

Claims

1. A method of producing an improved dense and crystalline coating in an as-sprayed condition onto a substrate using a modified laminar plasma plume process, said modified laminar plasma plume process comprising the steps of:
 - providing a cascade torch;
 - establishing a coating process standoff distance of 3 inches or greater as measured from an outlet of the cascade torch to the substrate;
 - generating a laminar plasma plume that contacts the substrate, wherein the laminar plasma plume is characterized as a substantially columnar shape-like structure along a longitudinal axis of the laminar plasma plume, the laminar plasma plume having a longitudinal length substantially equal to the coating process standoff distance;
 - pre-heating the substrate with the laminar plasma plume to form a heated substrate;
 - feeding powder particles;
 - heating the powder particles to form molten powder particles;
 - directing the molten powder particles from an outlet of the cascade torch into the laminar plasma plume;
 - impinging the molten powder particles onto the heated substrate, and
 - crystallizing the powder particles to form the improved dense and crystalline coating, said crystallizing occurring without the use of auxiliary heating or a post-heat treatment step.
2. The method of claim 1, further comprising the step of transferring thermal energy in the laminar plasma plume towards the heated substrate.
3. The method of claim 1, further comprising minimizing radial heat losses from the laminar plasma plume.

4. The method of claim 1, wherein the method of pre-heating the substrate to a temperature that is at or above a glass transition temperature of the coating.
5. The method of claim 1, wherein the improved dense and crystalline coating in the as-sprayed condition has a crystallinity that is higher than a corresponding coating produced by a turbulent plasma plume as measured by x-ray diffraction.
6. The method of claim 1, wherein the molten powder particles upon impinging the heated substrate undergoes cooling at a cooling rate that is lower in comparison to a coating prepared by a conventional turbulent plasma plume process.
7. The method of claim 1, wherein the step of introducing powder particles occurs without substantial disruption of the laminar plasma plume.
8. The method of claim 1, further comprising maintaining stability of the substantially columnar shape-like structure of the laminar plasma plume.
9. The method of claim 1, wherein the improved dense and crystalline coating in the as-sprayed condition has a density that is higher than a corresponding coating produced by a turbulent plasma plume as visually observed by optical microscopy at a magnification of 200-500 X.
10. A method of using a laminar plasma flow regime to create an improved dense and crystalline coating, comprising:
 - providing a cascade torch, comprising a cathode and an anode, and one or more inner electrode inserts between the cathode and the anode to provide arc stability;

establishing a predetermined coating process standoff distance as measured from an outlet of the cascade torch to a surface of the substrate;

generating a laminar plasma plume that is defined, at least in part, by a longitudinal length along a longitudinal axis of the laminar plasma plume that extends from the outlet of the cascade torch to the substrate, wherein the laminar plasma plume is characterized as substantially columnar shape;

pre-heating the surface of the substrate with the laminar plasma plume to a localized deposition spot temperature to form a heated substrate;

introducing a powder material without substantially disrupting the laminar plasma plume;

heating the powder particles to form molten powder particles;

directing the molten powder particles from an outlet of the cascade torch into the laminar plasma plume and towards the heated substrate;

impinging the molten powder particles onto the heated substrate, and

crystallizing the powder particles to form the improved dense and crystalline coating, said crystallizing occurring without the use of auxiliary heating or a post-heat treatment step.

11 The method of claim 10, further comprising cooling the coating at a cooling rate sufficient to reduce or minimize formation of amorphous phases in comparison to a corresponding coating produced by a turbulent plasma plume.

12. The method of claim 10, wherein the predetermined coating process standoff distance is 3 inches or more.

13. The method of claim 10, further comprising creating and maintaining the longitudinal length of the laminar plasma plume to be substantially equal to the predetermined coating process standoff distance.

14. The method of claim 10, further comprising operating the cascade torch to minimize heat losses from the laminar plasma plume in a radial direction of the laminar plasma plume.
15. The method of claim 10, further introducing the powder particles directly into the laminar plasma plume.
16. The method of claim 10, further comprising minimizing atmospheric air entrainment into the laminar plasma plume.
17. The method of claim 10, further wherein the localized deposition spot temperature of the substrate is at or above a glass transition temperature of the coating.
18. The method of claim 10, further comprising maintaining substantial uniformity of the laminar plasma plume along the radial direction of the laminar plasma plume.
19. The method of claim 10, further comprising transferring thermal energy from the laminar plasma plume to the substrate in a direction that is substantially parallel to the longitudinal axis of the laminar plasma plume.
20. The method of claim 10, further comprising maintaining contact of the laminar plasma plume with the substrate during formation of the improved dense and crystalline coating.
21. The method of claim 10, wherein the localized deposition spot temperature to form the heated substrate is greater than a corresponding localized deposition spot temperature created by a turbulent plasma plume.