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Editorial Open Access

Terahertz Sensor for Noncontact and Non-destructive Inspection of Automotive Paints

Yao-Chun Shen*

Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool L69 3GJ, UK

***Corresponding author:** Yao-Chun Shen, Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool L69 3GJ, UK, Tel: +44-151-794-4575; E-mail: y.c.shen@liverpool.ac.uk

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Editorial

The application of paint to a car body can be a complicated process. Expensive auto body paint is usually applied in four layered stages and often includes clear coat, primer and base coats as well as electro coat layers. The result of these successive paint layers is a surface that exhibits complex light interactions, giving the car a smooth, glossy and sparkly finish. More importantly, these paint layers not only provide appealing color effects, but also have important functions such as rust prevention and waterproofing. It is hence of great interest to characterize car paint properties including thickness and uniformity for the purpose of quality control and quality assurance.

The most common method currently used to measure the thickness of paint layers is ultrasonic sensor which is portable and easy to use. However, for high precision measurement ultrasonic sensor has to be attached to the sample thus it is not a noncontact method. In addition, most commercial ultrasonic sensor head has an active probe area of over 8 mm in diameter and it performs best on a smooth, flat and hard surface. Consequently ultrasonic method is not suitable for characterising car components with non-flat surface or for high-resolution imaging applications. Magnetic gauges and eddy current measurements are two other methods capable of measuring the thickness of car paint layers. However, like ultrasonic method both magnetic gauges and eddy current measurement techniques require direct contact between the sensor and the painted car surface. In addition, all these methods can only cover a limited number of sampling points on selected cars and hence lack the capability to identify paint defects, monitor drying processes and map the thickness distribution of the paint layers over a large surface of the vehicle.

The terahertz (THz) region of the electromagnetic spectrum spans the frequency range between the mid-infrared and the millimetre/microwave (300 GHz–30 THz). THz technology has advantages of being non-ionizing, non-destructive, and able to image at depth [1,2]. It has been demonstrated that THz imaging is a powerful noncontact technique for quantitatively characterizing individual layers of a multi-layered system such as pharmaceutical tablets, in both off-line and on-line applications [3,4]. Yasui et al. [5] reported that THz technology could be used for characterizing car paint samples with relative thick paint layers. Very recently Su et al. [6] demonstrated that the individual layer thickness of all four layers of real-world car paint samples could be determined from THz measurement.

Figure 1 shows the schematic diagram of a typical THz imaging system. In brief, THz generation and detection was achieved using an ultrafast Ti:sapphire laser. A beam splitter separated the near-infrared light into two beams: an excitation beam and a probe beam. The excitation beam is used to pump a THz emitter antenna for generating a short pulse of broadband THz radiation. The generated THz pulse is focused onto the sample. As most polymer and coating materials are transparent or semi-transparent to THz radiation, THz pulses will be able to penetrate into the sample. At each interface or change in refractive index, portion of the THz radiation will be reflected/scattered back. The reflected THz radiation is detected using a THz receiver antenna which is gated by the probe beam from the same ultrafast laser system. In this way, the time–resolved electric field of the THz pulse could be recorded by scanning the time–delay between the THz pulse and the near-infrared probe beam using a variable delay stage. By raster scanning THz probe across the sample surface THz images can be subsequently obtained.

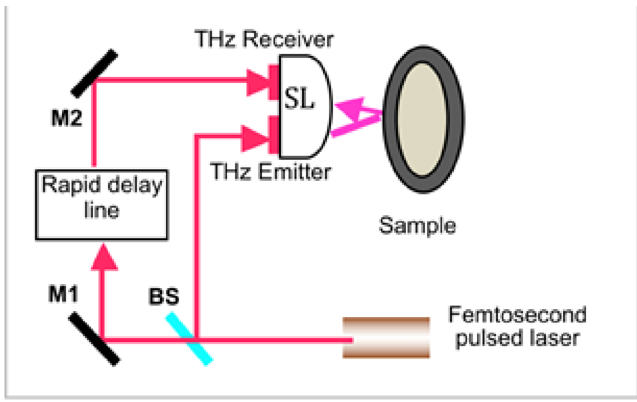

Figure 1: Schematic diagram of a terahertz pulsed imaging (TPI) system. SL: silicon lens system; BS: Beam Splitter; M1–M2: metallic mirrors. Both terahertz emitter and detector were directly attached to a specially designed silicon lens system, thus avoiding the requirement of nitrogen purging (water vapour absorption was minimised owing to the short distance between the terahertz lens and the sample (reproduced from [3]).

As an example, Figure 2 shows a typical THz B-scan map and THz signal measured for a real world car paint sample what has four paint layers on a metal substrate [6]. Layer thickness and refractive index information can be extracted by comparing the measured THz waveform with the simulated ones. Using a rigorous one-dimensional electromagnetic model for THz propagation in a multi-layered medium combined with a numerical fitting method, the refractive index, extinction coefficient, and thickness of individual paint layers were determined. The THz sensor was shown to be able to resolve coating layers down to a thickness of 18 microns and was validated for both single- and multi-layer automobile paint samples [6]. The THz results were found to be in good agreement with the results obtained

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by conventional techniques that are currently used for non-destructive testing during car manufacture, e.g., ultrasound and eddy current measurements [6]. Compared to conventional techniques, TPI has the advantage that it is a non-contact method and that it is able to spatially resolve the thickness uniformity distribution information by two-dimensional mapping.

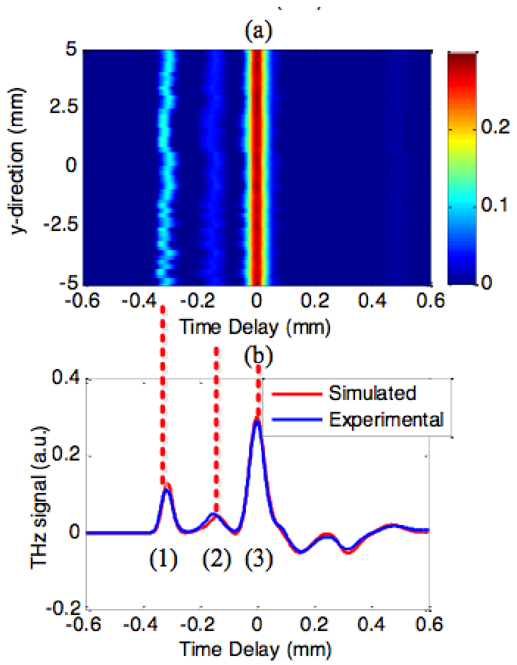

Figure 2: A typical THz b-scan map (top) and THz signal (bottom) of a four-layer paint on a metallic substrate. Layer thickness and refractive index information can be extracted by comparing the measured THz waveform with the simulated ones (reproduced from [6]).

In summary I have introduced in this article a new sensing technology, e.g., THz imaging as a powerful technique for non-destructive and quantitative characterisation of automotive car paints. Hope that this will raise the awareness of the emerging opportunity and usefulness offered by this exciting technology as in my view THz senor will have potential for in-line paint thickness measurement and monitoring wet to dry transformation processes.

References

1. Ferguson B, Zhang XC (2002) Materials for terahertz science and technology. Nat Mater 1: 26-33.
2. Zeitler JA, Shen YC (2013) Industrial Applications of Terahertz Imaging. In: Peiponen KE, Zeitler A, Kuwata-Gonokami M (eds.), Terahertz Spectroscopy and Imaging. Springer Berlin Heidelberg, 451-489.
3. Shen YC (2011) Terahertz pulsed spectroscopy and imaging for pharmaceutical applications: A review. Int J Pharm 417: 48–60.
4. May RK, Evans MJ, Zhong S, Warr I, Gladden LF, Shen YC, et al. (2011) Terahertz In-Line Sensor for Direct Coating Thickness Measurement of Individual Tablets During Film Coating in Real-Time. J. Pharmaceutical Sciences 100: 1535-1544.
5. Yasui T, Yasuda T, Sawanaka K, Araki T (2005) Terahertz paintmeter for noncontact monitoring of thickness and drying progress in paint film. Appl. Opt 44: 6849-56.
6. Ke Su, Shen YC, Axel Zeitler J (2014) Terahertz sensor for non-contact thickness and quality measurement of automobiles paints of varying complexity. IEEE Trans. Terahertz Science and Technology 4: 432-439.