from excessive heating of blade materials caused by severe friction incursion conditions in a turbine, and/or the abradable coating is thermal sprayed at excessively high bulk hardness conditions.

[0009] Examples of severe wear damage include blade materials that soften upon heating, extreme bulk plastic deformation, and fracture. Other examples of severe wear damage include oxidation of blade materials that arises from heating caused by friction. Further examples of severe wear damage include combustion of blade materials (mostly confined to titanium alloys). Even further examples of severe wear damage include cracking of blade materials due to extreme blade cutting forces that arises from inefficient cutting against abradable shrouds with higher than specified hardness.

[0010] The present disclosure relate to a thermal spray material feedstock including chemically complex or "high entropy" oxides (HEOs) as abradable sealing coatings. HEOs allow for precise control of chemical, mechanical, and thermal properties for use in specific environments. In examples, HEOs of the present disclosure do not include any principle constituent oxide, such as zirconia, in a stabilized zirconia coating. In examples, the abradable sealing coating contains at least five principle oxide constituents at a high concentration of >5 mol%.

[0011] In example, the abradable sealing coating includes a sublattice with a mixture of five or more cations and at least one sublattice that comprises oxygen. The random ordering of five or more cations provides a material with a high configurational entropy (S_{config}). The inclusion of five or more elements also provides the ability to modify the phase composition to increase the abradability and chemical resistances in specific environments. Also, the inclusion of five or more elements leads to a high configurational entropy of individual phases, which results in an increased thermal stability. Thermal properties, such as thermal conductivity, can also be modified by including specific constituents to achieve superior performance.

[0012] HEOs have large lattice distortions and other defect concentrations, which results in low thermal conductivity. Due to their characteristically low thermal conductivity, HEOs have been investigated as thermal barrier coatings in turbine engines; however, the use of HEOs as abradable seal coatings has never been studied.

[0013] The present disclosure provides a new class of ceramic abradable seal compositions that exhibit an improved rub incursion behavior (abradability performance). Depending on the type of HEO that is employed, improved thermal properties, excellent sintering resistance, excellent phase stability, good thermal cycling performance, and resistance

to chemical attack (e.g., by CMAS) can be obtained in the abradable seal coating of the present disclosure.

[0013a] In one aspect, the present disclosure provides a thermal spray material feedstock, comprising: an oxide having calcia magnesia alumina silicate (CMAS) resistance, wherein when the oxide is reacted at 1250°C for 8 hours with a CMAS having a low melting temperature of 1110°C to 1125°C, the oxide exhibits a CMAS penetration depth of 100 μm or less.

[0013b] In another aspect, the present disclosure provides a method for manufacturing an abradable sealing coating comprising: plasma spraying the thermal spray material feedstock as disclosed herein onto a turbine blade or a part of a jet engine, wherein the thermal spray material feedstock comprises an oxide that interfaces with the turbine blade or the part of the jet engine.

[0013c] In another aspect, the present disclosure provides an abradable sealant coating comprising the HEO as described herein.

[0013d] In another aspect, the present disclosure provides a part of a jet engine comprising the abradable sealant coating as described herein.

[0013e] In another aspect, the present disclosure provides a turbine blade comprising the abradable sealant coating as described herein.

[0013f] In another aspect, the present disclosure provides an abradable sealant coating comprising 5 or more different oxide-forming metallic cations in an amount greater than 5 mol%.

DETAILED DESCRIPTION

[0014] In an embodiment, an oxide ceramic is used as a sealant material or abradable seal material. In example embodiments, the overall combined atomic composition of the oxide ceramic is represented by general formula M_xO_y, where M is chosen from the group of at least five different oxide-forming metallic cations in an amount greater than 5 mol%. M_xO_y is standard metallurgical shorthand. For example, the carbide $(Cr,Mo,W,Fe)_{23}C_6$ is commonly referred to as $M_{23}C_6$ and (TiNbTaZrHf)C is referred to as MC. Similarly, M_xO_y may be used to describe the oxide $(Zr,Ce,Y,Yb,Gd,Dy)_xO_y$, where "M" is chosen from the group of at least five oxide-forming metals.

[0015] In an embodiment, the configurational entropy S_{config} of the oxide ceramic is 1.5R per mole or greater, where R is the gas constant 8.314 $J \cdot K^{-1} \cdot mol^{-1}$. This value of S_{config} is a commonly accepted definition of a high-entropy material. In embodiments, the metal cations "M" and oxygen anions "O" may be distributed on one or more crystal sublattice(s).

[0016] In embodiments of the present disclosure, the metals “M” may include non-toxic and non-radioactive oxide-forming metals, such as:

an alkaline-earth metal, including Be, Mg, Ca, Sr, and Ba;

a transition metal, including Sc, Y, Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Mn, Re, Fe, Ru, Co, Ni, Cu, and Zn; and

a lanthanide, including La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Yb, and Lu.

For example, “M” is chosen from a group of at least 5 different oxide-forming metallic cations that includes at least one alkaline-earth metal, at least one transition metal, and at least one lanthanide. In another example, “M” is chosen from a group of at least 5 different oxide forming metallic cations from among an alkaline-earth metal, a transition metal, and a lanthanide.

[0017] In embodiments, the following metals may be used in HEO abradable seal coatings: (1) alkaline-earth metals, such as Mg and Ca; (2) transition metals, such as Y, Ti, Zr, Hf, V, Cr, Mo, and W; and (3) lanthanides, such as La, Ce, Pm, Sm, Eu, Gd, Tb, Dy, Er, and Yb.

[0018] In embodiments, the metal cations "M" and oxygen anions "O" may be distributed on one or more crystal sublattice(s). Accordingly, the oxide of the present disclosure may be physically manifested as one combined oxide structure of as a yet unknown

What is claimed:

1. A thermal spray material feedstock, comprising:

an oxide having calcia magnesia alumina silicate (CMAS) resistance,

wherein when the oxide is reacted at 1250°C for 8 hours with a CMAS having a low melting temperature of 1110°C to 1125°C, the oxide exhibits a CMAS penetration depth of 100 μm or less.

2. The thermal spray material feedstock of claim 1, wherein the oxide is a high entropy oxide (HEO).

3. The thermal spray material feedstock of claim 1, wherein the oxide comprises:

5-14 wt% of an alkaline earth metal oxide;

35-70 wt% of a rare earth metal oxide;

6-20 wt% of Y_2O_3; and

a balance of ZrO_2.

4. The thermal spray material feedstock of claim 1, wherein the oxide comprises:

5-9 wt% of an alkaline earth metal oxide;

41-63 wt% of a rare earth metal oxide;

15-24 wt% of Y_2O_3; and

a balance of ZrO_2.

5. The thermal spray material feedstock of claim 3, wherein the alkaline earth metal oxide is at least one of $CaCo_3$, CaO, or MgO.

6. The thermal spray material feedstock of claim 3, wherein the rare earth metal oxide is at least one of Yb_2O_3, Gd_2O, or Sm_2O_3.

7. The thermal spray material feedstock of claim 4, wherein the alkaline earth metal oxide is MgO.

8. The thermal spray material feedstock of claim 4, wherein the rare earth metal oxide is at least one of 1-2 wt% La_2O_3 and 24-38 wt% Gd_2O_3.

9. The thermal spray material feedstock of claim 1, comprising lower than 2 wt% of La_2O_3 or other sources of La.

10. The thermal spray material feedstock of claim 1, comprising a total costly oxide content comprising at least one of Hf–oxide, Ta–oxide, Dy–oxide, Nb –oxide, Nd–oxide, Gd–oxide, and Y–oxide that is 55 wt. % or lower.

11. The thermal spray material feedstock of claim 4, comprising a total costly oxide content comprising at least one of Y_2O_3 and Gd_2O_3 that is 55 wt. % or lower.

12. A method for manufacturing an abradable sealing coating comprising:

plasma spraying the thermal spray material feedstock of claim 1 onto a turbine blade or a part of a jet engine,

wherein the thermal spray material feedstock comprises an oxide that interfaces with the turbine blade or the part of the jet engine.

13. An abradable sealant coating comprising the HEO of claim 2.

14. The abradable sealant coating of claim 13, wherein the HEO has a high configurational entropy that is greater than 1.5R.

15. The abradable sealant coating of claim 13, further comprising a thermal barrier coating base coat.

16. The abradable sealant coating of claim 13, wherein the HEO is represented by general formula M_xO_y, wherein M is chosen from a group comprising at least 5 different oxide-forming metallic cations.

17. The abradable sealant coating of claim 13, wherein the HEO is represented by general formula M_xO_y wherein M is chosen from at least one member of Group II in the periodic table.

18. The abradable sealant coating of claim 13, wherein the HEO is represented by general formula M_xO_y wherein M is chosen from at least one lanthanide in the periodic table.

19. The abradable sealant coating of claim 13, wherein the HEO is represented by general formula M_xO_y, wherein M is chosen from at least one transition metal.

20. An abradable sealant coating comprising 5 or more different oxide-forming metallic cations in an amount greater than 5 mol%.

21. The abradable sealant coating of claim 15, wherein all oxides form a single phase solid solution.

22. The abradable sealant coating of claim 15, wherein multiple oxide phases are present.

23. The abradable sealant coating of claim 15, wherein the abradable sealant coating comprises a high level of porosity, may have a porosity having about 30-70% by cross-sectional area.

24. The abradable sealant coating of claim 15, wherein the coating comprises at least one fugitive phase.

25. The abradable sealant coating of claim 15, wherein the at least one fugitive phase comprises polyester, talc, and boron nitride.

26. A turbine blade comprising the abradable sealant coating of claim 13.

27. A part of a jet engine comprising the abradable sealant coating of claim 13.