6-24-2018

Structure and properties of condensed gradient coatings with NiAl-bond coat doped with Y or Dy

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STRUCTURE AND PROPERTIES OF CONDENSED GRADIENT METAL-CERAMIC THERMAL BARRIER COATINGS WITH NIAL-BOND COAT DOPED WITH Y OR DY

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The aim: Improvement of thermal cyclic durability of EB-PVD NiAl/ZrO_2-8%Y_2O_3 (NiAl/8YSZ) thermal barrier coatings (TBC) by doping oxidation-resistant metal bond coat of NiAl with Y or Dy additives.

Main tasks:

- check the possibility of deposition of EB-PVD TBC NiAl/8YSZ 30-50 μm/140-160 μm thick (including those with graded distribution of additives in the bond coat) in one process cycle.
- study the influence of Y and Dy additives to NiAl on the structure and properties of EB-PVD TBC NiAl/ZrO_2-8%Y_2O_3 in as-deposited condition and after vacuum heat treatment.

Materials and methods:

TBC NiAl/8YSZ, NiAlY/8YSZ and NiAlDy/8YSZ were deposited on one side of coupons of 12.7 mm diameter and 4 mm thickness, made from ZhS32, PWA 1480 and CMSX-4 superalloys. Single-step technology of TBC deposition in one EB-PVD unit by one deposition run was used: oxidation-resistant metal bond coat was deposited by evaporation of pre-fused NiAl tablet of the specified mass from one crucible with subsequent deposition of outer ceramic layer by evaporation of 8YSZ ingot from another crucible. Direct electron beam heating was applied in all the cases (both for sample preheating, and for evaporation of metal and ceramics).

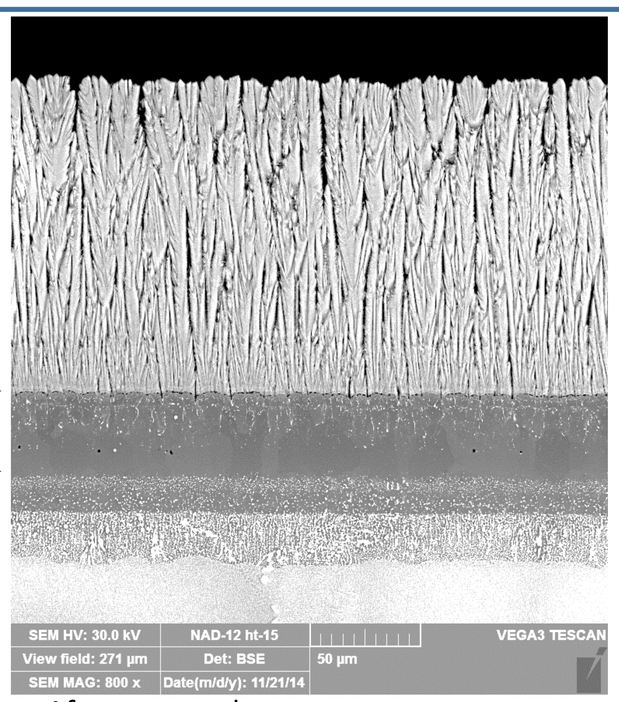
Thermal cyclic furnace tests were conducted with application of 1-hour cycle, including soaking at the temperature of 1150 °C for 45 min. Sample examination during testing was conducted every 20 cycles.

Outer ceramic layer ZrO_2-8% Y_2O_3

NiAl bond coat with graded distribution

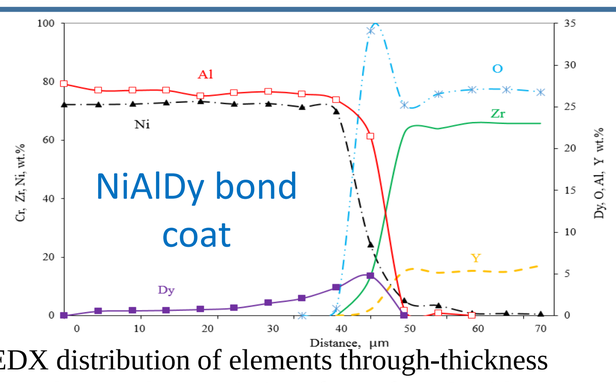
Interdiffusion zone

ZhS 32 superalloy substrate

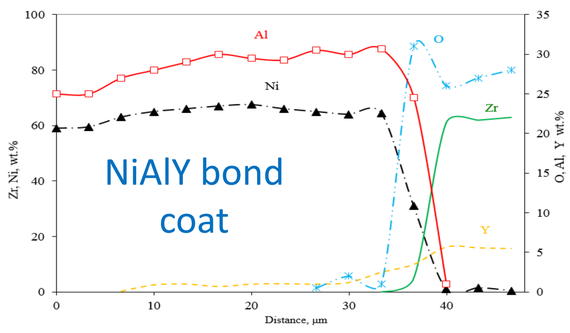


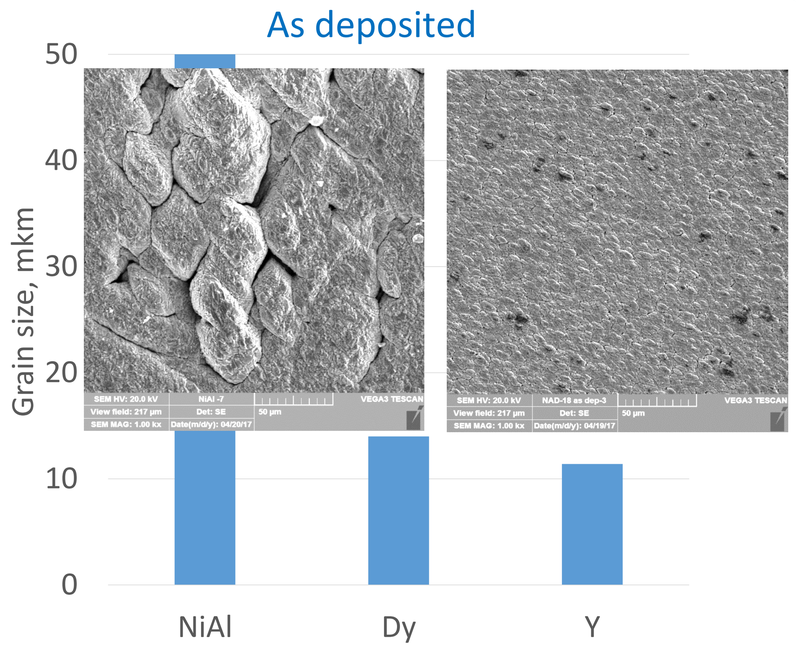
After vacuum heat treatment

Direct electron-beam evaporation and condensation of NiAlDy

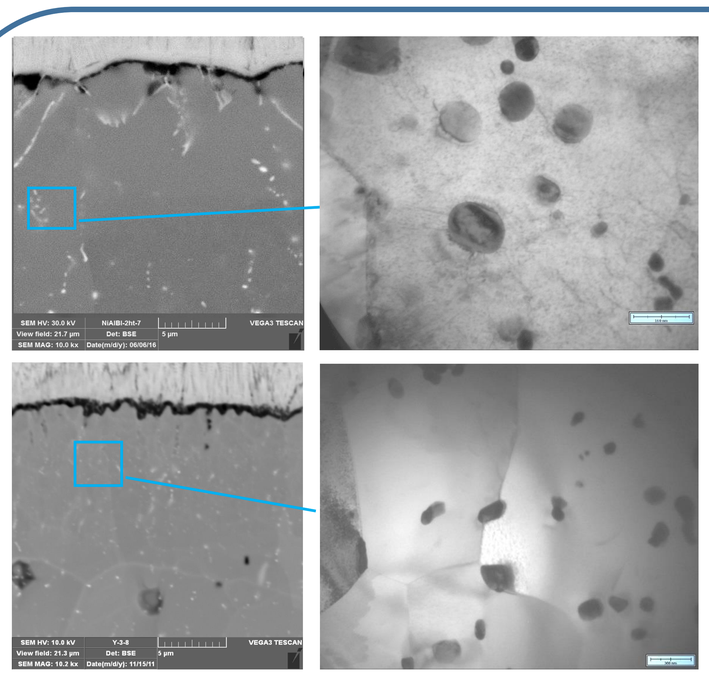


EDX distribution of elements through-thickness at the metal-ceramic interface of TBC with gradient composition NiAlDy(Y)/ZrO_2-8%Y_2O_3.



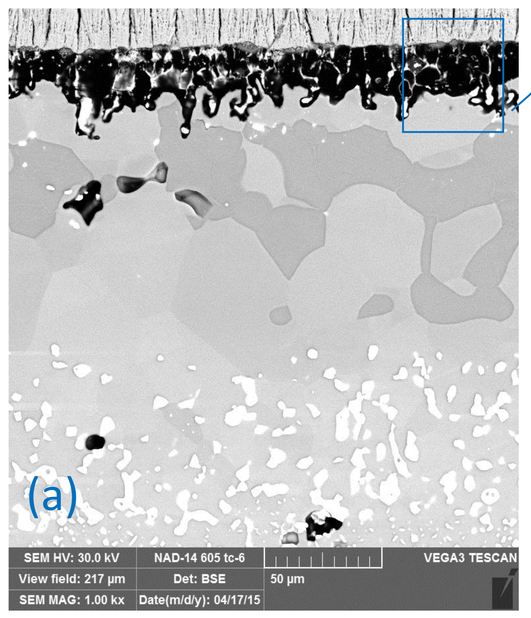


Doping β-NiAl with Y or Dy reduces the average grain size of the condensed NiAl layer by 4-5 times



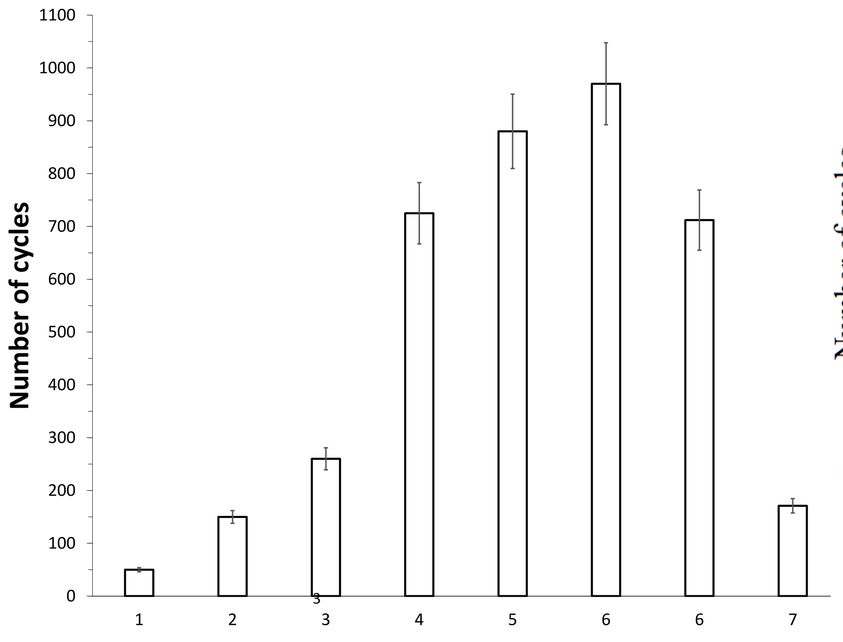
Presumably, globular and spindle-shaped particles of compounds Dy with Ni, Al and O (like DyNiAl, $DyNi_2Al_3$, $DyAlO_3$) segregates inside β-NiAl grains and along its boundaries (SEM and EDX analysis data)

Intermetallic Ni_5Y particles with equiaxial shape and uniform localization in the β-NiAl matrix - within the grains and along its boundaries, are precipitated, the size of the precipitate is 100 ... 200 nm.



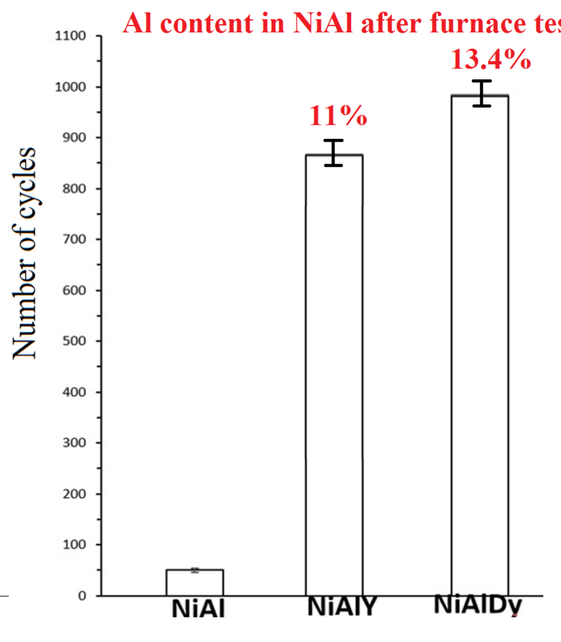
Microstructure after 600 thermal cycles of the: (a) gradient NiAlDy/ZrO2-8% Y_2O_3 coating, (b) TGO layer, (c) surface of the NiAlDy bond coat

Thermal-cyclic lifetime of NiAlDy/ZrO_2-8 %Y_2O_3 gradient coating with different Dy content



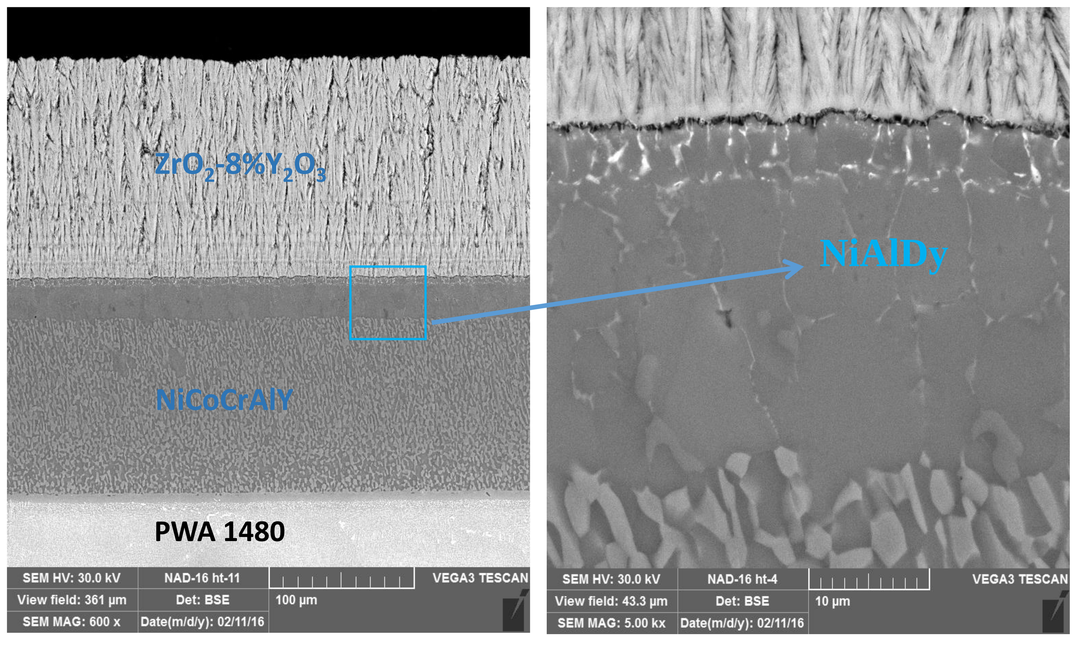
ZhS-32 superalloy samples

Thermal-cyclic lifetime of NiAl/ZrO_2-8 %Y_2O_3 coating with different dopants



CMSX-4 superalloy samples

Thermal-cyclic lifetime increase of NiCoCrAlY/ZrO_2-8%Y_2O_3 TBC by deposition of additional transitional zone NiAlDy in 1.5 times



Microstructure NiCoCrAlY+NiAlDy / ZrO_2-8%Y_2O_3

Transition zone NiAlDy

Conclusion: Doping of NiAl bond coat with Y or Dy makes it possible to increase the thermal cyclic durability of composite TBC deposited by EB-PVD by 8-15 times. The composite TBC NiAlDy / ZrO_2-8% Y_2O_3 with the graded distribution of dysprosium in the NiAl bond coat with its maximum concentration under the TGO layer at 4 ... 9% has the highest thermal cyclic durability. It is established that the dysprosium segregates along and inside grain boundaries of NiAl in the form of $Ni_xAl_yDy_z$ type particles of 5 nm to 20 μm sizes, and also in the Al_2O_3 scale layer at the metal-ceramic interface, presumably as a $DyAlO_3$ compound.

The positive effect of dysprosium doping is provided by:

- reduction of NiAl grain size by 4-5 times;
- increase of thermal stability of the NiAl bond coat by slowing down the diffusion processes by 20 ... 25%;
- increasing the adhesion of the scale layer of Al_2O_3 at the metal-ceramic interface due to the penetration of spindle-shaped particles based on dysprosium oxide inside the NiAl layer.