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Metallic and other inorganic coatings — Determination of thermal conductivity of thermal barrier coatings at elevated temperature

Revêtements métalliques et autres revêtements inorganiques — Détermination de la conductivité thermique des revêtements barrières thermiques à température élevée

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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Thermal barrier coatings are highly advanced material systems, generally applied to surfaces of hot-section components made of nickel or cobalt-based superalloys, such as combustors, blades, and vanes of power-generation gas turbines in thermal power plants and aero-engines operated at elevated temperatures.

The function of these coatings is to protect metallic components for extended periods at elevated temperatures by employing thermally insulating materials that can sustain an appreciable temperature difference between load bearing alloys and coating surfaces. These coatings permit the high-temperature operation by shielding these components, thereby extending their lives.

Although thermal conductivity is an important property of thermal barrier coatings, ISO 18555 only describes a method for measuring this parameter of thermal barrier coatings at room temperature.

Metallic and other inorganic coatings — Determination of thermal conductivity of thermal barrier coatings at elevated temperature

1 Scope

This document specifies a method for determining the thermal conductivity of ceramic top coat (TC) constituting thermal barrier coating (TBC) subjected to heat treatment, in a direction normal to the coating surface, from room temperature up to 1 000 °C.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method*

ISO 14188, *Metallic and other inorganic coatings — Test methods for measuring thermal cycle resistance and thermal shock resistance for thermal barrier coatings*

ISO 18555, *Metallic and other inorganic coatings — Determination of thermal conductivity of thermal barrier coatings*

ISO 18755, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of thermal diffusivity of monolithic ceramics by laser flash method*

EN 821-3, *Advanced technical ceramics – Monolithic ceramics. Thermophysical properties – Part 3: Determination of specific heat capacity*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14188, ISO 18555 and the following apply.

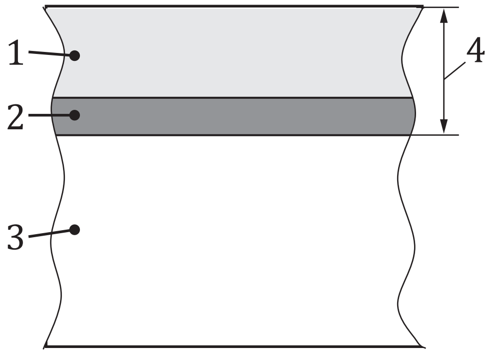
ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
thermal barrier coating
TBC
two-layer coating consisting of a metallic bond coat (BC) and a ceramic top coat (TC), in order to reduce heat transfer from outside of the top coat through the coating to the substrate of a heat-resistant metallic material

Note 1 to entry: See Figure 1.



Key

1 top coat (TC)

2 bond coat (BC)

3 substrate

4 thermal barrier coating

Figure 1 — Diagrammatic view of a section of a TBC

4 Principle

The TBC specimen shall be heat-treated prior to the measurement at elevated temperature in order to minimize the change of the coating microstructure. Since the heat-treated BC specimen consisting of the substrate and the BC can be treated as the same as the substrate specimen, the TBC specimen can be regarded as a two-layer model consisting of the substrate and the TC. Thermal conductivities of the substrate and TC are determined in accordance with calculation using the thermal diffusivities, specific heat capacities, and bulk densities[1]. The fundamental procedures are shown in Figure 2.

The fundamental procedures for determining the thermal diffusivities of the substrate and TC consist of the measurement of temperature-rise curves of two types of specimens (substrate and substrate with TBC) by a flash method, and of calculations. The thermal diffusivity of the TC is obtained by applying a multi-layer analytical model to the temperature-rise curve.

The specific heat capacities and bulk densities of the substrate and TC are separately measured.

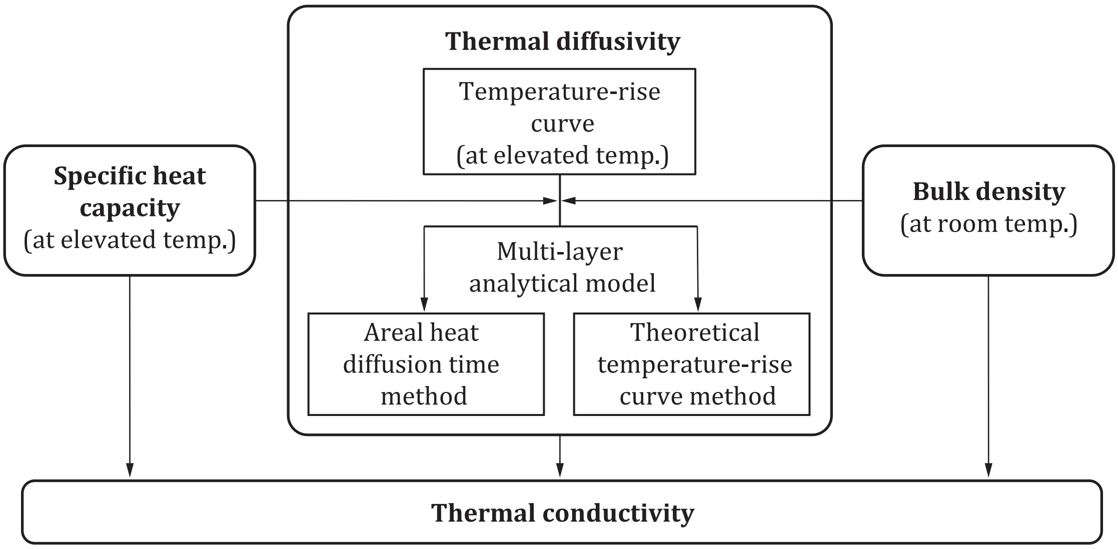
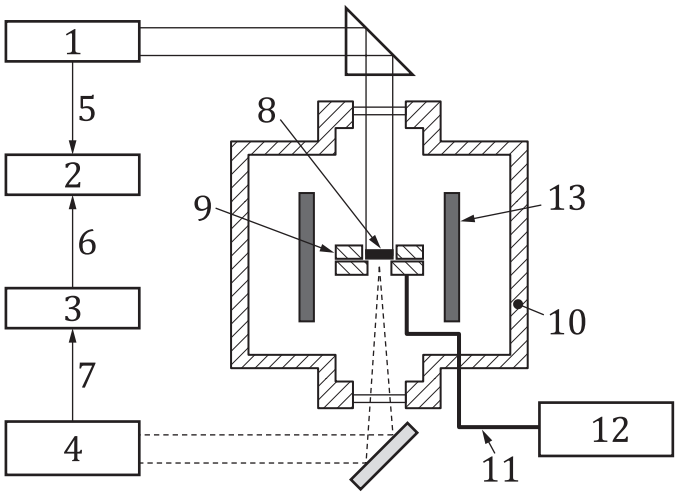


Figure 2 — Fundamental procedures for determining thermal conductivity

5 Apparatus for measuring thermal diffusivity

An example of the apparatus for measuring the thermal diffusivity is schematically shown in Figure 3.

The apparatus consists of pulse heating light source, data recorder, measurement circuit, infrared radiometer, specimen holder, chamber, thermocouple, temperature indicator and heater. The apparatus shall be specified in accordance with ISO 18755 and should be calibrated using reference data and reference materials in reference to ISO 18755:2005, Annex E.



Key

1	pulse heating light source	8	specimen
2	data recorder	9	specimen holder
3	measurement circuit	10	chamber
4	infrared radiometer	11	thermocouple
5	trigger signal	12	temperature indicator
6	amplification of signal	13	heater
7	temperature signal of specimen rear surface		

Figure 3 — Typical apparatus for measuring the thermal diffusivity in accordance with the flash method

6 Specimen

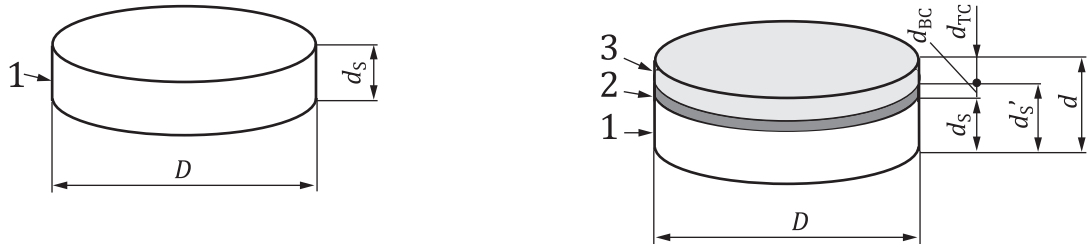
6.1 Shape and dimensions

The shape and dimensions of the specimen shall be as follows.

The two types of specimens, the substrate and TBC specimens, shall be used.

The specimen shape shall be a flat disk (Figure 4) or flat square plate (Figure 5). The diameter or side length of the specimen shall be from 10×10^{-3} m to 15×10^{-3} m.

The thickness of substrate, BC, and TC is given in Table 1.

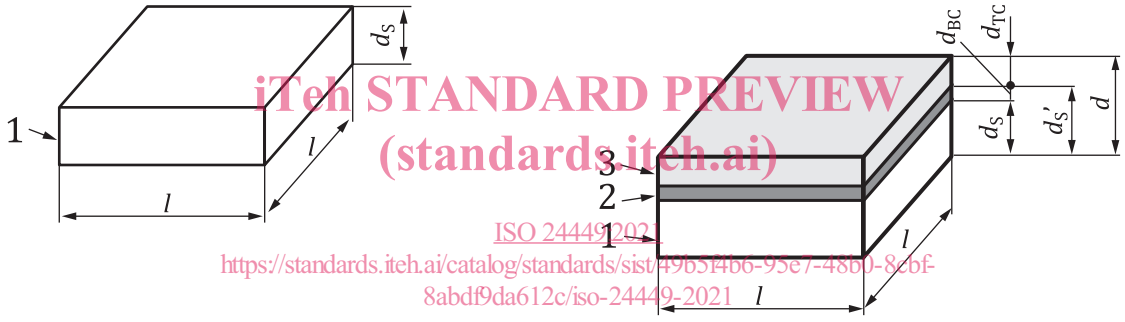


a) Substrate specimen **b) TBC specimen**

Key

1 substrate
2 bond coat (BC)
3 top coat (TC)
D diameter
d_S thickness of substrate
d_{BC} thickness of BC
d_{TC} thickness of TC
d_S' thickness of substrate and BC
d total thickness of TBC specimen

Figure 4 — Shape of flat disk specimens



a) Substrate specimen **b) TBC specimen**

Key

1 substrate
2 bond coat (BC)
3 top coat (TC)
l side length
d_S thickness of substrate
d_{BC} thickness of BC
d_{TC} thickness of TC
d_S' thickness of substrate and BC
d total thickness of TBC specimen

Figure 5 — Shape of flat square plate specimens

Table 1 — Thickness of substrate, BC, and TC

Symbol	Designation	Thickness (x 10^{-3} m)
d_S	thickness of substrate	$1{,}00 \le d_S \le 2{,}00$
d_{TC}	thickness of TC	$0{,}30\ (d_S + d_{BC}) \le d_{TC}$
d	thickness of TBC specimen	$d = d_S + d_{BC} + d_{TC} \le 3{,}00$

The thickness tolerance of substrate shall be $\pm 0{,}01 \times 10^{-3}$ m.

The difference between maximum and minimum thickness shall be $\le 0{,}01\ d$ for the TBC specimen.

The selections of the shape, the dimension, and the thickness shall be decided in accordance with the agreement between parties involved in the transaction.