Terahertz Car Paint Thickness Sensor: Out of the Lab and Into the Factory

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***Abstract*— A terahertz sensor to determine the individual thicknesses of car paint layers is deployed onto the factory floor of an automotive manufacturer. When illuminated with an incident terahertz pulse, reflections from the interfaces between layers are combined and detected. To precisely measure real paint formulations of representative thickness *in situ* on large curved panels, detailed calibrations of the refractive indices are required. We describe innovation to ensure that the instrument remains viable in the hostile environment of an industrial production line.**

I. INTRODUCTION

NEW paint processes in the automotive industry have the potential to be more cost-effective and efficient, but require better process monitoring and control than the current technology. This paper reports a terahertz multi-layer paint thickness sensor that was developed for inspection of real paint on actual car bodies, *in situ* at the production line. Terahertz instruments offer three key advantages over industry standard ultrasound technology: i) the terahertz method is inherently non-contact, enabling a greater degree of automation. ii) The instrument can measure moderately curved surfaces, where the ultrasound probe cannot make good contact. iii) The on-site calibration process is substantially faster than required for ultrasound, which requires that samples are sent off-site for time-consuming and expensive calibration procedures.

Ultimately, this technology is intended for in-line integrated robotic deployment on a car production line, providing real-time feedback to painting robots. Here, we report the results of a manual at-line demonstrator to measure paint structures on cars consisting of four layers: electrocoat, primer, basecoat and clearcoat, for solid, partially metallic (mica) and heavily metallic (aluminum) basecoats, on horizontal and vertical panels, of varying curvature. Unlike earlier proof of concept demonstrations of thickness measurements, with artificial coatings exhibiting strong contrasts, we find that typical car paints are very closely matched in refractive index. In real world films, we cannot use simple mathematical descriptions where the refractive index is assumed real and frequency-independent: hence a more physical model is required.

II. RESULTS

The instrument is situated in an inspection bay, on a production line immediately following the paint dryer. For this first deployment, a probe head is manually placed in proximity to the car body, guided by a visible laser displacement gauge. The instrument is able to measure horizontal and vertical surfaces along one side of the car, including previously hard-to-measure regions of moderate convex and concave curvature. Calibration of the constituent layers of a paint stack is used to determine the complex, frequency-dependent refractive index profile, and a calibration file is saved to a library for each paint type. This is called by the integrated user interface, which is able to measure, process and display the thickness result with a single mouse click. Based on these data the paint thickness is calculated from the time-domain waveforms acquired at strategic points around the car body. The individual layer measurements were compiled, and compared with PELT ultrasound measurements systematically taken immediately prior to the terahertz probe. Over 50% of measurements lay within ±2 µm of the nominal value, 75% within ±5 µm and 100 % within ±10 µm.

One limitation to industrial deployment of terahertz instruments based on photoconductive switches is the sensitivity of laser alignment to the ambient conditions [1]. We have isolated the instrument by mounting the laser on anti-vibration mounts in a temperature-controlled enclosure for stability. The ergonomic head is coupled by polarization-maintaining fiber that is strain relieved to minimize distortion, and is designed to cope with vibration, high humidity and temperature fluctuations in the proximity of the drying ovens.

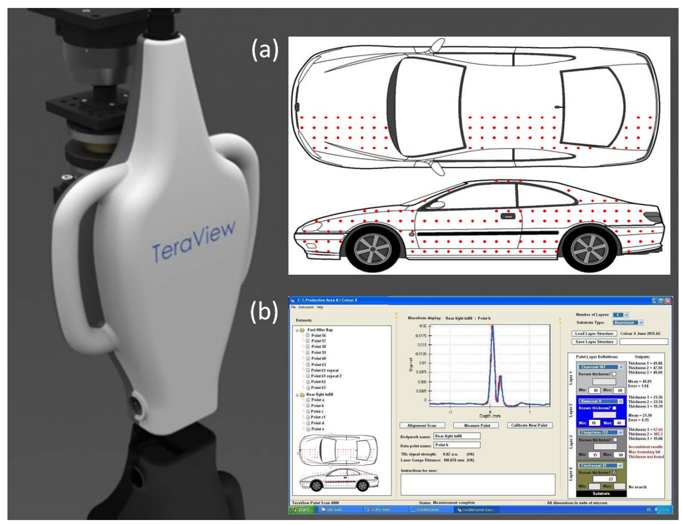

Fig. 1. Image of the THz sensor head, with inset: (a) spot measurements from one side of the car; and (b) the software interface for use by non-specialists.

III. SUMMARY

A highly optimized terahertz paint measurement system for industrial deployment has been demonstrated under realistic conditions, and compares well with industry standard methods. Advanced calibration allows accuracies of up to ±2 µm to quantify the thickness of paint films. This work is partially funded by the Technology Strategy Board (Award 101262).

REFERENCES

[1]. J.A. Zeitler and Y.C. Shen, "Industrial Applications of Terahertz Imaging," Chap. 18, (Springer, Berlin, Heidelberg, 2012).