processes.

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modus high-tech electronics

Willis, Germany

For several decades now modus has been operating as a pioneering force in the AOI sector. Our objective is to develop fast scanner systems for industrial use. Modus develops, produces and sells automatic test and inspection systems (AOI) for production control of volume manufacturing.
The increasing miniaturization of electronic devices plus the escalating demands towards quality control and cost effectiveness makes it necessary to have test control units, which are fast, reliable and easy to set up.
The modus inspection systems, fast, reliable and easy to set up, are available both as in-line and off-line. With the ultra-fast scan speed, 100 % inspection of visible parts can be introduced into a production line without any loss or reduction to the speed of the line.
Modus has many customers in the automotive, industrial and consumer electronics sectors. Several customers manufacture small batch / high variety, they have a high expectation for production quality and production reliability.
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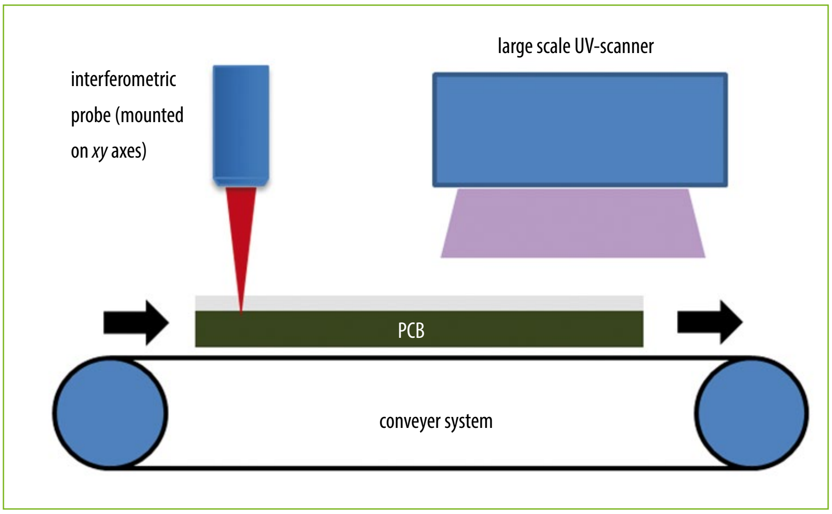

Fig. 4 Sketch of the combined AOI inspection system

same optical path back to the fiber coupler and finally into the spectrometer.

The used interferometric measuring principle as shown in Fig. 1b is based on the reflection of the light due to changing refractive indices at each interface of the measured material i.e. air-to-coating (beam 1) and coating-to-PCB substrate (beam 2). For the sake of clarity, the light beams in Fig. 1b are impinging the surface under an angle in contrast to the realistic, perpendicular case.

The resulting difference in travelled distance causes a phase shift between the two reflected beams, that induces a frequency modulation on the intensity signal of the spectrometer (cf. Fig. 2a). Calculating the Fourier transformed spectrum yields a thickness peak representing the optical thickness of the coated layer. The knowledge of the refractive index of the coating allows absolute information of the layer thickness.

Camera sensor technology for large-scale fluorescence thickness inspection

The AOI (automated optical inspection) thickness inspection system, developed by Modus Hightech Electronics is based on a scanner system (cf. Fig. 3a). The coated PCB is illuminated by an ultraviolet light source exciting the fluorescence tracers in the coating material. The resulting radiation in the visible light spectrum is detected by a CCD line camera, where the intensity $I(t)$ directly correlates with the thickness of the coating via

$$I(t) = I_0 \, e^{-\int_0^t \varepsilon c \, dt} .$$

Here, I_0 depicts the initial light intensity, c the tracer concentration, ε the extinction coefficient and t the coating thickness. This is shown in Fig. 3b with a false color image.

Due to the fast image acquisition of the system, this approach is capable of inspecting large areas e.g. the simultaneous inspection of both sides of the PCB even at positions that are hard to access by mechanical probes.

However, due to missing information on the tracer concentration in the coating material and its absorption properties, only relative thickness values can be inferred with this approach.

Conformal coating thickness inspection in the production process

The combination of the camera based vision system and the interferometric sensor is the key to automate the conformal coating process. This combined approach ensures absolute thickness inspection of complete PCBs at minimum cycle-times, which is crucial for the quality of the coating process step and consequently for the life-time of the final product.

Time-consuming offline thickness measurements at salient positions of the PCB to generate input parameters for the AOI systems are no longer necessary beforehand. Furthermore, changes in the composition of the coating material throughout the production period as well as batch changes have no influence on the measuring results.

Inspection procedure

The schematic setup and of the AOI inspection system is shown in Fig. 4. The system can directly be integrated into the transport system of the production line. The PCBs enter the inspection system via a conveyer belt.

At first, a specially chosen reference profile of the coating thickness is measured on each PCB with the Precitec CHRocodile sensor. The interferometric probe is mounted on movable xy axes to adapt the measuring positions of the reference profile according to the specific product being scanned.

Second, the modus UV-scanner is taking an intensity picture of the complete surface of the PCB. Correlating these intensity values with the thickness values along the chosen profile using the integrated acquisition software of modus yields a characteristic function for each coating as plotted in Fig. 5.

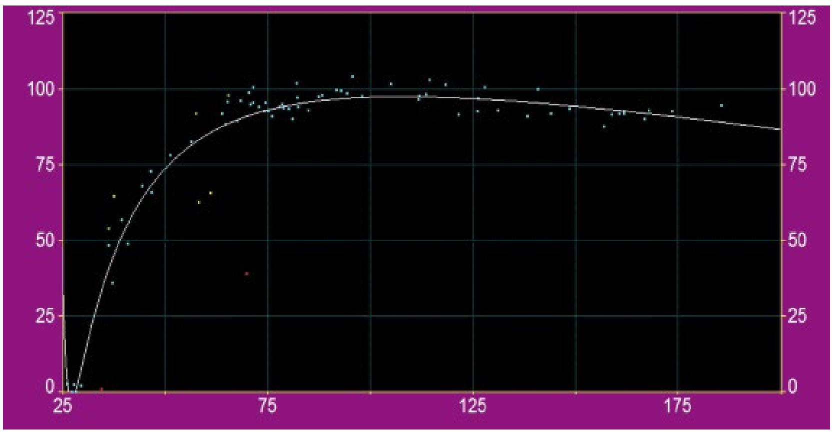

Fig. 5 Reference curve of fluorescence intensity vs. coating thickness

This function graph specific for each coating determines definitely the relation between absolute coating thickness and fluorescence intensity. Consequently, each intensity map of the scanner (Fig. 3b) directly represents an absolute thickness map of the PCB.

Conclusions

The future strategy of monitoring and controlling manufacturing processes, especially with regards to Industry 4.0 and end-to-end supervision of every production step, will be the use of reliable and suitable sensor systems. As shown in this paper to the combination of different sensor approaches can create significant added value.

For the potential user, it is very important that the complexity of the resulting machine is controllable. This is one of the main aspects for the system manufacturer during the development. Close contact to all the user groups in the end helps to a trouble-free integration into the production environment and satisfied operators.

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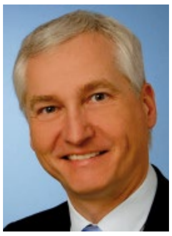
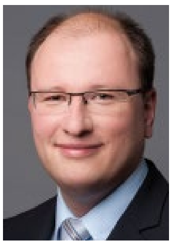


Markus Kogel-Hollacher began his activities in the area of lasers while working for his MS degree (RWTH Aachen University, Germany) at the Fraunhofer Institute for Laser Technology in 1994. In 1996 he joined Precitec Optronik GmbH. In 2008 he obtained his PhD at the Technical University of Berlin, Germany.
In his position as head of the department R&D Projects, he oversees governmentally funded projects. At present, he is a member of the board of directors at the LIA and earned the 3rd place in the Innovation Award Laser Technology in 2012 and the 2nd place in 2014.



Matthias Breier graduated at RWTH Aachen University in computer engineering. After graduation he worked as research scientist at the Chair for image processing and computer vision at RWTH Aachen University.
In his research project, he worked on 3D surface reconstruction of printed circuit board for recycling purposes. Currently, he is employed at Modus High-Tech Electronics in Willich as application engineer.

Daniel Schröder began his activities in the field of optical laser diagnostics while working on his diploma degree at Ruhr-Universität Bochum, Germany, at the department of Application-oriented Plasma Physics in 2009. In 2016, he obtained his PhD for the diagnostics of the dynamics in high-pressure microplasmas for medical applications. In 2016 he joined the technical sales team of Precitec Optronik.

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