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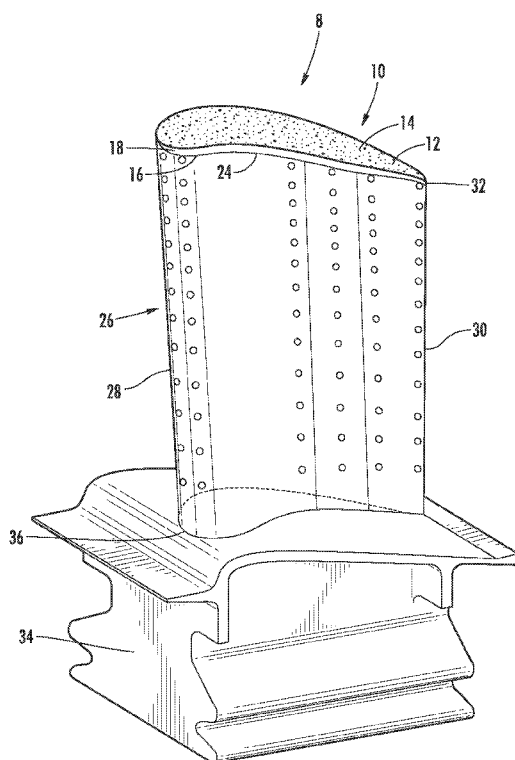
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(54) Title: ABRASIVE COATED TURBINE BLADE TIP



(57) Abstract: A squealer tip having a coating including an abrasive is disclosed. The squealer tip may be attached to a radially outer surface of the airfoil tip and formed from at least one support material including at least one abrasive particle formed from a refractory carbide material that has a better resistance to thermal degradation compared to conventional blade tip abrasive materials as well as negligible chemical reaction with metal elements in the metal matrix used to attach the abrasive. In at least one embodiment, the abrasive particle may be tantalum carbide. The squealer tip may also extend radially outward from the tip and cover at least a portion of the radially outer surface of the tip



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ABRASIVE COATED TURBINE BLADE TIP

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Development of this invention was supported in part by the United States Department of Energy, Advanced Turbine Development Program, Contract No. DE-FC26-05NT42644. Accordingly, the United States Government may have certain rights in this invention.

FIELD OF THE INVENTION

This invention is directed generally to turbine blades, and more particularly to airfoil tips for turbine blades.

BACKGROUND

Typically, gas turbine engines include a compressor for compressing air, a combustor for mixing the compressed air with fuel and igniting the mixture, and a turbine blade assembly for producing power. Combustors often operate at high temperatures that may exceed 2,500 degrees Fahrenheit. Typical turbine combustor configurations expose turbine blade assemblies to these high temperatures. As a result, turbine blades must be made of materials capable of withstanding such high temperatures.

Typically, turbine blades are formed from a root portion at one end and an elongated portion forming a blade that extends outwardly from a platform coupled to the root portion at an opposite end of the turbine blade. The blade is ordinarily composed of a tip opposite the root section, a leading edge, and a trailing edge. The tip of a turbine blade often has a tip feature to reduce the gap between ring segments and blades in the gas path of the turbine. The tip features are often referred to as squealer tips and are frequently incorporated onto the tips of blades to help reduce pressure losses between turbine stages. These features are designed to minimize the gap between the blade tip and the ring segment.

Turbine blade tips are often coated with abrasive blade treatments to provide the turbine blades with startup cutting capacity. However, many abrasive blade treatments degrade rapidly when exposed to the hot gas environment within a gas turbine engine. As such, the blade lose their ability to continue cutting during warm restarts throughout the break-in period of the gas turbine engine. Thus, a more robust abrasive blade treatment is needed.

SUMMARY OF THE INVENTION

A turbine airfoil abradable coating system with a squealer tip having a coating including an abrasive that is capable of withstanding the high temperatures of a hot gas path is disclosed. The squealer tip may be attached to a radially outer surface of the tip and may be formed from at least one support material including at least one abrasive particle formed from a refractory carbide material that has a better resistance to thermal degradation compared to current blade tip abrasive materials as well as negligible chemical reaction with metal elements in the metal matrix used to attach the abrasive. In at least one embodiment, the abrasive particle may be tantalum carbide. The squealer tip may also extend radially outward from the tip and may cover at least a portion of the radially outer surface of the tip.

The squealer tip of the turbine airfoil abradable coating system may be a component of a generally elongated blade having a leading edge, a trailing edge, a tip at a first end, and a root coupled to the blade at an end generally opposite the first end for supporting the blade and for coupling the blade to a disc. A stationary ring segment may be positioned radially outward from the tip of the generally elongated blade and secured in position such that an inner surface of the stationary ring segment is positioned in close proximity to the generally elongated blade to limit combustion gases passing between the stationary ring segment and the generally elongated blade. The inner surface of the stationary ring segment may be coated with a thermal barrier coating. The squealer tip may be attached to a radially outer surface of the tip and formed from at least one support material including at least one abrasive particle formed at least partially from tantalum carbide. In another embodiment, the abrasive particle may be formed only from tantalum carbide. In yet another embodiment, the squealer tip may include more than one abrasive particle

and may include a plurality of abrasive particles. The squealer tip may extend radially outward from the tip and may cover at least a portion of the radially outer surface of the tip.

The squealer tip may be attached to a radially outer surface of the tip and may be formed from at least one support material including at least one abrasive particle. The squealer tip may extend radially outward from the tip and may cover at least a portion of the radially outer surface of the tip. In at least one embodiment, the squealer tip may cover all of the radially outer surface of the tip.

The squealer tip may be coated with a metal matrix used to attach the abrasive particles to the tip of the generally elongated blade. The metal matrix may be formed at least partially from a metallic material, such as, but not limited to, any high temperature oxidation resistant material, such as cobalt, nickel, aluminum, chromium and yttrium (CoNiCrAlY). In another embodiment, the metal matrix may be formed only of CoNiCrAlY.

In addition to the metal matrix, the squealer tip may include a refractory carbide material that has superior resistance to thermal degradation compared to conventional blade tip abrasive materials. The metal matrix may support the refractory carbide material, which may have only negligible chemical reactions with the metal matrix. In at least one embodiment, the abrasive particle may be formed at least partially from tantalum carbide. In another embodiment, the abrasive particle may be formed only from tantalum carbide. The metal matrix may include one abrasive particle or a plurality of abrasive particles. The tantalum carbide particles may be between 100 and 200 microns in size. Such size increases the efficiency of the squealer tip 10 by enhancing the durability of the metal matrix with the abrasive particle during the first 2,000 hours of service use and thereafter when the capability of tip rub during warm startups exists within large industrial gas turbine (IGT) engines that are built on site and typically do not have a run-in procedure.

An advantage of this invention is that combination of tantalum carbide particles having a size between 100 and 200 microns in size and CoNiCrAlY create an abrasive blade tip treatment with high survivability through 2,000 hours of service at conventional IGT Row 1 turbine blade tip temperatures, thereby improving clearance control for longer turbine engine service times.

Another advantage of this invention is that the turbine airfoil abradable coating system increases the overall engine efficiency due to its superior resistance to thermal degradation compared to the currently available abrasive blade tips.

Yet another advantage of this invention is that the turbine airfoil abradable coating system increases the effective lifetime of turbine blades in a gas turbine engine.

Another advantage of this invention is that the turbine airfoil abradable coating system reduces the risk of blade tip wear due to tip rubbing against a radially outward stationary ring segment.

These and other embodiments are described in more detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and form a part of the specification, illustrate embodiments of the presently disclosed invention and, together with the description, disclose the principles of the invention.

Figure 1 is a perspective view of a turbine blade with a squealer tip attached thereto.

Figure 2 is a detailed cross-sectional view of the abrasive particles within the metal matrix forming the squealer tip attached to a turbine airfoil and positioned in close proximity to a radially outward ring segment.

Figure 3 is a screen shot of photographs of diffusion couple preparation testing the turbine airfoil abradable coating system.

Figure 4 is a magnified view of TaC particles in CoNiCrAlY matrix after 2,000 hours at 1,010 degrees Celsius.

Figure 5 is a further magnified view from Figure 4 of intact TaC particles with no visible reaction in CoNiCrAlY matrix after 2,000 hours at 1,010 degrees Celsius.

Figure 6 is a scanning electron microscope backscattered image showing intact particles and no visible reaction with CoNiCrAlY after 2,000 hours.

Figure 7 is an energy dispersive spectroscopy dot map showing elemental concentrations in TaC particles with slight yttrium and cobalt penetration but no loss of tantalum.

DETAILED DESCRIPTION OF THE INVENTION

As shown in Figures 1-7, a turbine airfoil abradable coating system 8 with a squealer tip 10 having a coating 12 including an abrasive 14 is disclosed. The squealer tip 10 may be attached to a radially outer surface 16 of the airfoil tip 24 and may be formed from at least one support material 18 including at least one abrasive particle 14 formed from a refractory carbide material that has a better resistance to thermal degradation compared to conventional blade tip abrasive materials as well as negligible chemical reaction with metal elements in the metal matrix used to attach the abrasive 14. In at least one embodiment, the abrasive particle 14 may be tantalum carbide. The squealer tip 10 may also extend radially outward from the tip 24 and may cover at least a portion of the radially outer surface 16 of the tip 24.

As shown in Figures 1 and 2, the squealer tip 10 may be attached to a radially outward tip 24 of a turbine blade 20. The turbine blade 20 may be formed from a generally elongated blade 26 having a leading edge 28, a trailing edge 30, a tip 24 at a first end 32, and a root 34 coupled to the blade 20 at a second end 36 generally opposite the first end 32 for supporting the blade 20 and for coupling the blade 20 to a disc. At least one stationary ring segment 40 may be positioned radially outward from the tip 24 of the generally elongated blade 26 and secured in position such that an inner surface 42 of the stationary ring segment 40 is positioned in close proximity to the generally elongated blade 26 to limit combustion gases passing between the stationary ring segment 40 and the generally elongated blade 26. The inner surface 42 of the stationary ring segment 40 may be coated with a fugitive material, such as, but not limited to, a thermal barrier coating 44. The thermal barrier coating 44 may be any appropriate material that protects the stationary ring segment 40, such as, but not limited to, a porous ceramic coating. The stationary ring segment 40 may be positioned such that a gap 38 exists between the outermost surface 46 of the turbine blade 20 and the stationary ring segment 40 to prevent the blade from contacting the stationary ring segment 40. However, the size of the gap 38 is minimized to limit engine inefficiencies.

The squealer tip 10 may be attached to a radially outer surface 44 of the tip 24 and may be formed from at least one support material 18 including at least one abrasive particle 14. The squealer tip 10 may extend radially outward from the tip 24

and may cover at least a portion of the radially outer surface 16 of the tip 24. In at least one embodiment, the squealer tip 10 may cover all of the radially outer surface 16 of the tip 24.

The squealer tip 10 may be formed from a metal matrix 18 used to attach the abrasive particles 14 to the tip 24 of the generally elongated blade 26. The metal matrix may be formed at least partially from a metallic material, such as, but not limited to, any high temperature oxidation resistant material, such as cobalt, nickel, aluminum, chromium and yttrium (CoNiCrAlY). In another embodiment, the metal matrix 18 may be formed only of CoNiCrAlY.

In addition to the metal matrix 18, the squealer tip 10 may include a refractory carbide material that has superior resistance to thermal degradation compared to conventional blade tip abrasive materials. The metal matrix 18 may support the refractory carbide material, which may have only negligible chemical reactions with the metal matrix 18. In at least one embodiment, the abrasive particle 14 may be formed at least partially from tantalum carbide. In another embodiment, the abrasive particle 14 may be formed only from tantalum carbide. The metal matrix 18 may include one abrasive particle 14 or a plurality of abrasive particles 14. The tantalum carbide particles 14 may be between 100 and 200 microns in size. Such size increases the efficiency of the squealer tip 10 by enhancing the durability during the first 2,000 hours of service use and thereafter when the capability of tip rub during warm startups exists within large IGT engines that are built on site and typically do not have a run-in procedure.

The compatibility of the tantalum carbide and the CoNiCrAlY have been tested. Diffusion couples were produced by mixing an TaC abrasive offered by American Elements, product number TA-C-02-GR with CoNiCrAlY powder offered by Praxair, part number Co-512-2 in a 50:50 ratio. The mixed powder was placed into 0.5 milliliter alumina crucibles for furnace exposure. The furnace exposure was at 1,010 degree Celsius in air for 100, 500, 2,000 and 4,000 hours. The cycle was 22 hours of heat and two hours of cooling to room temperature each day. After 2,000 hours, the crucible containing the TaC/CoNiCrAlY powder was removed from the furnace and epoxy was vacuum impregnated into the crucible to form a dense compact before sectioning and polishing. The crucible and contents were mounted,

polished and examined via a scanning electronic microscope, using energy dispersive spectroscopy to determine if any chemical reactions had occurred between the TaC and matrix elements. Figures 3-6 show that the TaC grains are intact with almost no degradation after 2,000 hours at 1,010 degrees Celsius in air. Figure 7 shows that there is little or no chemical reaction between the TaC and the CoNiCrAlY particles, indicating that the TaC material will be chemically stable in the CoNiCrAlY matrix used to plate the abrasive particles 14 to the turbine blade tips 24, such as via a TRIBOMET plate.

During use, the squealer tip 10 with the metal matrix support material 18 and the abrasive particle 14 possess excellent cutting ability during initial (cold) startup of a turbine engine, thereby enabling the turbine blade 20 to wear in with the abradable ceramic coating on the stationary ring segment 40. The metal matrix support material 18 and the abrasive particle 14 is configured to survive for at least 2,000 hours while exposed to the hot gas path temperatures at a row 1 blade location in an IGT engine.

The foregoing is provided for purposes of illustrating, explaining, and describing embodiments of this invention. Modifications and adaptations to these embodiments will be apparent to those skilled in the art and may be made without departing from the scope or spirit of this invention.

CLAIMS

I claim:

1. A turbine airfoil abradable coating system, comprising:
 - a generally elongated blade having a leading edge, a trailing edge, a tip at a first end, and a root coupled to the blade at an end generally opposite the first end for supporting the blade and for coupling the blade to a disc;
 - at least one stationary ring segment positioned radially outward from the tip of the generally elongated blade and secured in position such that an inner surface of the at least one stationary ring segment is positioned in close proximity to the generally elongated blade to limit combustion gases passing between the at least one stationary ring segment and the generally elongated blade;
 - a squealer tip attached to a radially outer surface of the tip and formed from at least one support material including at least one abrasive particle formed at least partially from tantalum carbide; and
 - wherein the squealer tip extends radially outward from the tip and covers at least a portion of the radially outer surface of the tip.
2. The turbine airfoil abradable coating system of claim 1, wherein the at least one support material is formed at least partially from CoNiCrAlY.
3. The turbine airfoil abradable coating system of claim 1, wherein the at least one support material is formed only from CoNiCrAlY.
4. The turbine airfoil abradable coating system of claim 1, wherein the at least one abrasive particle is formed only from tantalum carbide.
5. The turbine airfoil abradable coating system of claim 1, wherein the squealer tip covers all of the radially outer surface of the tip.
6. The turbine airfoil abradable coating system of claim 1, wherein the at least one abrasive particle comprises a plurality of abrasive particles.

7. The turbine airfoil abradable coating system of claim 1, wherein the tantalum carbide is between 100 and 200 microns in size.

8. The turbine airfoil abradable coating system of claim 1, wherein the inner surface of the at least one stationary ring segment is coated with a thermal barrier coating.

9. A turbine blade, comprising:
a generally elongated blade having a leading edge, a trailing edge, a tip at a first end, and a root coupled to the blade at an end generally opposite the first end for supporting the blade and for coupling the blade to a disc;
a squealer tip attached to a radially outer surface of the tip and formed from at least one support material including at least one abrasive particle formed at least partially from tantalum carbide; and
wherein the squealer tip extends radially outward from the tip and covers at least a portion of the radially outer surface of the tip.

10. The turbine blade of claim 9, wherein the at least one support material is formed at least partially from CoNiCrAlY.

11. The turbine blade of claim 9, wherein the at least one support material is formed only from CoNiCrAlY.

12. The turbine blade of claim 9, wherein the at least one abrasive particle is formed only from tantalum carbide.

13. The turbine blade of claim 9, wherein the squealer tip covers all of the radially outer surface of the tip.

14. The turbine blade of claim 9, wherein the at least one abrasive particle comprises a plurality of abrasive particles.

15. The turbine blade of claim 9, wherein the tantalum carbide is between 100 and 200 microns in size.

16. A turbine blade, comprising:
- a generally elongated blade having a leading edge, a trailing edge, a tip at a first end, and a root coupled to the blade at an end generally opposite the first end for supporting the blade and for coupling the blade to a disc;
 - a squealer tip attached to a radially outer surface of the tip and formed from at least one support material including at least one abrasive particle formed at least partially from tantalum carbide;
 - wherein the squealer tip extends radially outward from the tip and covers at least a portion of the radially outer surface of the tip;
 - wherein the at least one support material is formed at least partially from CoNiCrAlY; and
 - wherein the tantalum carbide is between 100 and 200 microns in size.
17. The turbine blade of claim 16, wherein the at least one support material is formed only from CoNiCrAlY.
18. The turbine blade of claim 16, wherein the at least one abrasive particle is formed only from tantalum carbide.
19. The turbine blade of claim 16, wherein the squealer tip covers all of the radially outer surface of the tip.
20. The turbine blade of claim 16, wherein the at least one abrasive particle comprises a plurality of abrasive particles.

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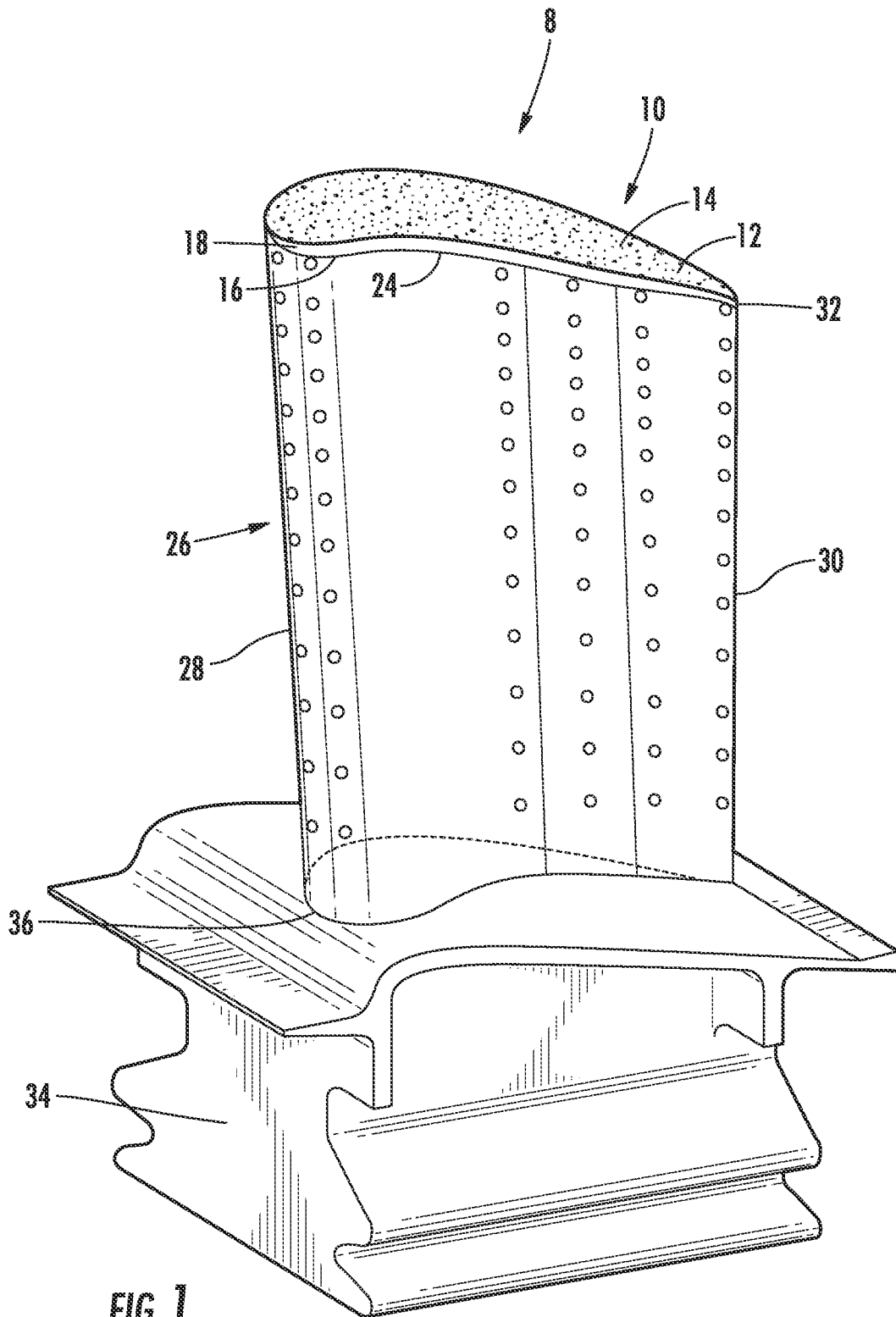


FIG. 1

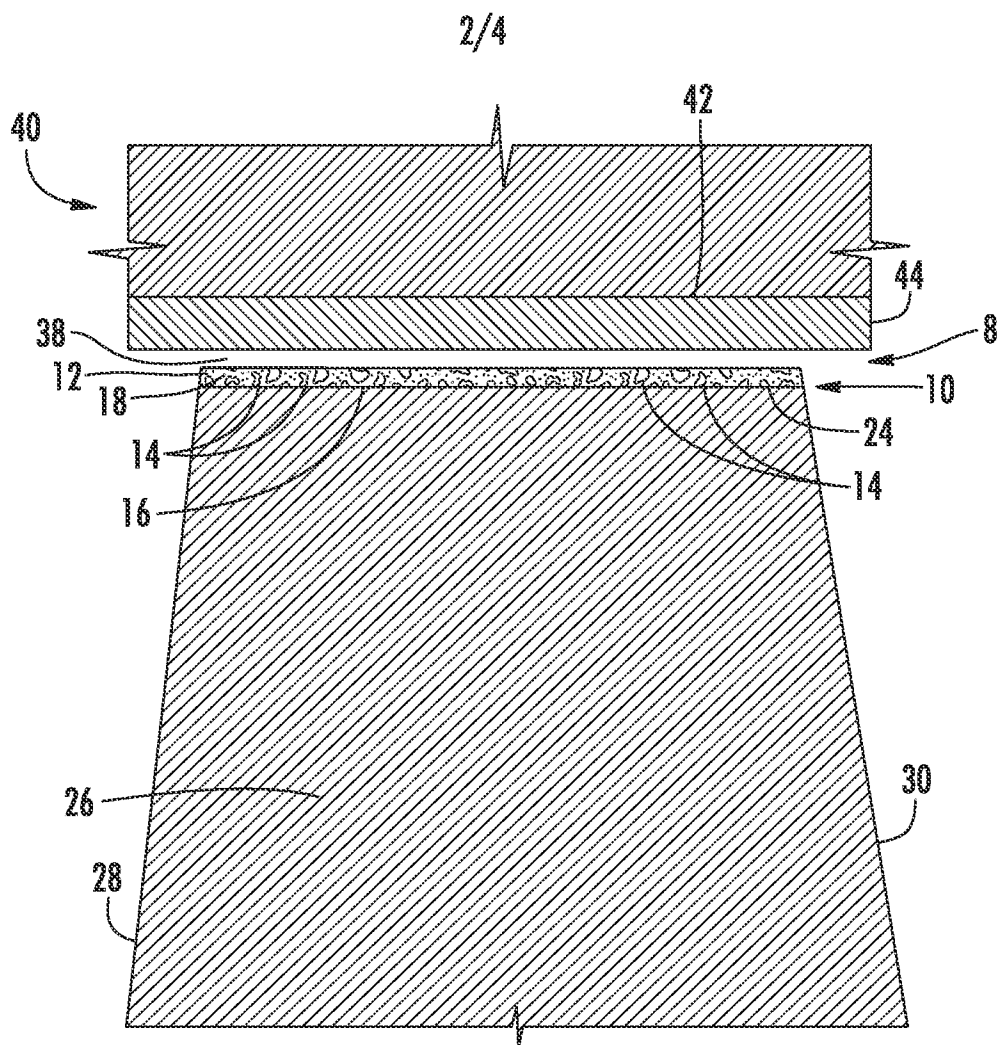


FIG. 2

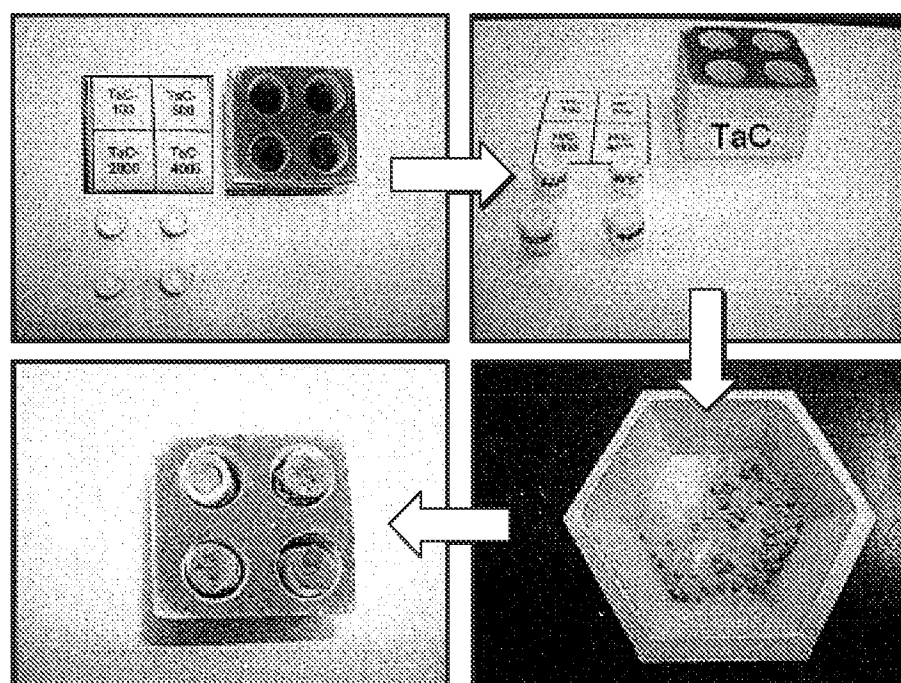


FIG. 3

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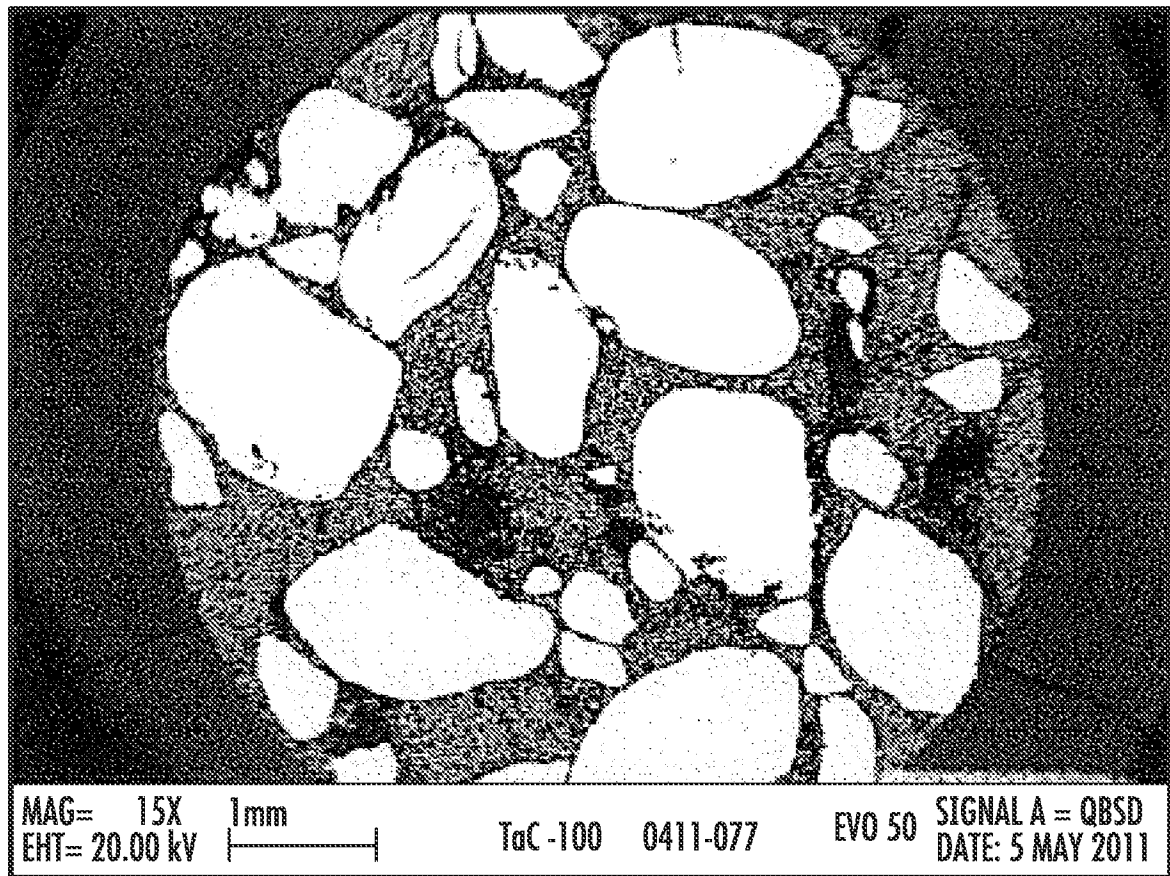


FIG. 4

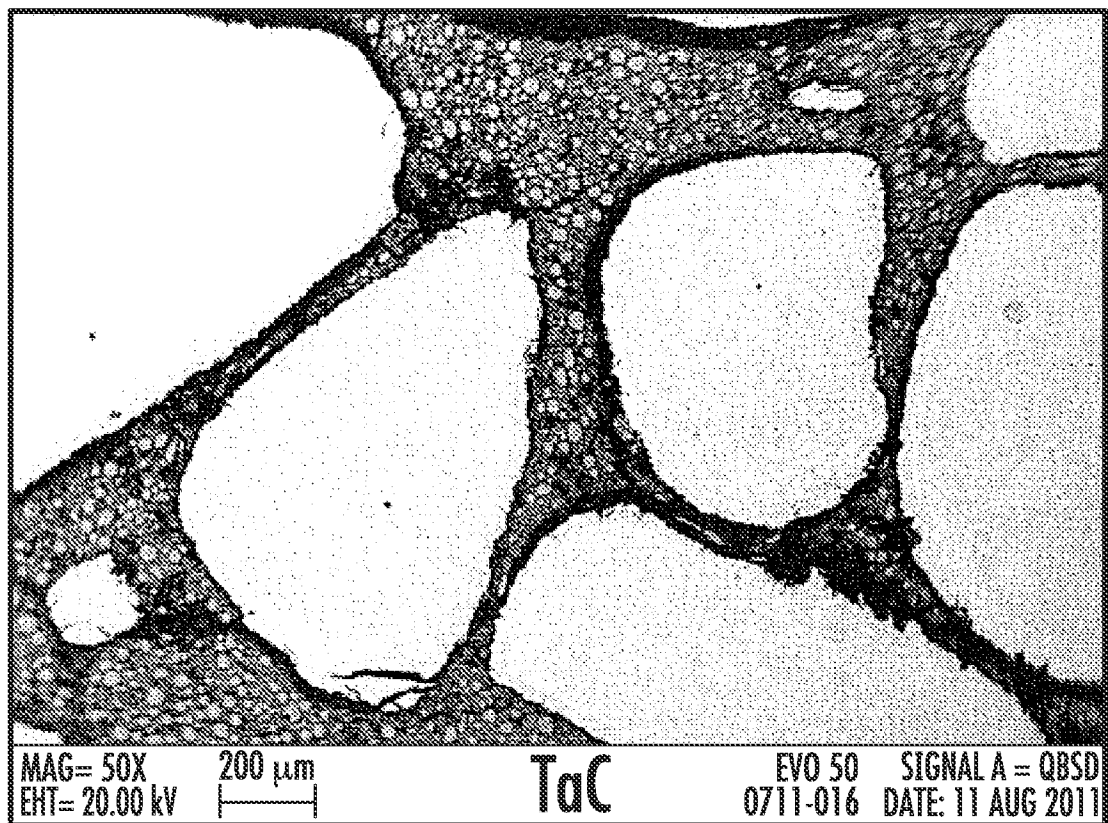


FIG. 5

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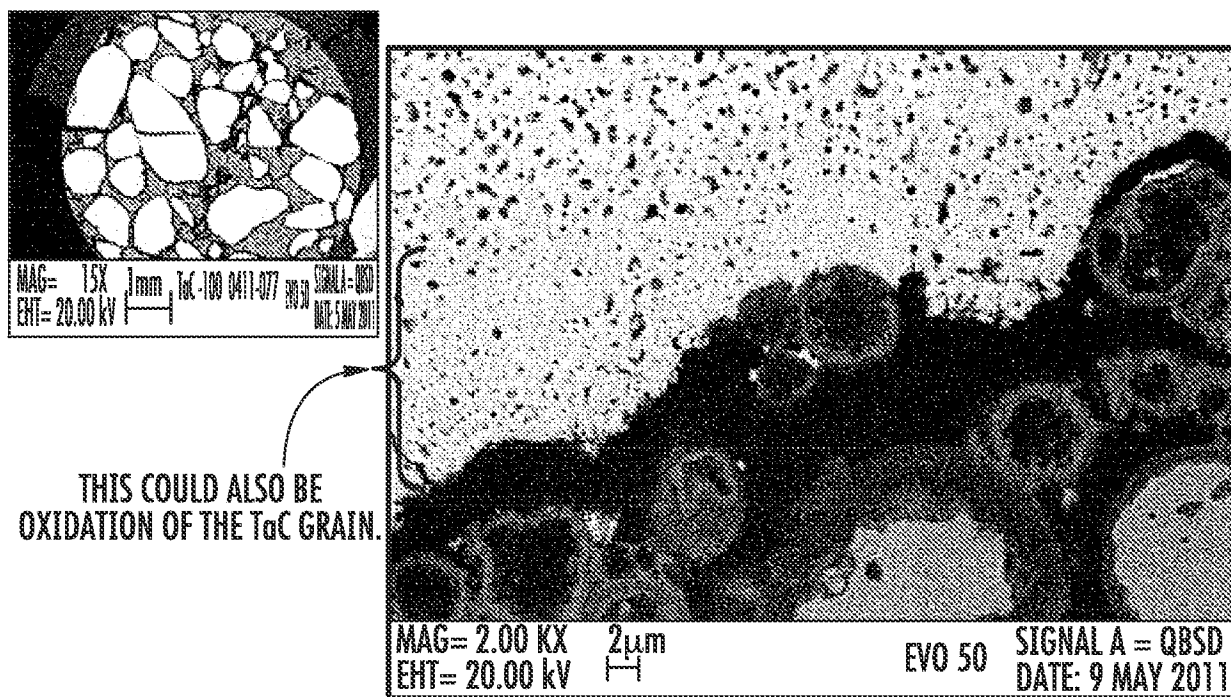


FIG. 6

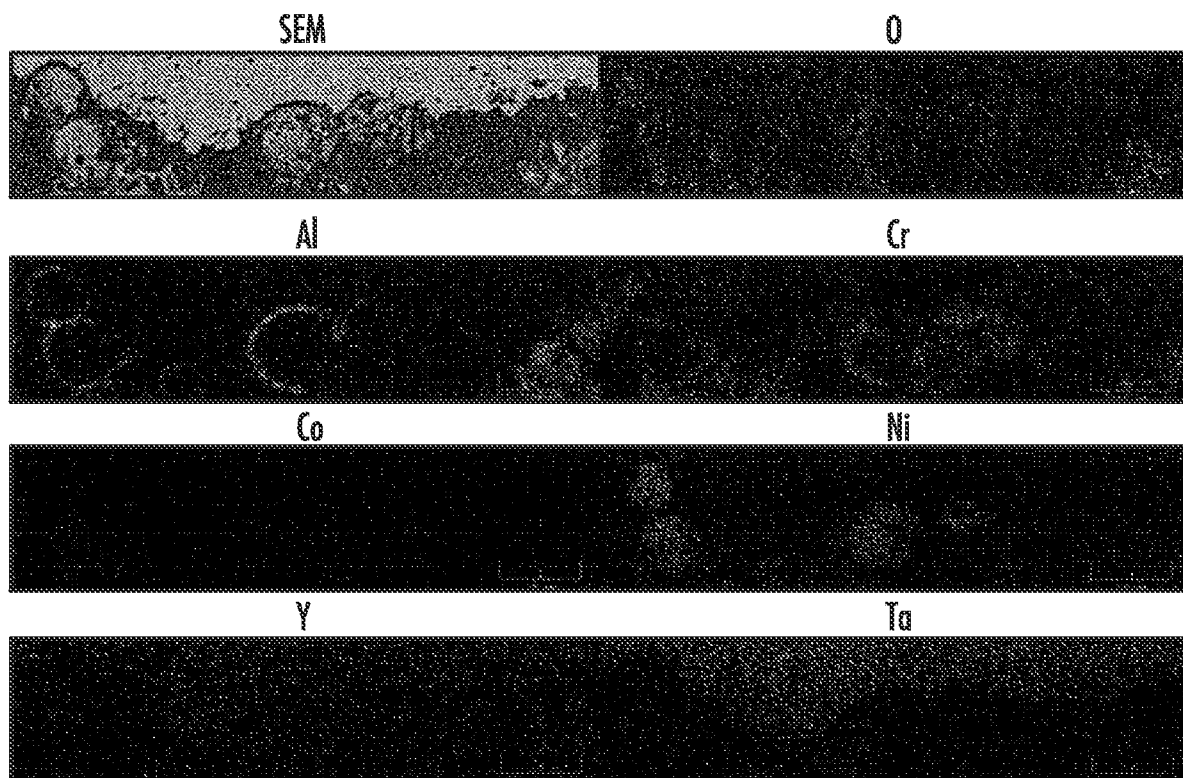


FIG. 7