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Determination of the residual stress of TGO layer in thermal barrier coating by photoexcitation fluorescence piezoelectric spectroscopy

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Foreword

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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~~www.iso.org/members.html.

Introduction

~~Thermally~~The thermally grown oxide (TGO) layer of a thermal barrier coating (TBC) is the fundamental cause of interface crack and eventual spalling failure of the ceramic layer. Therefore, the TGO layer and its interfaces with each layer are risky areas for ~~thermal barrier coating~~TBC failure and peeling. ~~By~~The residual stress in the TGO of a TBC can be determined using the photoexcitation fluorescence piezoelectric spectroscopy (PFPS) method~~, the residual stress in TGO of thermal barrier coating can be determined, which~~. This provides an important basis for the lifetime evaluation of ~~thermal barrier coating~~TBC and ~~is also a necessary process~~ to understand the failure mechanism of the ~~thermal barrier coating~~TBC.

This method to test the residual stress in the TGO layer is a non-destructive testing method, unlike the curvature and drilling methods, which cause damage to the sample. Unlike ~~XRD~~x-ray diffraction, the penetration depth is only tens of micrometers.

The inclusion of Cr^{3+} in the TGO of ~~thermal barrier coating~~a TBC is a prerequisite for testing the residual stress of the TGO layer of ~~thermal barrier coating~~TBC by photoexcited fluorescence piezoelectric spectroscopy. No matter what method is used to prepare the ~~thermal barrier coating~~TBC system, the bond coat ~~must contain~~contains a Cr element.

The size, shape~~,~~ and composition of the substrate material are not specified and differentiated. In addition, the preparation method of the ~~thermal barrier coating~~TBC is not specified and differentiated.

The residual stress of the TGO layer is one of the main factors causing the failure of the ~~thermal barrier coating.~~TBC. However, no standard document is available for the test method process and the result of the photoexcited fluorescence piezoelectric spectroscopy test of residual stress in the TGO layer of the ~~thermal barrier coating.~~TBC. Therefore, it is necessary to develop a standardized and unified test method process~~, which will be~~ that is conducive to the formation, simulation~~,~~ and testing of residual stress in the TGO layer of the ~~thermal barrier coating~~TBC and even the prediction of the service life of ~~thermal barrier coating~~the TBC.

Determination of the residual stress of TGO layer in thermal barrier coating by photoexcitation fluorescence piezoelectric spectroscopy

1 Scope

This document describes thespecifies a test method for the determination of the residual stress of the TGO layer in thermal barrier coating (TBC) by photoexcitation fluorescence piezoelectric spectroscopy.

This test method requiresspecifies that there must beis a Cr element in the bond coat of the thermal barrier coating, i.e. Cr element shall exist in the TGO layerTBC.

This test method of determiningto determine the residual stress in the TGO layer of the thermal barrier coatingTBC system is not limited by the preparation method of the thermal barrier coatings.TBCs. Particularly, the thermal barrier coatingTBC system prepared by electron beam-physical vapour deposition (EB-PVD) has a better effect.

This method provides guidance on determining reliable estimates of residual stresses from fluorescence spectral data and estimating uncertainties in the results.

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

ISO 19477, *Metallic and other inorganic coatings — Measurement of Young's modulus of thermal barrier coatings by beam bending*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14188 and ISO 19477 and the following apply.

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

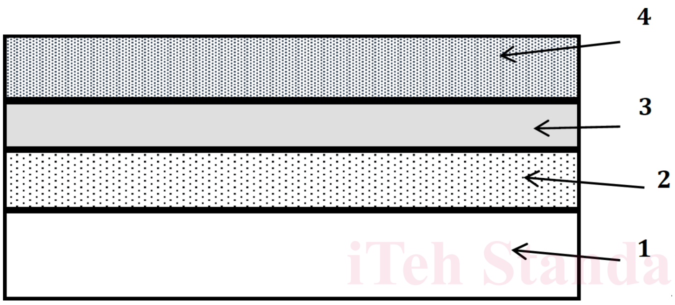
— ISO Online browsing platform: available at https://www.iso.org/obphttps://www.iso.org/obp

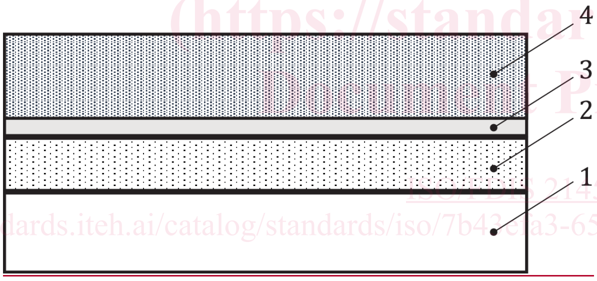
— IEC Electropedia: available at https://www.electropedia.org/https://www.electropedia.org/

3.1 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 TCtop coat through the coating to the substrate

Note 1 to entry: Thermal barrier coating is a thermal protection technology that combines ceramic materials, known for high temperature resistance and low thermal conductivity, with substrate alloy in the form of coating to reduce the surface temperature of hot-end components, enhance resistance to high-temperature oxidation corrosion in substrate materials~~,~~ and ultimately improve the engine's thrust-to-weight ratio, thermal efficiency~~,~~ and the service life of hot-end components under high temperature and stress.

Note 2 to entry: Thermal barrier coating systems usually consist of a metal bond coat and an insulating ceramic coat (see ~~**Figure 1**).~~Figure 1). In the thermal barrier coating system, due to the large difference in thermal expansion coefficient between the ceramic coat and the substrate material, it is easy to produce large thermal stress in the service process, leading to premature failure. In order to improve the physical compatibility and alleviate the thermal expansion mismatch between the ceramic coat and the substrate, a metal bond coat is often introduced between the substrate and the ceramic coat. At the same time, the oxide film generated by the oxidation of the bonding layer can also improve the high-temperature oxidation resistance and corrosion resistance of the substrate alloy. At present, MCrAlYX (M = Ni and/or Co, X = Hf, Ta, Si, etc.) is widely used as a bond coat.





Key

1 substrate

2 bond coat

3 ~~(TGO)~~thermally grown oxide

4 ceramic insulation top coat

Figure 1 — Diagram of a section of the thermal barrier coating system

3.2 ~~3.2~~
thermally grown oxide
TGO
oxide grown between top and bond coat when the coating system is heated

Note 1 to entry: In the preparation process and high-temperature service environment, the oxygen molecules in the air and the oxygen atoms of the ceramic coat ~~will~~ diffuse to the interface between the ceramic coat and the bond coat and react with the metal elements diffused from the bond coat to form the thermally grown oxide layer (TGO). As Al has the strongest diffusion activity, it ~~will be~~is the first to react to form dense TGO with α-Al_2O_3 composition. Dense TGO can effectively slow down the diffusion of other metal elements in the bond coat and inhibit the further oxidation of the bond coat, providing an advantage. However, the growth of TGO also induces thermal mismatch stress, leading to the

