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(54) **High temperature shape memory alloy actuators**

(57) A high temperature component having an actuator body 201 including an actuatable portion comprising a shape memory alloy containing one more of Ni, Al, Nb, Ti and Ta and a platinum-group metal. The shape mem-

ory alloy has an altered geometry at a predetermined temperature. The actuator body 201 is also capable of operation in and is resistant to high temperature oxidizing atmospheres. A method for forming an actuator and a method for high temperature control are also disclosed.

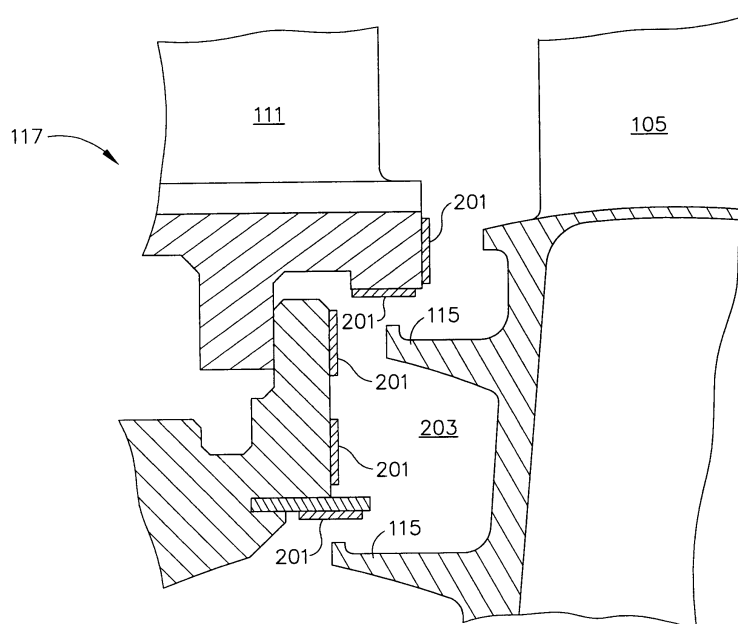


FIG. 2

Description

FIELD OF THE INVENTION

5 **[0001]** The present disclosure generally relates to components, such as gas turbine engine components, comprising structures with shape memory alloy for actuation at high temperatures.

BACKGROUND OF THE INVENTION

10 **[0002]** In a gas turbine engine, air is pressurized in a compressor, mixed with fuel in a combustor and is ignited to generate hot combustion gases. The hot combustion gases flow into a turbine section of the engine. The turbine section of the engine typically includes a plurality of stages that may include a combination of turbine blades and turbine vanes. The expanding combustion gases drive the turbine by exerting pressure on the blades that rotate a turbine shaft. The rotation of the turbine shaft is utilized to generate electricity or produce mechanical drive power. The vanes typically
15 include an airfoil configuration and guide the combustion gases to the turbine blades of the next stage of the turbine. These combustion gases expose the turbine blades and vanes to high temperatures and corrosive atmospheres.

[0003] Significant advances in high temperature capabilities have been achieved through the development of high-performance materials, including iron, nickel and cobalt-based superalloys, to handle the combination of operating stresses and temperatures while maintaining mechanical integrity and dimensional stability. Further improvements
20 in turbine efficiency and reliability have come from the use of environmental coatings capable of protecting superalloys from oxidation and hot corrosion. However, because no shape memory alloys have been found to withstand the high temperatures and oxidative atmospheres present during operation of a turbine engine, shape-changing actuators do not exist for these and similar high-temperature applications.

[0004] Shape memory alloys based on the Ni-Ti system have been commercially employed in a variety of low temperature applications. However, above temperatures of about 250°C the Ni-Ti systems experience rapid degradation in shape memory response due to phase changes and oxidation.

[0005] Therefore, a component comprising shape memory alloys for use in high temperature applications is desired, having the ability to operate and/or actuate in high temperatures and oxidative atmospheres, such as the operational conditions of a turbine engine.

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SUMMARY OF THE INVENTION

[0006] One embodiment of the disclosure includes a high temperature gas turbine engine component having an actuator body including an actuatable portion comprising a shape memory alloy containing Ni, Al, Nb, Ti and/or Ta and
35 a platinum-group metal (PGM). The actuator body has an altered geometry at a predetermined temperature. The actuator is also resistant to high temperature oxidation.

[0007] Another embodiment of the disclosure includes a method for forming a high temperature shape memory alloy for actuation. The method includes providing a shape memory alloy containing one or more elements selected from the group consisting of Ni, Al, Nb, Ti, Ta and combinations thereof and a platinum-group metal selected from the group
40 consisting of Pt, Pd, Rh, Ru, Ir and combinations thereof. The alloy is heated to a predetermined elevated temperature. The alloy is then deformed at the predetermined temperature to impart a shape memory for high temperature. Depending on the functional needs, the shape memory alloy may be thermo-mechanically treated iteratively to achieve better reversibility of the shape memory alloy. The alloy is then affixed to a structure/component to form a high temperature shape memory actuator.

[0008] Still another embodiment of the present disclosure includes a method for providing high temperature actuation control. The method includes providing a high temperature actuator including an actuator body having an actuatable portion comprising a shape memory alloy containing one or more elements selected from the group consisting of Ni, Al, Nb, Ti, Ta and combinations thereof and a platinum-group metal selected from the group consisting of Pt, Pd, Rh, Ru, Ir and combinations thereof. The actuator body has an altered geometry at a predetermined temperature. The actuator
50 is resistant to high temperature oxidation. The method includes exposing the actuator to a predetermined temperature to change the geometry of the actuatable portion. The predetermined temperature can be achieved via changes in environmental temperature, electrical resistance heating, or the like.

[0009] Other features and advantages of the present disclosure will be apparent from the following more detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings which illustrate, by way
55 of example, the principles of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIG. 1 shows a cross-sectional view depicting a portion of the turbine section of a gas turbine engine according to an embodiment of the present disclosure.

FIG. 2 shows an enlarged view of a portion of the turbine section of a gas turbine engine according to an embodiment of the present disclosure shown in FIG. 1.

FIG. 3 shows an actuator according to an embodiment of the present disclosure.

FIG. 4 shows an actuator according to another embodiment of the present disclosure.

FIG. 5 shows photographs of Example 1 and Comparative Example 2 shape memory alloy coatings subject to thermal cycling.

FIG. 6 shows a graph of weight gain versus thermal oxidizing cycles of Example 1 and Comparative Example 2 shape memory alloy coatings.

[0011] Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

DETAILED DESCRIPTION OF THE INVENTION

[0012] Disclosed herein are materials for use in high temperature actuators. "Actuators", "actuate", "actuatable" and grammatical variations thereof, as used herein, are meant to include devices or components and motions or function including the moving or controlling of a mechanical device or system in response to exposure to a condition, such as exposure to a predetermined temperature or range of temperatures. For example, a shape memory alloy may be incorporated into an actuator, wherein the shape memory alloy may be utilized to manipulate or move surfaces or portions of components in a controlled manner when exposed to a predetermined temperature. In addition, shape memory alloy containing actuators may irreversibly deploy or otherwise move during initial exposure to a temperature and remain substantially motionless thereafter. The actuators, according to certain embodiments, include components or portions of components including one or more shape memory alloys capable of use at high temperatures and oxidizing conditions, such as the conditions present in a gas turbine engine.

[0013] Turbine engine components are generally formed of high temperature alloys, such as superalloys, and are known for high temperature performance in terms of tensile strength, creep resistance and oxidation resistance. Examples include nickel-based alloys, cobalt-based alloys, iron-based alloys, and titanium-based alloys. In one embodiment, shape memory alloy material may be fabricated into a turbine component to provide the desired component actuator functionality. The fabrication may comprise mechanical attachment or metallurgical bonding of the shape memory alloy into the actuator body and/or turbine component.

[0014] Shape memory alloys according to embodiments of the present disclosure are characterized by a temperature-dependent phase change. These phases include a martensite phase and an austenite phase. In the following discussion, the martensite phase generally refers to a lower temperature phase whereas the austenite phase generally refers to a higher temperature phase. The martensite phase is generally more deformable, while the austenite phase is generally less deformable. When the shape memory alloy is in the martensite phase and is heated to above a certain temperature, the shape memory alloy begins to change into the austenite phase. The temperature at which this phenomenon starts is referred to as the austenite start temperature (A_s). The temperature at which this phenomenon is complete is called the austenite finish temperature (A_f). When the shape memory alloy is in the austenite phase and is cooled, it begins to transform into the martensite phase. The temperature at which this phenomenon starts is referred to as the martensite start temperature (M_s). The temperature at which the transformation to martensite phase is completed is called the martensite finish temperature (M_f).

[0015] Shape memory alloys can exhibit a one-way shape memory effect, an intrinsic two-way shape memory effect, or an extrinsic two-way shape memory effect, depending on the particular alloy composition, processing history, and - in the case of extrinsic - the actuator construction. Annealed shape memory alloys typically only exhibit the one-way shape memory effect. Heating above the austenite finish temperature subsequent to low-temperature deformation (below M_f) of the shape memory material will recover the original, high-temperature austenite (above A_f) shape. Hence, one-way shape memory effects are observed upon heating.

[0016] Intrinsic and extrinsic two-way shape memory materials are characterized by a shape transition both upon heating from the martensite phase to the austenite phase, as well as upon cooling from the austenite phase back to the martensite phase. Intrinsic two-way shape memory behavior must be induced in the shape memory material through processing. Such procedures may include deformation of the material while in the martensite phase, followed by repeated heating and cooling through the transformation temperature under constraint. Once the material has been trained to exhibit the two-way shape memory effect, the shape change between the low- and high-temperature states is generally reversible and persists through a high number of thermal cycles. In contrast, structures that exhibit the extrinsic two-way shape memory effect combine a shape memory alloy that exhibits a one-way effect with another element that provides a restoring force to recover the low-temperature shape. Examples of extrinsic two-way shape memory effect include affixing shape memory alloy to a dissimilar material, modifying the surface of the shape memory alloy via laser annealing or shot peening, and the like. In such cases, a portion of the actuator body is used to induce the one-way shape memory actuation on heating, while another portion of the actuator body is used to provide the shape-restoring force on cooling through the transformation temperature.

[0017] One embodiment of the disclosure includes a method for forming a shape memory actuator. Shape memory alloys according to the present disclosure may be utilized in actuator mechanisms to provide actuation in response to a predetermined temperature. The shape memory alloys are imparted with a desired geometry and/or configuration for actuation during operation of the actuator. The method includes providing a shape memory alloy containing Ni, Al, Nb, Ti, Ta or combinations thereof and a platinum-group metal. The alloy may be made by known methods for making shape memory alloys. For example, the alloys may be made using vacuum melting, such as vacuum induction melting, or vacuum arc melting, to form an ingot of the shape memory alloy composition, optionally followed by deformation processing, such as rolling, extrusion, forging, drawing, and/or swaging. Alternatively, the shape memory alloy can be manufactured by deposition (e.g., thermal spray, physical vapor deposition, vacuum arc deposition). In addition, the alloy may also be made via powder consolidation. Once made, the alloy is heated to a temperature sufficient to impart the desired high temperature shape, for example to a temperature above the austenite finish temperature. The alloy is deformed at the elevated temperature to impart a geometry desired for high temperature operation. Upon cooling to the martensite phase, the shape memory alloy retains the geometry of the austenite phase. Any subsequent deformation of this alloy below A_s will be recovered upon reheating to above A_f . The reversibility of the shape memory effect can be improved via thermo-mechanical training. This training may include slightly deforming the alloy in the low-temperature martensite state. An example of slightly deforming may include imparting a plastic strain of about 2%. The alloy is then annealed at a temperature near or above A_f . The deformation and annealing process is repeated for a number of cycles, such as one to ten cycles, or until the desired reversibility of the shape memory effect is attained.

[0018] Suitable shape memory alloy materials for providing actuation include, but are not intended to be limited to, nickel-aluminum based alloys, particularly nickel-aluminum alloys having platinum-group metal (i.e., PGM) additions (rhodium, ruthenium, palladium, iridium, and platinum). The alloy composition is selected so as to provide the desired shape memory effect for the application such as, but not limited to, transformation temperature and strain, the strain hysteresis, actuation force, yield strength (of martensite and austenite phases), damping ability, resistance to oxidation and hot corrosion, ability to actuate through repeated cycles, capability to exhibit two-way shape memory effect, and a number of other engineering design criteria. For actuation in gas turbine engine applications, the shape memory alloy possesses excellent resistance to oxidation (up to about 1150°C for the hottest applications) and - in the case where actuation near the operating temperature is required - a high transformation temperature. Suitable shape memory alloy compositions may include, but are not limited to alloys having the formula $(A_{1-x} \text{PGM}_x)_{0.5+y} B_{0.5-y}$, wherein A is one or more of Ni, Co and Fe; PGM comprises one or more platinum-group elements, including Pt, Pd, Rh, Ru, and Ir, and B includes one or more of Al, Cr, Hf, Zr, La, Y, Ce, Ti, Mo, W, Nb, Re, Ta, and V; x ranges from greater than 0 to about 1 or from about 0.1 to about 0.6 atomic fraction and y ranges from about -0.1 to 0.23, preferably about 0 to about 0.23 or from about 0.01 to about 0.2 atomic fraction. In addition, the alloy may further include up to about 1 at% carbon and/or boron. One embodiment includes the formula wherein A is Ni, PGM is one or more of Pt and Pd; B is one or more of Al, Cr, Hf and Zr. Another embodiment includes the formula wherein A is Ni; PGM is Pd; B is Ti and Al; x is about 0.4 and y is from about -0.1 to about 0.1. Still another embodiment includes B comprising Ti and Al with a Ti to Al ratio of from about 0.1 to about 10. Still another embodiment includes B comprising up to 10 at% Cr and up to 2 at% of one or more of Hf, Zr, and Y.

[0019] Still another embodiment includes alloy systems having the formula $\text{Ru}_{0.5+y}(\text{Nb}_{1-x} \text{Ta}_x)_{0.5-y}$. These alloy systems further include phases, such as the martensite phase and the austenite phase, suitable for shape memory properties. One embodiment of the ruthenium containing system includes an alloy wherein y is about -0.06 to about 0.23 atomic fraction and x is from about 0 to about 1.

[0020] Although the shape memory alloy may be formed into an actuator body or a portion of an actuator body, the shape memory alloy may also be directly affixed to the high temperature component. The specific method of affixing will depend, in part, on the desired geometry and the compositions of the shape memory alloy and the actuatable component. The various methods of affixing the shape memory alloy to the base component structure may generally be categorized

as mechanical joining, deposition or metallurgical bonding. Suitable methods of mechanical joining include, but are not limited to, riveting, bolting, bracing or wire tying. Suitable methods of deposition include, but are not limited to, cladding or coating via arc spray, electro-spark deposition, laser cladding, vacuum plasma spray, inert gas shrouded thermal spray, plasma transfer arc, physical vapor deposition, or vacuum arc deposition. Methods of metallurgically bonding

include, but are not limited to, brazing, co-extrusion, explosion bonding, hot-isostatic-pressing (HIP), forge-bonding, diffusion bonding, inertia welding, translational friction welding, fusion welding, friction-stir welding, and the like.

[0021] Although reference has been made to affixing the shape memory alloy onto the turbine component, it is also noted that a turbine component comprising the shape memory alloy of the present disclosure may be separate and/or detached from fixed or rotating turbine components. For example, suitable components may include a separated seal component having a structure that is free-floating within a cavity that expands to a desired geometry upon heating.

[0022] FIG. 1 is a view depicting a centerline cross-section of a gas turbine engine utilizing a shape memory actuator according to an embodiment of the present disclosure. The turbine section 100 is a three-stage turbine, although any number of stages may be employed, depending on the turbine design. Turbine disks 101 are mounted on a shaft (not shown) extending through a bore in disks 101 along the centerline 103 of the engine, as shown. Turbine blades 102 are affixed to the disks 101. Specifically, a first stage blade 105 is attached to first stage disk 106, while second stage blade 107 is attached to second stage disk 108 and third stage blade 109 is attached to third stage disk 110. Vanes 111 extend from a casing 113. Hot combustion gases flow over vanes 111 and blades 102 in the hot gas flow path. The first stage blade 105, the second stage blade 107, the third stage blade 109 and the vanes 111 extend into the hot gas flow path. The vanes 111 serve to direct the hot gas flow while blades 102 mounted on disks 101 rotate as the hot gases impinge on them, extracting energy to operate the engine.

[0023] Wheelspace seals 115 serve to seal the disks 101 and the lower portions of the turbine blades 102 from the hot combustion gases, and to maintain the hot combustion gases in the hot gas flow path. The seals 115 form a boundary to prevent leakage of the hot gases. Whereas seals 115 are subject to leakage during rotation, particularly at operational temperatures, it is desirable to minimize the amount of leakage that occurs. The actuators, including actuator bodies comprising shape memory alloy material according to an embodiment of the disclosure, may be utilized to deploy at elevated temperatures, such as the operational temperatures of the gas turbine engine, to reduce the amount of leakage that occurs through the seals 115.

[0024] FIG. 2 shows an enlarged view of area 117 from FIG. 1, showing a portion of the gas turbine forward of first stage blade 105 and first stage disk 106. A plurality of shape actuators 201 fabricated of shape memory alloy are affixed along the wheelspace seal path 203, wherein combustion gas leakage may take place. The shape actuators 201 may be affixed to the surfaces along wheelspace seal path 203 in any suitable manner, including joining to the metallic surface or otherwise incorporating or affixing the actuator 201 to the surface. The shape actuator 201 is configured to permit motion or actuation at or below the temperature of gas turbine engine operation. In particular, the actuation may occur when the temperature within the wheelspace seal path 203 begins to exceed about the austenite start temperature. At the austenite start temperature, the geometry of the shape memory alloy within shape actuator 201 begins to change. While the process may be irreversible, the shape actuator 201 may include two-way shape memory characteristics, wherein cooling of the shape actuator 201 (e.g., a reduction in temperature within the wheelspace seal path 203) below about the martensite start temperature results in phase change to the martensite phase and a return to its corresponding low-temperature geometry. The altered geometry of the shape memory alloy permits motion of the shape actuator 201. The motion may be provided by affixing the actuator 201 to a rigid surface at a single point or a plurality of points, wherein the shape actuator 201 may include a straight, bent or curved geometry when in the austenite phase. The bending or other motion in this embodiment provides a reduced cross-section through which leakage may occur within the wheelspace seal path 203, thereby improving the performance of the seal 115, particularly at operational temperatures. Although FIG. 2 shows a plurality of actuators 201, any number or a single actuator 201 may be utilized, wherein the positioning of the actuators 201 may include any position that provides the desired functionality during assembly and/or deployment. Actuators 201 may be individually disposed or segmented to accommodate the configuration of individual parts, such as around the circumferential direction of vanes 111. Alternately, one or more actuators 201 may be affixed to the surfaces of a turbine component during or after the turbine assembly.

[0025] FIG. 3 shows an example of an actuator 201 affixed to a surface in a manner that permits pivotal movement within seal path 203 upon exposure to temperatures above about the austenite start temperature. The actuator 201 in this example is affixed to a surface of a turbine component at location and at a distance from the pivot axis so as to allow rotation of the actuator about the pivot axis during actuation.

[0026] FIG. 4 shows an example of an actuator 201 affixed along a location on the surface a turbine component in a manner that permits bending or arcing of at least a portion of the actuator 201 into the wheelspace seal path 203 upon exposure to temperatures above about the austenite start temperature.

[0027] While FIGs. 1-4 have been described with respect to turbine seals, the present disclosure is not limited to use in turbine seals. The present disclosure may include shape actuators 201 for use in any high temperature and/or oxidizing atmosphere. While not so limited, the shape actuators 201 include the shape memory alloy according to the present

disclosure that may be used in, adjacent to, or in cooperation with turbine nozzles, blades, shrouds, shroud hangers, combustors, exhaust nozzles, disks, and other seals exposed to high temperatures. Specifically, the shape actuators 201 may include exhaust nozzles or associated structures, wherein the exhaust nozzle geometry may be altered or configured at operational temperatures by use of the shape memory alloys therein to provide control or management of the flow of exhaust gases. In another embodiment, shape actuators 201, according to embodiments of the present disclosure, may include exhaust chevrons to provide take-off noise reduction and cruise aerodynamic efficiency. Further still, shape actuators 201, according to embodiments of the present disclosure, include cooling air diverters for controlling, regulating and/or optimizing cooling air flow distribution within a gas turbine engine.

EXAMPLE

[0028] Single crystal superalloy Rene N5 test coupons were coated with a test material. The test coupons were 25 millimeters in diameter and 3.25 mm in thickness. An Example 1 included a 50 micrometer coating of (Ni,Pt)Al having an approximate composition according to the formula Ni-40Al-6Co-5Pt-4Cr (at %). A Comparative Example 2 included a 275 micrometer NiTi coating having a composition according to the formula Ni-47Ti (at %). The Comparative Example 2 is representative of the broadly used NiTi-family of shape memory alloys. The coupons were subjected to repeated thermal cycles in air, wherein they were heated to a temperature of 1150°C for a duration of 1 hour, followed by cooling to room temperature. FIG. 5 shows Example 1 and Comparative Example 2, prior to thermal cycling, after 1 cycle and after 100 cycles. It is noted that Comparative Example 2 failed due to severe oxidation after a single cycle, while Example 1 remained intact even after 100 cycles at 1150°C. FIG. 6 graphically illustrates the relative mass gain for Example 1 and Comparative Example 2. As is seen from this example, a high-temperature resistant composition of shape memory alloy can withstand the harsh oxidizing environment representative of turbine operation, while the NiTi-based shape memory alloy known in the art for low-temperature operation is too severely oxidized to be useful at high temperatures.

[0029] While the invention has been described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

[0030] For completeness, various aspects of the invention are now set out in the following numbered clauses.

1. A high temperature gas turbine engine component comprising:

an actuator body, the actuator body having an actuatable portion comprising a shape memory alloy containing one more elements selected from the group consisting of Ni, Al, Nb, Ti, Ta and combinations thereof and a platinum-group metal selected from the group consisting of Pt, Pd, Rh, Ru, Ir and combinations thereof, the shape memory alloy having an altered geometry above a predetermined temperature; and

wherein the actuator is resistant to high temperature oxidizing atmospheres.

2. The component of clause 1, wherein the altered geometry of the actuator body modifies a gas flow path.

3. The turbine engine component of clause 1, wherein the predetermined temperature is reached or exceeded by the turbine engine component during operation, the actuatable portion being substantially in a martensite phase below the predetermined temperature and substantially in an austenite phase above the predetermined temperature.

4. The turbine engine component of clause 1, wherein the actuator body is affixed to or is adjacent to a component selected from the group consisting of a nozzle, an exhaust structure, a shroud, a shroud hanger, a blade, a disk, a seal, a combustor and combinations thereof.

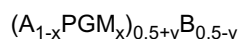
5. The turbine engine component of clause 1, wherein the actuator body is formed into a component selected from the group consisting of a nozzle, an exhaust structure, a shroud, a shroud hanger, a blade, a disk, a seal, a combustor and combinations thereof.

6. The turbine engine component of clause 1, wherein the actuator body further comprises a superalloy.

7. The turbine engine component of clause 1, wherein the shape memory alloy is resistant to oxidation at temperature

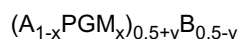
up to about 1150°C.

8. The turbine engine component of clause 1, wherein the shape memory alloy comprises an alloy of the following formula:



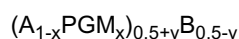
wherein A is an element selected from the group consisting of Ni, Co, Fe and combination thereof; B is an element selected from the group consisting of Al, Cr, Hf, Zr, La, Y, Ce, Ti, Mo, W, Nb, Re, Ta and V, and combinations thereof; PGM is a platinum-group element selected from the group consisting of Pt, Pd, Ru, Rh, Ir and combinations thereof, x is from greater than 0 to about 1 and y is from about 0 to about 0.23.

9. The turbine engine component of clause 8, wherein the shape memory alloy comprises an alloy of the following formula:



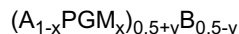
wherein x is from about 0.05 to about 0.6, and y is from about 0.01 to about 0.2.

10. The turbine engine component of clause 1, wherein the shape memory alloy comprises an alloy of the following formula:



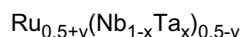
wherein A is substantially Ni and Co, PGM is one or both of Pt and Pd, B is substantially Al and Ti, and the ratio of Ti to Al is from about 0.1 to about 10.

11. The turbine engine component of clause 8, wherein the shape memory alloy comprises an alloy of the following formula:



wherein B further comprises up to 10 at% Cr and up to 2 at% of one or both of Hf, Zr, and Y.

12. The turbine engine component of clause 1, wherein the shape memory alloy comprises an alloy of the following formula:



wherein x is from about 0 to about 1, and y is from about -0.06 to about 0.23.

13. A method for forming a high temperature actuator body comprising:

providing a shape memory alloy containing one more elements selected from the group consisting of Ni, Al, Nb, Ti, Ta and combinations thereof and a platinum-group metal selected from the group consisting of Pt, Pd, Rh, Ru, Ir and combinations thereof;

heating the alloy to a predetermined elevated temperature;

deforming the alloy to a geometry at the predetermined high temperature to impart the high-temperature shape; and

cooling the alloy to form a high temperature shape memory actuator portion.

14. The method of clause 13, wherein the body is further configured to modify a gas flow path at an elevated temperature.

15. The method of clause 13, wherein the process further comprises affixing the actuator portion to a gas turbine

engine component

16. The method of clause 13, wherein affixing comprises a process selected from the group consisting of mechanical joining, deposition, metallurgical bonding and combinations thereof.

17. The method of clause 16, wherein the affixing is mechanical bonding selected from the group consisting of riveting, bolting, bracing, wire tying and combinations thereof.

18. The method of clause 13, wherein the affixing is deposition selected from the group consisting of arc spray, electro-spark deposition, laser cladding, vacuum plasma spray, inert gas shrouded thermal spray, plasma transfer arc, physical vapor deposition, vacuum arc deposition and combinations thereof.

19. The method of clause 13, wherein the affixing is metallurgically bonding selected from the group consisting of brazing, co-extrusion, explosion bonding, hot-isostatic-pressing (HIP), roll-bonding, forge-bonding, diffusion bonding, translational friction welding, fusion welding, friction-stir welding, inertia welding and combinations thereof.

20. A method for providing high temperature actuation comprising:

providing a high temperature actuator, the actuator comprising:

an actuator body, the actuator body having an actuatable portion comprising a shape memory alloy containing one more elements selected from the group consisting of Ni, Al, Nb, Ti, Ta and combinations thereof and a platinum-group metal selected from the group consisting of Pt, Pd, Rh, Ru, Ir and combinations thereof, the shape memory alloy having an altered geometry above a predetermined temperature; and

exposing the actuator to a predetermined temperature to provide the actuatable portion with a desired geometry.

21. A method for providing high temperature actuation comprising:

providing a high temperature actuator, the actuator comprising: an actuator body, the actuator body having an actuatable portion comprising a shape memory alloy containing one more elements selected from the group consisting of Ni, Al, Nb, Ti, Ta and combinations thereof and a platinum-group metal selected from the group consisting of Pt, Pd, Rh, Ru, Ir and combinations thereof, the shape memory alloy having an altered geometry above a predetermined temperature; and

exposing the actuator to a predetermined temperature to provide the actuatable portion with a desired geometry.

22. The method of clause 20, wherein the predetermined temperature is a temperature above which the actuatable portion exhibits a substantially austenite phase, the predetermined temperature being a temperature above which the turbine engine component is disposed or operates in the deployed state.

23. The method of clause 20, wherein the altered geometry modifies a gas flow path.

24. The method of clause 20, wherein the actuator body is affixed to or is adjacent to a component selected from the group consisting of a turbine nozzle, a turbine exhaust structure, a turbine shroud, a turbine shroud hanger, a turbine blade, a turbine disk, a hot gas path seal, a combustor and combinations thereof.

25. The method of clause 20, wherein the actuator body is fabricated into a component selected from the group consisting of a turbine nozzle, a turbine exhaust structure, a turbine shroud, a turbine shroud hanger, a turbine blade, a turbine disk, a hot gas path seal, a combustor and combinations thereof.

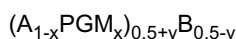
Claims

1. A high temperature gas turbine engine component comprising:

an actuator body, the actuator body having an actuatable portion comprising a shape memory alloy containing one more elements selected from the group consisting of Ni, Al, Nb, Ti, Ta and combinations thereof and a

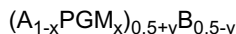
platinum-group metal selected from the group consisting of Pt, Pd, Rh, Ru, Ir and combinations thereof, the shape memory alloy having an altered geometry above a predetermined temperature; and wherein the actuator is resistant to high temperature oxidizing atmospheres.

2. The component of claim 1, wherein the altered geometry of the actuator body modifies a gas flow path.
3. The turbine engine component of claim 1 or claim 2, wherein the predetermined temperature is reached or exceeded by the turbine engine component during operation, the actuatable portion being substantially in a martensite phase below the predetermined temperature and substantially in an austenite phase above the predetermined temperature.
4. The turbine engine component of any preceding claim, wherein the actuator body is affixed to or is adjacent to a component selected from the group consisting of a nozzle, an exhaust structure, a shroud, a shroud hanger, a blade, a disk, a seal, a combustor and combinations thereof.
5. The turbine engine component of any preceding claim, wherein the actuator body is formed into a component selected from the group consisting of a nozzle, an exhaust structure, a shroud, a shroud hanger, a blade, a disk, a seal, a combustor and combinations thereof.
6. The turbine engine component of any preceding claim, wherein the shape memory alloy comprises an alloy of the following formula:



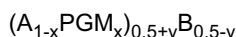
wherein A is an element selected from the group consisting of Ni, Co, Fe and combination thereof; B is an element selected from the group consisting of Al, Cr, Hf, Zr, La, Y, Ce, Ti, Mo, W, Nb, Re, Ta and V, and combinations thereof; PGM is a platinum-group element selected from the group consisting of Pt, Pd, Ru, Rh, Ir and combinations thereof, x is from greater than 0 to about 1 and y is from about -0.1 to about 0.23.

7. The turbine engine component of claim 6, wherein the shape memory alloy comprises an alloy of the following formula:



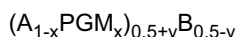
wherein x is from about 0.05 to about 0.6, and y is from about 0.01 to about 0.2.

8. The turbine engine component of any preceding claim 1, wherein the shape memory alloy comprises an alloy of the following formula:



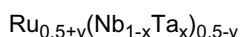
wherein A is substantially Ni and Co, PGM is one or both of Pt and Pd, B is substantially Al and Ti, and the ratio of Ti to Al is from about 0.1 to about 10.

9. The turbine engine component of claim 6, wherein the shape memory alloy comprises an alloy of the following formula:



wherein B further comprises up to 10 at% Cr and up to 2 at% of one or more of Hf, Zr, and Y.

10. The turbine engine component of any preceding claim, wherein the shape memory alloy comprises an alloy of the following formula:



wherein x is from about 0 to about 1, and y is from about -0.06 to about 0.23.

11. A method for forming a high temperature actuator body comprising:

providing a shape memory alloy containing one more elements selected from the group consisting of Ni, Al,

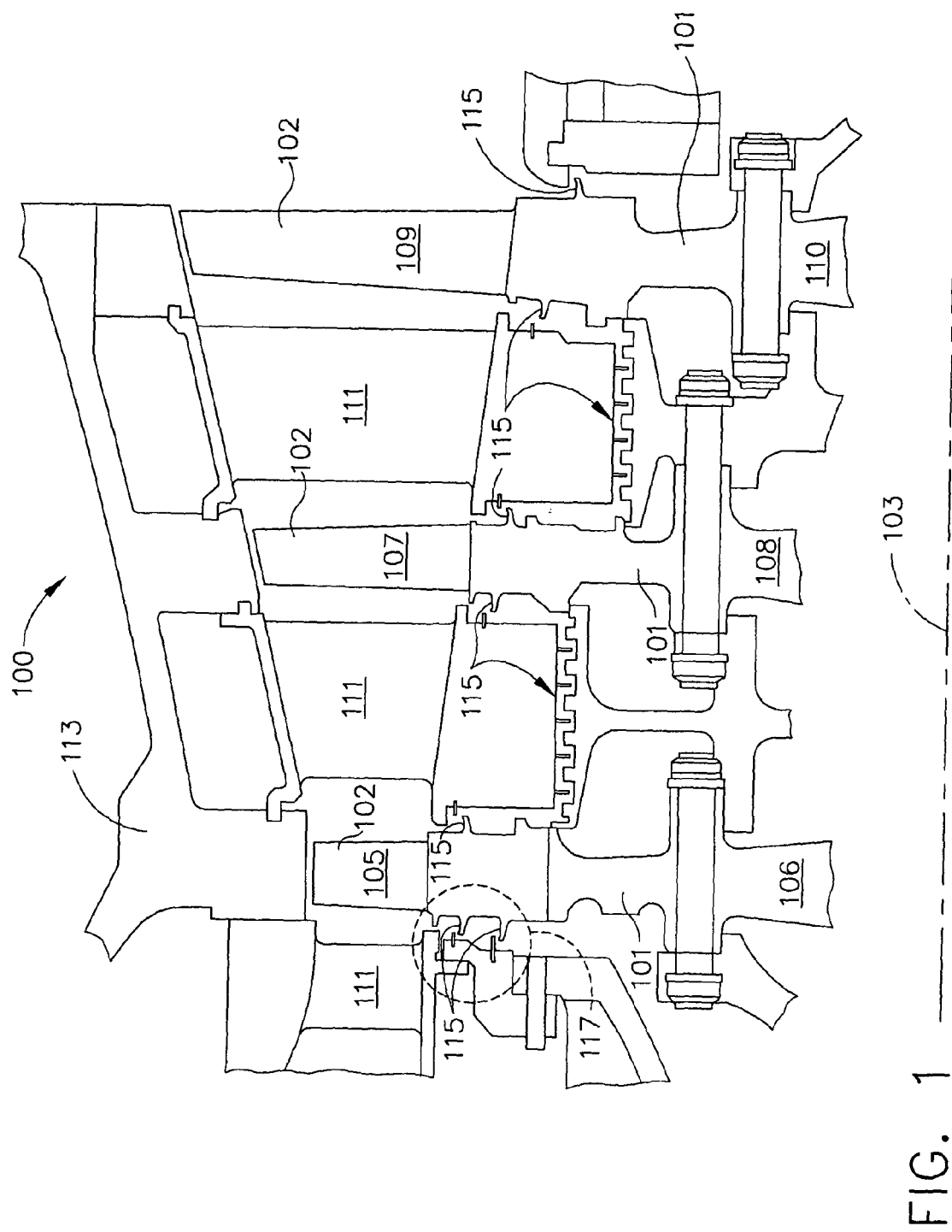
Nb, Ti, Ta and combinations thereof and a platinum-group metal selected from the group consisting of Pt, Pd, Rh, Ru, Ir and combinations thereof;
heating the alloy to a predetermined elevated temperature;
deforming the alloy to a geometry at the predetermined high temperature to impart the high-temperature shape;
and
cooling the alloy to form a high temperature shape memory actuator portion.

12. The method of claim 11, wherein the body is further configured to modify a gas flow path at an elevated temperature.

13. The method of claim 11 or claim 12, wherein the process further comprises affixing the actuator portion to a gas turbine engine component

14. The method of claim 13, wherein affixing comprises a process selected from the group consisting of mechanical joining, deposition, metallurgical bonding and combinations thereof.

15. The method of claim 14, wherein the affixing is mechanical bonding selected from the group consisting of riveting, bolting, bracing, wire tying and combinations thereof.



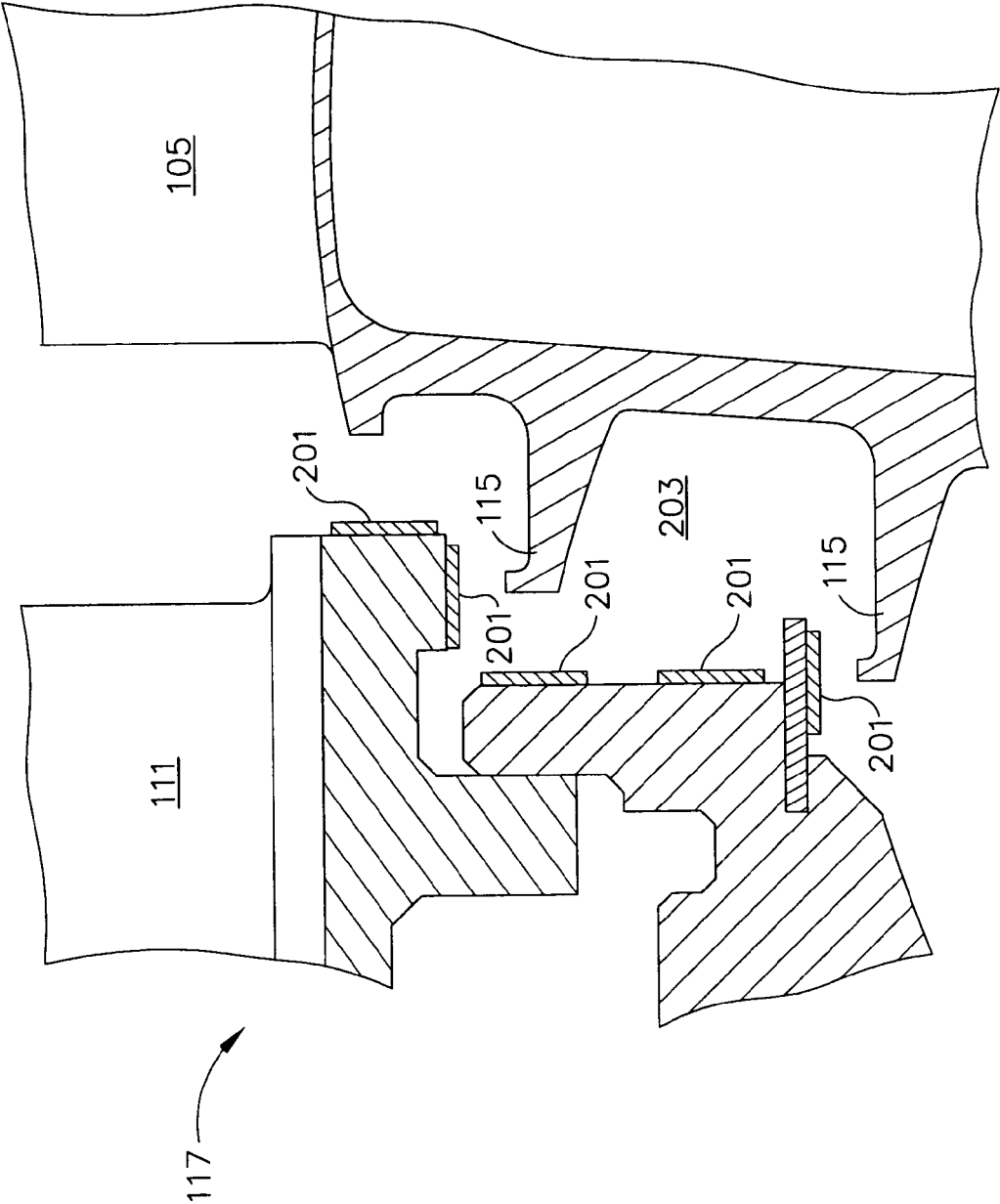


FIG. 2

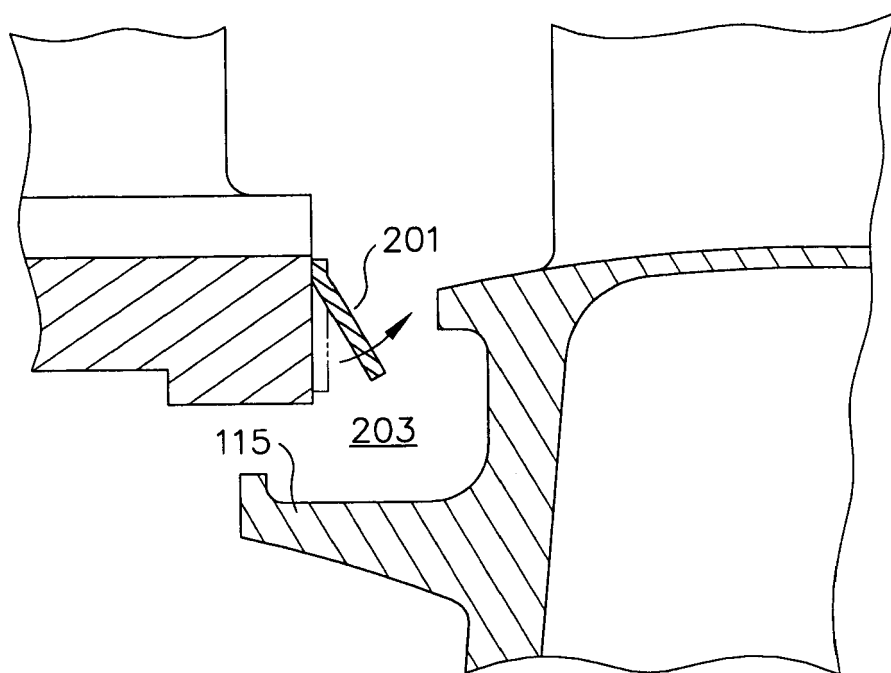


FIG. 3

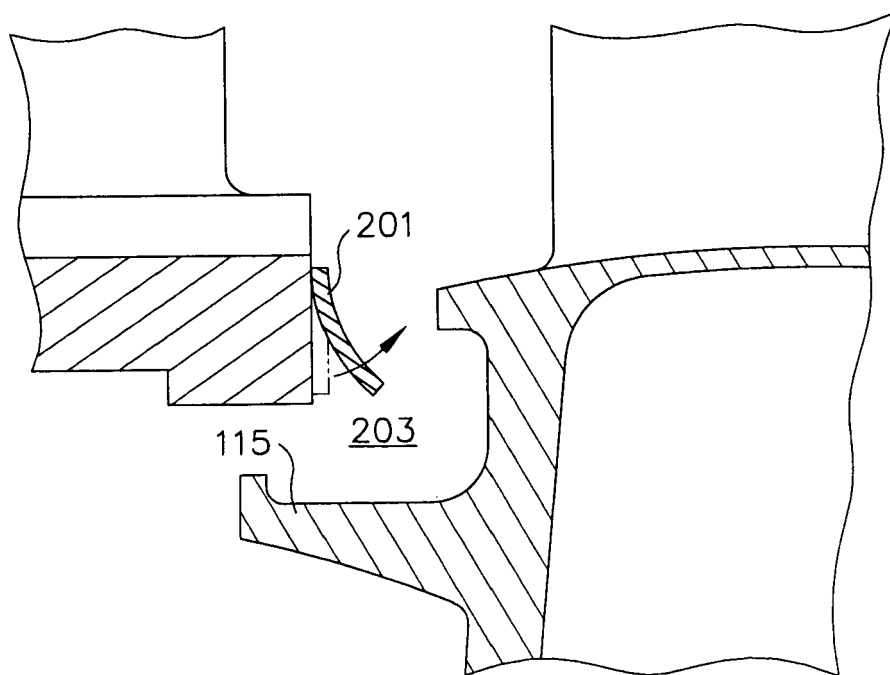


FIG. 4

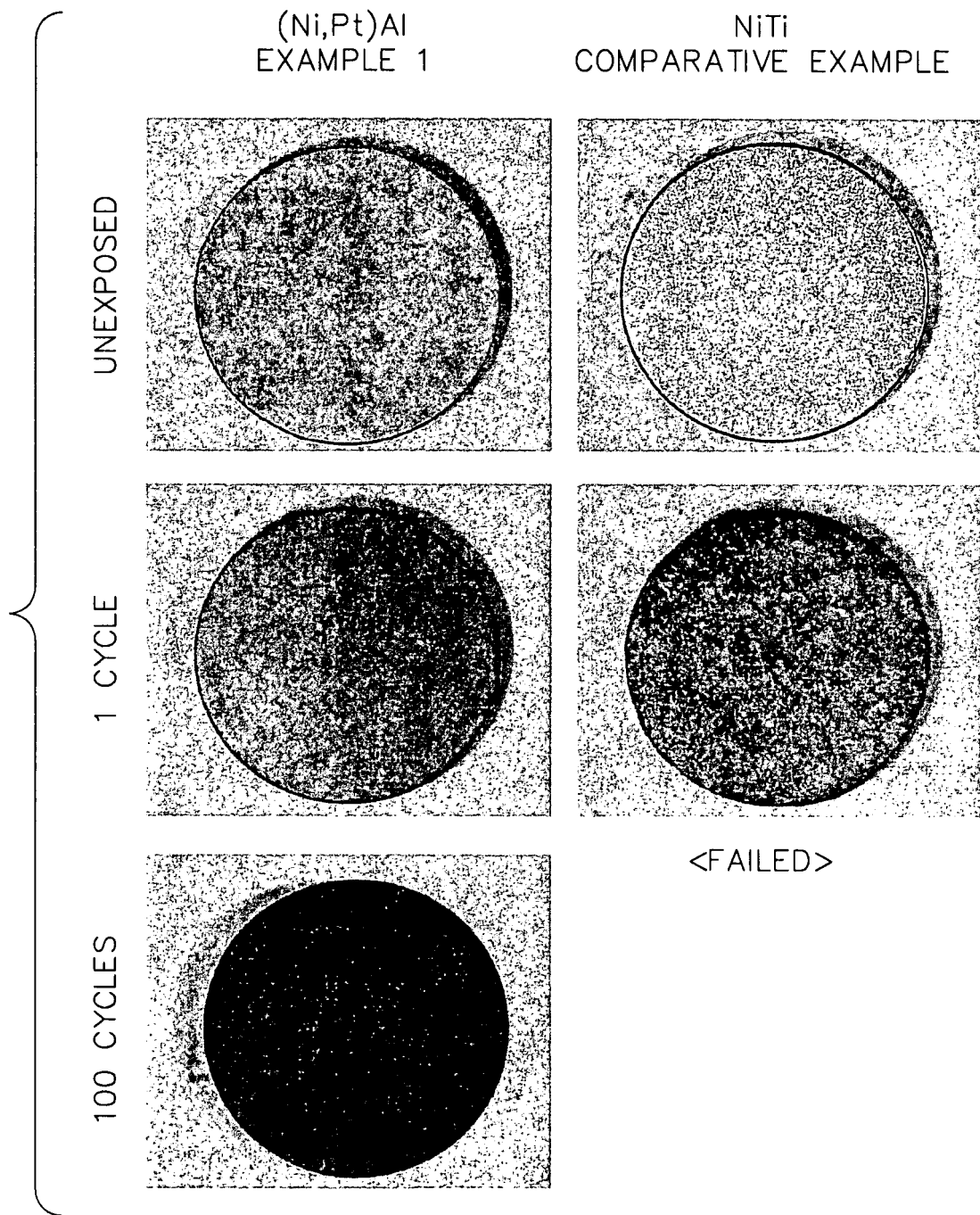


FIG. 5

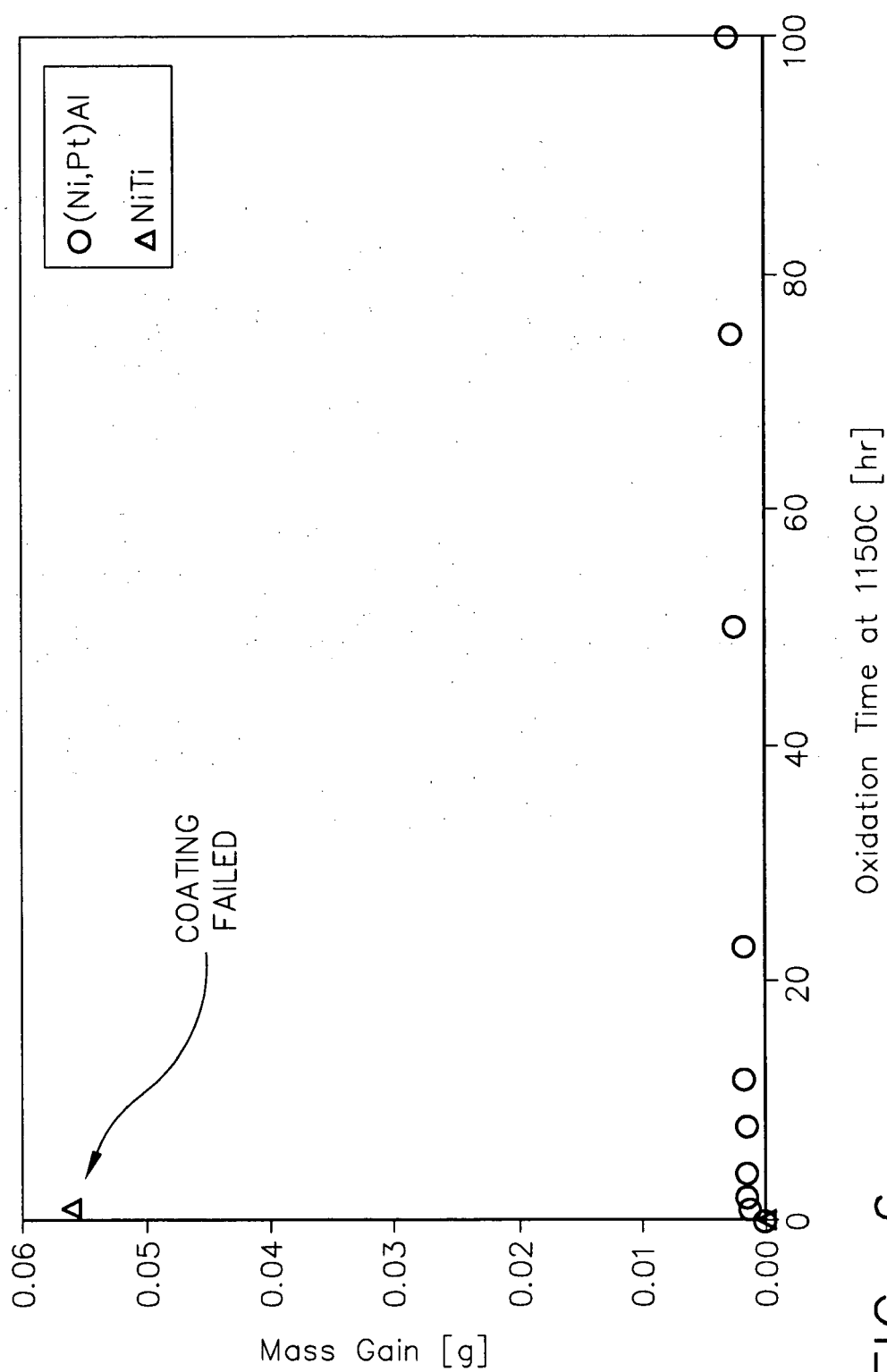


FIG. 6