What is claimed is:

1. A thermal barrier coating comprising:

a top coat, wherein the top coat is a high entropy oxide (HEO) having a high configurational entropy, the HEO being of the form M_xO_y, where M represents a group of at least 5 different oxide-forming metallic cations, x represents the number of metal cations (M) or atoms, and y represents the number of oxygen anions (O) or atoms,

wherein the HEO maintains phase composition without transformation from room temperature to the operating temperature range of the top coat, and at least five of the different oxide-forming metallic cations (M) comprise Y, Zr, Ca, Gd, La, Yb, Ti, or Ce, such that the HEO comprises at least five different metal oxides which are from the group:

a) Y_2O_3 in an amount of from 5% by weight to 20% by weight,

b) ZrO_2 in an amount of from 12% by weight to 55% by weight,

c) CaO in an amount of from 0% by weight to 15% by weight,

d) Gd_2O_3 in an amount of from 0% by weight to 30% by weight,

e) La_2O_3 in an amount of from 0% by weight to 26% by weight,

f) Yb_2O_3 in an amount of from 0% by weight to 32% by weight,

g) TiO_2 in an amount of from 0% by weight to 10% by weight, or

h) CeO_2 in an amount of from 0% by weight to 18% by weight,

wherein the percentages of the at least five of the metal oxides add up to at least 97% by weight.

2. The thermal barrier coating of claim 1 comprising at least five different metal oxides from the group:

a) Y_2O_3 in an amount of from 8% by weight to 18% by weight,

b) ZrO_2 in an amount of from 17% by weight to 52% by weight,

c) CaO in an amount of from 0% by weight to 11% by weight,

d) Gd_2O_3 in an amount of from 0% by weight to 28% by weight,

e) La_2O_3 in an amount of from 0% by weight to 24% by weight,

f) Yb_2O_3 in an amount of from 0% by weight to 30% by weight,

g) TiO_2 in an amount of from 0% by weight to 7% by weight, or

h) CeO_2 in an amount of from 0% by weight to 15% by weight,

wherein the percentages of the at least five metal oxides add up to at least 97% by weight.

3. The thermal barrier coating of claim 1 comprising Y_2O_3 in an amount of from 8% by weight to 12% by weight, ZrO_2 in an amount of from 48% by weight to 55% by weight, Yb_2O_3 in an amount of from 14% by weight to 18% by weight, TiO_2 in an amount of from 4% by weight to 8% by weight, and CeO_2 in an amount of from 12% by weight to 17% by weight, said percentages adding up to at least 97% by weight.

4. The thermal barrier coating of claim 3 further comprising at least one additional metal oxide in an amount up to 2% by weight, said weight percentages adding up to at least 99% by weight.

5. The thermal barrier coating of claim 3 further comprising HfO_2 in an amount up to 2% by weight, said weight percentages adding up to at least 99% by weight.

6. The thermal barrier coating of claim 1 comprising:

three metal oxides which are

Y_2O_3 in an amount of from 13% by weight to 19% by weight,

ZrO_2 in an amount of from 14% by weight to 25% by weight, and

Gd_2O_3 in an amount of from 20% by weight to 30% by weight, and

any two of the metal oxides which are

Yb_2O_3 in an amount of from 23% by weight to 32% by weight,

La_2O_3 in an amount of from 18% by weight to 25% by weight, or

CaO in an amount of from 6% by weight to 12% by weight,

the percentages of the five metal oxides adding up to at least 97% by weight.

7. The thermal barrier coating of claim 1, wherein the configurational entropy of the oxide is at least 1.5R per mole, where R is the gas constant $J \cdot K^{-1} \cdot mol^{-1}$.

8. The thermal barrier coating of claim 1, wherein the five or more different oxide-forming metallic cations are present in compositions between 5 and 35 atomic %.

9. The thermal barrier coating of claim 1, further comprising a thermal barrier coating bond coat.

10. The thermal barrier coating of claim 1, wherein the HEO is a single phase or single crystalline structure from room temperature up to at least 2,000°F.

11. The thermal barrier coating of claim 1, wherein the HEO is a single phase or single crystalline structure which is cubic from room temperature up to at least 2,000°F.

12. The thermal barrier coating of claim 1, wherein the HEO is a single phase or single crystalline structure from 1800°F to 2600°F.

13. The thermal barrier coating of claim 1, wherein the HEO is a single phase or single crystalline structure which is tetragonal from room temperature up to at least 2000°F.

14. The thermal barrier coating of claim 1, wherein the HEO is a single phase or single crystalline structure from room temperature up to the melting point of the HEO.

15. The thermal barrier coating of claim 1, wherein the HEO does not undergo phase transformation to a different crystalline structure for at least 700°F up to the melting point of the HEO.

16. A thermal barrier coating material comprising:

a high entropy oxide (HEO) having a high configurational entropy, the HEO being of the form M_xO_y, where M represents a group of at least 5 different oxide-forming metallic cations, x represents the number of metal

cations (M) or atoms, and y represents the number of oxygen anions (O) or atoms,

wherein the HEO is a single phase across the operating temperature range of a top coat, and at least five of the different oxide-forming metallic cations (M) comprise Y, Zr, Ca, Gd, La, Yb, Ti, or Ce, such that the HEO comprises at least five different metal oxides which are from the group:

a) Y_2O_3 in an amount of from 5% by weight to 20% by weight,

b) ZrO_2 in an amount of from 12% by weight to 55% by weight,

c) CaO in an amount of from 0% by weight to 15% by weight,

d) Gd_2O_3 in an amount of from 0% by weight to 30% by weight,

e) La_2O_3 in an amount of from 0% by weight to 26% by weight,

f) Yb_2O_3 in an amount of from 0% by weight to 32% by weight,

g) TiO_2 in an amount of from 0% by weight to 10% by weight, or

h) CeO_2 in an amount of from 0% by weight to 18% by weight,

wherein the percentages of the at least five of the metal oxides add up to at least 97% by weight.

17. The thermal barrier coating material of claim 16 comprising Y_2O_3 in an amount of from 8% by weight to 12% by weight, ZrO_2 in an amount of from 48% by weight to 55% by weight, Yb_2O_3 in an amount of from 14% by weight to 18% by weight, TiO_2 in an amount of from 4% by weight to 8% by weight, and CeO_2 in an amount of from 12% by weight to 17% by weight, said percentages adding up to at least 97% by weight.

18. The thermal barrier coating material of claim 16 which is at least one of a powder, a wire, a bar, an ingot and a rod.

19. A thermal spray powder comprising the top coat material of claim 16.

20. A coated substrate comprising a substrate and a thermal barrier coating of claim 9 wherein the top coat of the thermal barrier coating is bonded by the thermal barrier coating bond coat to the substrate.

21. A method for reducing delamination of a top coat from a substrate comprising bonding a thermal barrier coating of claim 9 to a substrate wherein the top coat of the thermal barrier coating is bonded by the thermal barrier coating bond coat to the substrate.

22. The thermal barrier coating material of claim 16, which is agglomerated and sintered.

23. The thermal barrier coating material of claim 22 which is in powdered form.

24. A method for making a thermal barrier coating comprising agglomerating and sintering a thermal barrier coating material of claim 16 to obtain a sintered agglomerate, and forming the sintered agglomerate into a powder for thermal spraying.