Effect of Y, Zr and O Contents in MCrAlY-Type Bondcoats on the Lifetime of Thermal Barrier Coatings

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Motivation

Processing of MCrAlY-bondcoats for thermal barrier coating (TBC) systems results in oxidation of reactive elements (RE), such as Y and Zr.

This oxidation process can influence RE-effect on growth and adhesion of thermally grown oxide (TGO) and consequently TBC-lifetime.

Effect of oxygen content in bondcoat on lifetime of various TBC-systems has not been extensively studied. In industry only maximum allowed oxygen content in MCrAlY-powder is typically specified.

Experimental

Substrate Material: Ni-base superalloy IN-738

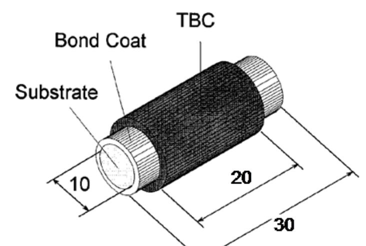
Bondcoats:

300 µm thick NiCoCrAlY bondcoats (<30 Co, <20Cr, 10 Al) with 0.3%Y (Y); 0.6%Y + 0.6%Zr (Y+Zr); 0.1%Y+0.2%Zr (Low Y+Zr) vacuum plasma sprayed with different oxygen pressures in spray chamber to produce 0.05% (Low O) and 0.20% (High O) contents
Heat treatment vacuum of 10^{-5} mbar for 2 h at 1120°C + 24 h at 875°C
Smoothening prior to EB-PVD TBC deposition

Topcoats :

Standard 300 µm yttria stabilized zirconia (YSZ) TBC's manufactured by electron beam physical vapor deposition (EB–PVD) or air plasma spraying (APS).

Sample geometry :



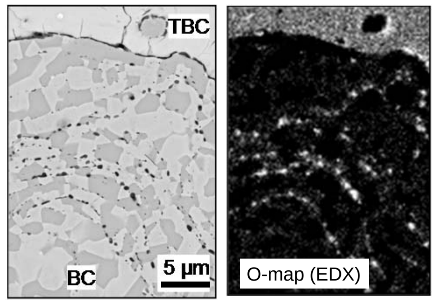
Testing :

Cyclic oxidation at 1000°C or 1100°C in laboratory air with 2 h heating and 15 min cooling using pressurized air

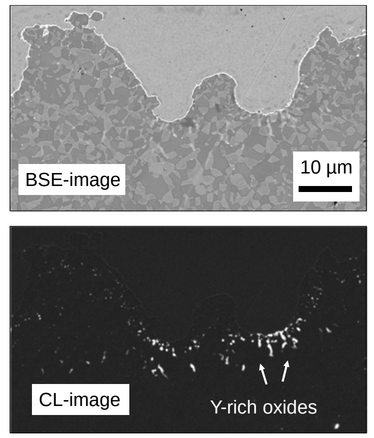
Analytical studies :

SEM on polished cross-sections

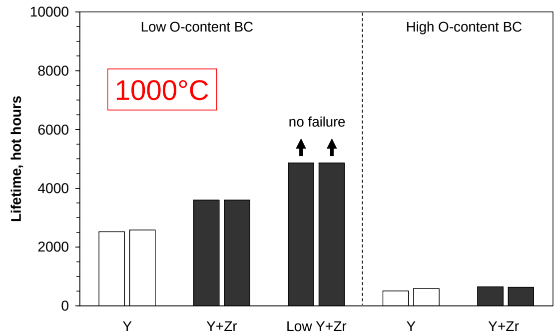
Y High O bondcoat
(as-received microstructure)



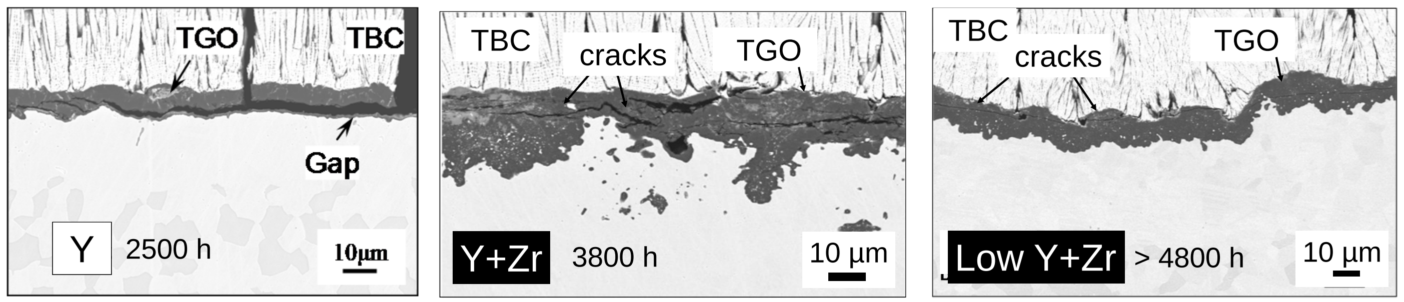
Y Low O bondcoat
(microstructure after heat-treatment)



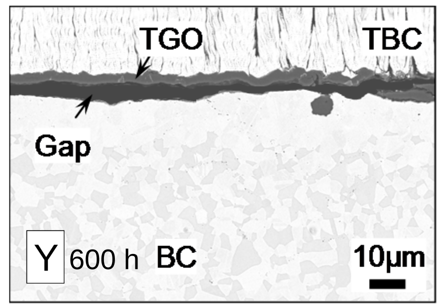
Results : EB – PVD TBC Systems



Low O Bondcoats



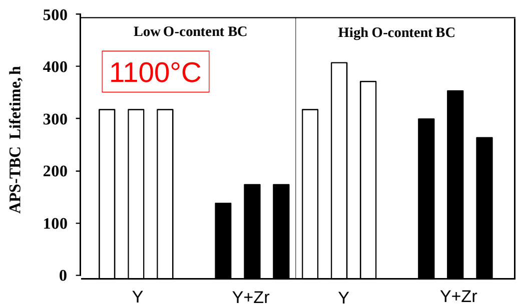
High O Bondcoat



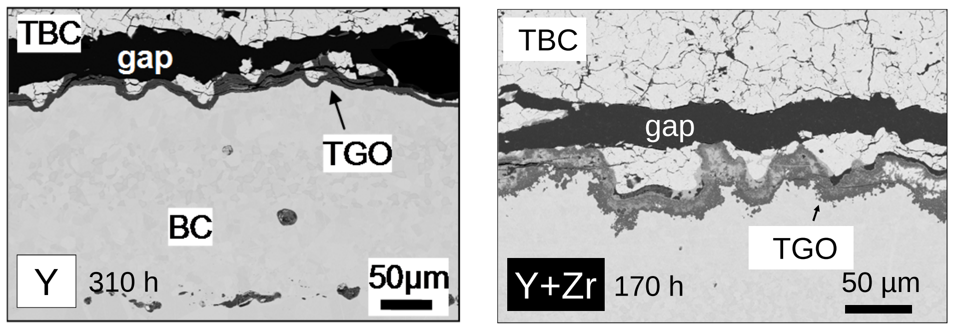
Observations

- *For Zr-free bondcoats failure at flat TGO/bondcoat interface*
- *Thinner TGO at failure in High O than in Low O bondcoats*
- *Addition of Zr to Low O bond-coat shifts crack path from TGO/BC-interface to within TGO*

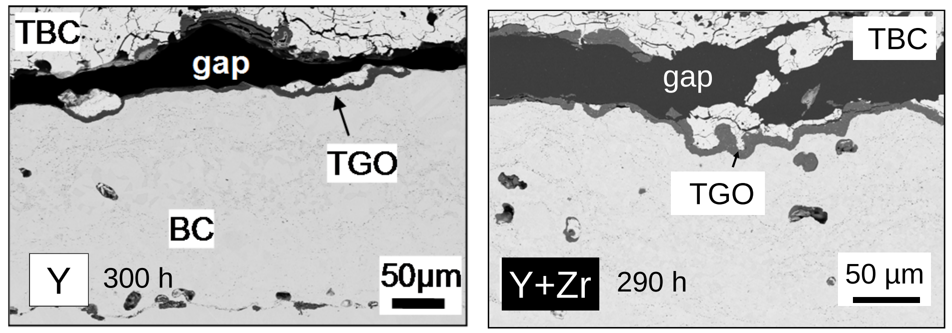
Results : APS TBC Systems



Low O Bondcoats



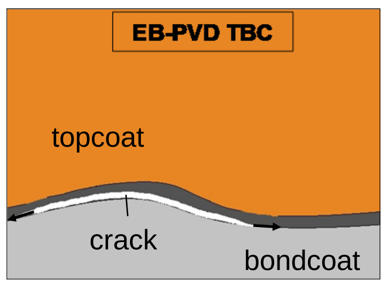
High O Bondcoats



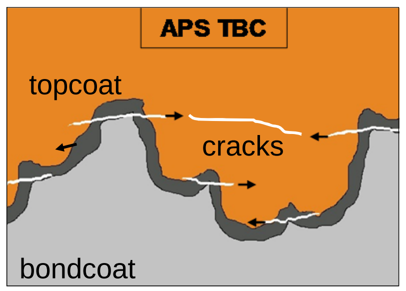
Observations

- *Failure mode : crack propagation mainly through topcoat*
- *All systems show similar TGO-morphologies and failure mode / lifetime except that with Y+Zr Low O bondcoat*

TBC failure mechanisms with Y-doped bondcoats



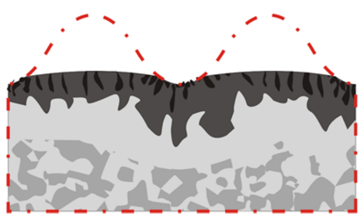
- *Rapid crack propagation at flat TGO / bondcoat interface*
- *Tying up Y by high O content in bondcoat > worse TGO adherence, shorter TBC lifetime*



- *Crack initiation after relatively short times by TGO-delamination at bondcoat hills*
- *TBC-lifetime mainly determined by crack propagation within topcoat. Bondcoat O-content less important*

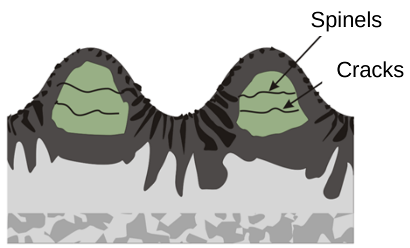
Effect of minor Zr addition to Low O bondcoat

EB-PVD TBC
after smoothening



- *Positive for TBC lifetime*
- *(crack propagation path removed from TGO/bondcoat interface)*

APS TBC



- *Negative for TBC lifetime : local breakway oxidation*

Conclusions

EB-PVD TBC's

- *Lifetime strongly depends on TGO-adhesion and consequently on oxygen content in bondcoat*
- *An optimum RE-reservoir determined by RE and O contents should exist for a given system*

APS TBC's

- *Hardly any effect of RE-reservoir and O-content on TBC-lifetime unless bondcoat is "overdoped"*

(in agreement with relatively good performance of HVOF and APS bondcoats known from other studies)

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