

Thickness measurement of coatings and characterization of surfaces with surface waves —

Part 2: Guide to the thickness measurement of coatings by photothermic method

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National foreword

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Foreword

This document (EN 15042-2:2006) has been prepared by Technical Committee CEN/TC 262 “Metallic and other inorganic coatings”, the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2006, and conflicting national standards shall be withdrawn at the latest by October 2006.

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1 Scope

This document describes methods for the measurement of the thickness of coatings by means of thermal waves generated by a radiation source.

The method can be used for coatings whose thermal properties (e.g. thermal conductivity) are different from those of the substrates in a range from a few microns to some hundred microns.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/DGuide 99998, *Guide to the expression of uncertainty in measurement (GUM) – Supplement 1: Numerical methods for the propagation of distributions*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

amplitude of the thermal wave

ΔT_0

maximum local temperature variation of the oscillating part for periodic-harmonic heating processes

NOTE See Equation 2.

3.2

penetration depth of thermal waves

depth at which the temperature variation below a modulated heated surface is still measurable.

NOTE In general, the penetration depth is of the order of magnitude of the thermal diffusion length

3.3

modulation frequency

f

frequency at which the intensity of the heating radiation varies periodically

3.4

phase (phase shift) of the thermal wave

$\Delta \Phi$

measure of the temporal delay of the temperature oscillation relative to the excitation for periodic-harmonic heating processes

NOTE See Equation 3.

3.5

photothermal efficiency

η

proportion of the incident radiation intensity that is converted into heat

NOTE In most technical applications it is approximately identical to the absorption.

3.6**thermal diffusion length** μ

characteristic length of the thermal diffusion with pulsed heating or periodically modulated heating, where the temperature amplitude has decreased to about 1/e or 37 %

NOTE 1 1/e, with natural number e = 2,71828.

NOTE 2 See Equation 4.

3.7**thermal diffusion time** τ

characteristic time that a thermal wave or a temperature pulse requires for penetrating a layer of finite thickness

NOTE See Equation 7.

3.8**thermal diffusivity** α

thermal parameter characterizing heat propagation in a body with time-dependent heating

NOTE See Equation 6.

3.9**thermal effusivity** e

thermal parameter determining the surface temperature of a body with time-dependent heating

NOTE See Equation 5.

3.10**thermal wave**

spatiotemporally variable temperature field that is set up in a body (or medium) with time-dependent heating and is described by the heat conduction equation

NOTE 1 see Equation 1.

NOTE 2 The thermal wave is generated in one limiting case by a periodic-harmonic excitation, in the other limiting case by a pulsed excitation.

3.11**thermal reflection coefficient** R_{ts}

thermal parameter that is a degree of the reflection of the thermal wave at the boundary interface between two layers of different effusivity and thus describes the heat transfer across this boundary interface

NOTE See Equation 8.

4 Symbols and abbreviation

Symbol	Unit	Description	See Equation
$\Delta T(x, t)$	K	amplitude of the temperature oscillation of the thermal wave	1
$\Delta T_0(x)$	K	amplitude of the temperature oscillation of the thermal wave at the surface ($x = 0$)	2
$\Delta \Phi$	rad	phase of the temperature oscillation of the thermal wave	3
μ	m	thermal diffusion length	4
e	$\text{Ws}^{1/2}/(\text{m}^2\text{K})$	thermal effusivity	5
α	m^2/s	thermal diffusivity	6
τ	s	thermal diffusion time	7
F_0	W/m^2	heat flow/excitation power density	7
η		photothermal efficiency	
k	$\text{W}/(\text{m}\cdot\text{K})$	thermal conductivity	12
ρ	Kg/m^3	mass density	13
c	$\text{J}/(\text{kg}\cdot\text{K})$	specific heat capacity	13
f	s^{-1}	modulation frequency	
i_0	W/m^2	incident radiant power density	2
x	m	location below the boundary interface	
t	s	time	

5 Foundations of photothermal materials testing

5.1 Physical foundations

5.1.1 Thermal waves

The concept "thermal wave(s)" describes a spatially and temporally variable temperature field that is generated in a body by time-dependent heating. Besides the concept thermal wave the term "temperature wave" is also used in technical literature. The excitation of the spatiotemporally variable temperature field mathematically described by a diffusion equation - the heat conduction equation - can occur in the one limiting case periodic-harmonically and in the other limiting case pulsed.

The physical foundations [1], [5], [6], [7] can be derived both for the harmonic excitation and for the pulsed excitation, and are related by a Fourier transformation. This clause considers primarily the harmonic excitation; the derivation for the pulsed excitation can be found in [8].