Defense Systems Information Analysis Center

DSIAC TECHNICAL INQUIRY (TI) RESPONSE REPORT

Noncontacting Methods for Adhesive Bond Primer Thickness Measurements

Report Number:
DSIAC-2019-1085
Completed April 2019

DSIAC is a Department of Defense Information Analysis Center

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
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1. REPORT DATE *(DD-MM-YYYY)* 01-04-2019	**2. REPORT TYPE** Technical Research Report		**3. DATES COVERED** *(From - To)*
4. TITLE AND SUBTITLE Noncontacting Methods for Adhesive Bond Primer Thickness Measurements			**5a. CONTRACT NUMBER** FA8075-14-D-0001 **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Doyle Motes			**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Defense Systems Information Analysis Center (DSIAC) Texas Research Institute Austin, Inc. 415 Crystal Creek Drive Austin, TX 78746			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Defense Technical Information Center (DTIC) 8725 John J. Kingman Rd. Ft. Belvoir, VA 22060-6218			**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release: distribution unlimited.			
13. SUPPLEMENTARY NOTES Materials and Manufacturing Processes			
14. ABSTRACT The Defense Systems Information Analysis Center (DSIAC) received a technical inquiry requesting information on available options for noncontact thickness measurements of a mostly transparent adhesive primer. The inquirer specified that it would be preferable if the solution were handheld, but a desktop device was also acceptable. DSIAC subject matter experts from Texas Research Institute Austin drew upon their extensive experience in noncontacting and nondestructive measurements to provide answers and insight on this topic. Two methods, terahertz wave imaging and ellipsometry, are described briefly before a list of commercial options for bond thickness measurements.			
15. SUBJECT TERMS adhesive primer, nondestructive inspection, bond thickness			

16. SECURITY CLASSIFICATION OF: U			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Ted Welsh, DSIAC Director
a. REPORT U	**b. ABSTRACT** U	**c. THIS PAGE** U	UU	10	**19b. TELEPHONE NUMBER** *(include area code)* 443-360-4600

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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ABSTRACT

The Defense Systems Information Analysis Center (DSIAC) received a technical inquiry requesting information on available options for noncontact thickness measurements of a mostly transparent adhesive primer. The inquirer specified that it would be preferable if the solution were handheld, but a desktop device was also acceptable. DSIAC subject matter experts from Texas Research Institute Austin drew upon their extensive experience in noncontacting and nondestructive measurements to provide answers and insight on this topic. Two methods, terahertz wave imaging and ellipsometry, are described briefly before a list of commercial options for bond thickness measurements.

ACKNOWLEDGMENTS

The Defense Systems Information Analysis Center would like to thank the following individuals for contributing their expertise to this work: David Forsyth, Mark Keiser, Carl Magnuson, Ph.D., and Mark F. A. Warchol, P.E. (Texas Research Institute Austin).

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1.0 TI Request

1.1 INQUIRY

What noncontact methods are used to measure cured or uncured adhesive bond primer thicknesses?

1.2 DESCRIPTION

The inquirer requested information on new options for handheld devices (or desktop devices) that measure noncontact thickness of mostly transparent adhesive primers and identified the following limitations of their current handheld contact instruments as undesirable for potential new devices:

- The contact method creates dimples in the bond area.
- There are sometimes unreliable readings generated for thin primer areas (i.e., less than 0.1 mils).
- The systems need to be recalibrated each time the device is used on a different metal with a different surface preparation.

2.0 TI Response

The Defense Systems Information Analysis Center subject matter experts (SMEs) from Texas Research Institute Austin (TRI Austin), including author Doyle T. Motes, P.E., drew upon their extensive experience in noncontacting and nondestructive measurements to provide insight on the inquiry topic.

2.1 SME RESPONSE

The most common suggestion was to use eddy current (EC) or ultrasonic testing (UT) methods. However, the tolerances on typical EC or UT instruments available in a nondestructive evaluation lab and conventional UT and EC thickness gauges have an accuracy that is approximately one tenth of what is required by the inquirer (i.e., it is only capable of resolving a coating thickness of 0.001 inch or 1 mil). It was suggested that the dimpling from the UT instrument may be eliminated with hydrophilic plastic. In addition, for an ultrasonic measurement, the frequencies likely need to be very high for the sound waves to interact substantially with the coating; however, this depends on the properties of the coating. A noncontacting measurement is possible with ultrasonics, but it requires an immersion or a squirter system (which may not be appropriate for an uncured bond). Terahertz (THz) wave imaging and ellipsometry were identified as potential options to address problem.

2.1.1 THz Wave Imaging

THz imaging has been used in a pulse-echo c-scan configuration to map variations in the peak amplitude of the echo off the metal surface. The variations occur when the attenuation from the coating affects the signal [1, 2]. This configuration is very similar to UT signal analysis, but the microwave signals do not penetrate the metallic substrate. Gating is used for signal analysis to determine the peak amplitude, although the data acquisition must be capable of sub pico-second resolution (as shown in Figure 1). The reflection-mode THz inspection system identified in Figure 1 is used for performing inspections on the National Aeronautics and Space Administration's Space Shuttle external tank thermal protection system [1].

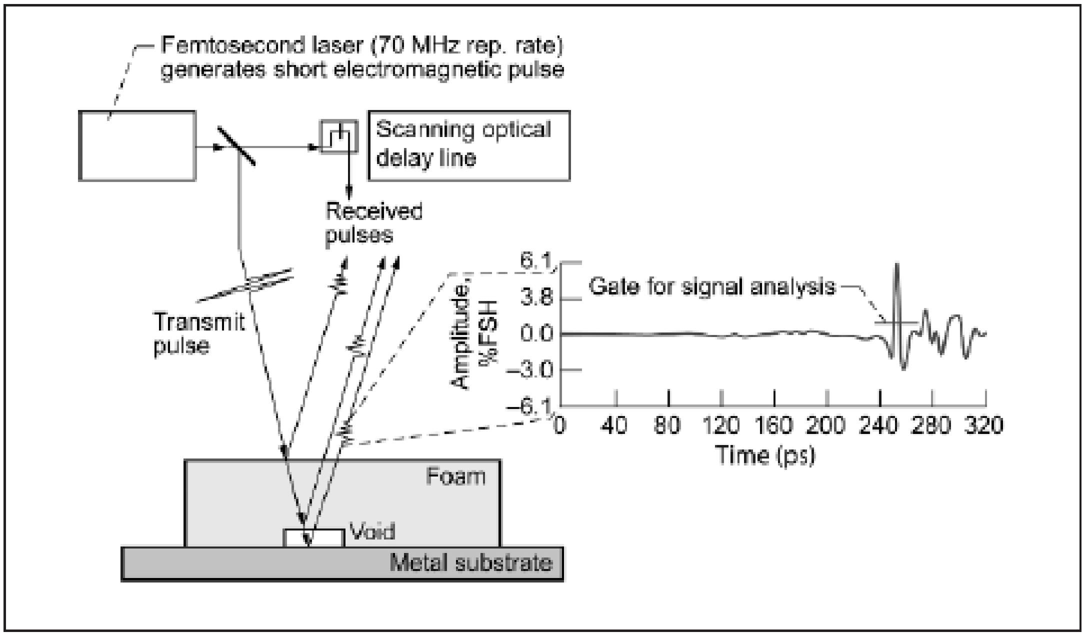

Figure 1: Basic Schematic of a Reflection-Mode THz Inspection System (Source: NASA).

2.1.2 Ellipsometry

In ellipsometry, the measured signal is the change in polarization as the incident radiation (which is transmitted in a known and characterized state) interacts with the material structure of interest (causing some of the light to be reflected, absorbed, scattered, or transmitted), as shown in Figure 2. The polarization change is quantified by the amplitude ratio and phase difference. The signal depends on the thickness as well as the material properties; therefore, ellipsometry can be a universal tool for contact-free determination of thickness and optical constants of various films [3].

Upon analyzing the change in the light's polarization, the ellipsometry method can yield information on layers that are thinner than the wavelength of the probing light itself, even down to a single atomic layer. Ellipsometry can probe the complex refractive index or dielectric function tensor, giving access to fundamental physical parameters. It is commonly used to characterize film thicknesses for single layers or complex multilayer stacks ranging from a few angstroms or tenths of a nanometer to several micrometers, with an excellent accuracy [4].

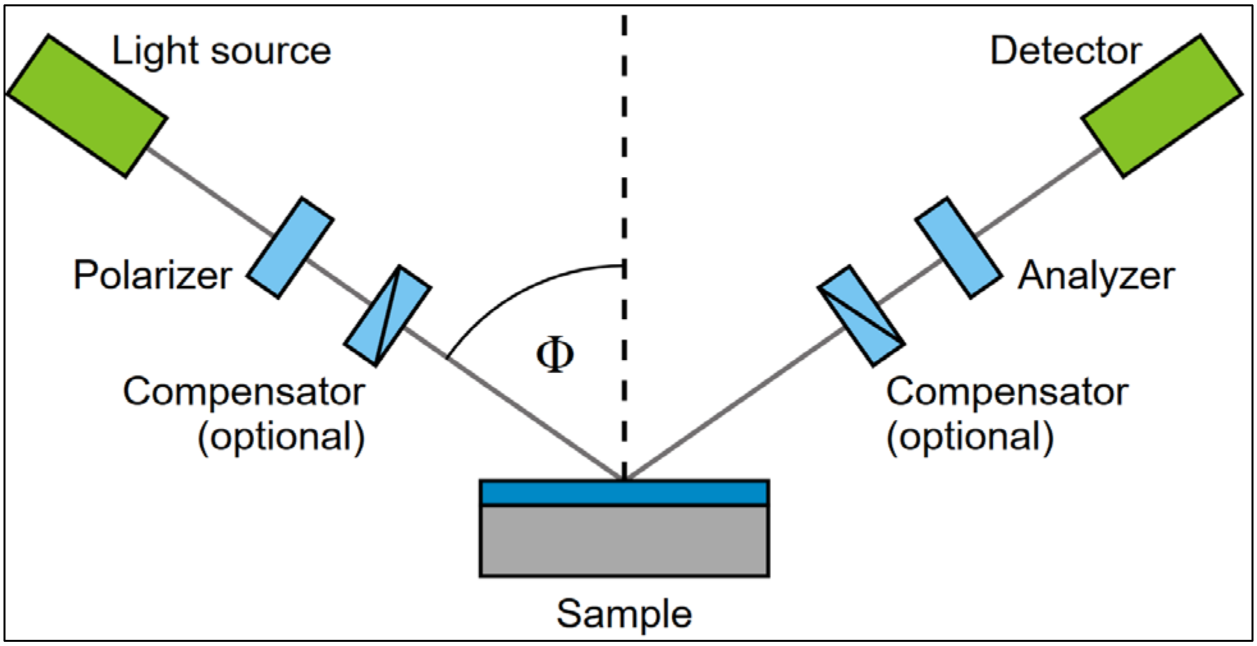

Figure 2: Schematic for an Ellipsometry Inspection (Source: Bauntgarn, at the English Wikipedia project).

2.2 COMMERCIALLY-AVAILABLE OPTIONS

There are several commercially-available options for performing coating thickness measurements, which have various degrees of precision. Some of the options may not be suitable for the inquirer's applications, but the following are immediately available to commercial customers:

- QNix's coating thickness gauges [5].
- DeFelsko's paint thickness measurement [6].
- Elcometer's coating thickness gauge [7].
- PCE Instruments' coating thickness gauge [8].

Other resources available to researchers interested in determining coating thicknesses can be found online; the article "Quality 101: Understanding Coating Thickness Measurement Test Methods" by P. Lomax may provide additional information [9]. Nondestructive measurement methods endorsed by the American Society for Testing and Materials (ASTM) are identified in the document *Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals* [10].

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BIOGRAPHY

Doyle Motes, a licensed professional engineer in Texas, is employed as a research engineer at TRI Austin, Inc. He has extensive experience in pulsed power, materials engineering and processing, and nondestructive testing and has published many documents in these fields. His research interests include additive manufacturing and three-dimensional printing, materials engineering and processing, nondestructive testing (in particular, ultrasound and eddy current testing), sustainment of aging weapon systems, automation of inspection/validation technologies, and materials state sensing. Mr. Motes holds bachelor's and master's degrees in mechanical engineering from the University of Texas at Austin.