[0007] Failure to utilize a coating having adequate fluid impermeability, in combination with adequate wear resistance and lubrication of the gate and seats components can, among other problems, lead to unacceptable galling and potential localized deformation, thereby causing leakage of fluid through the coating and eventually through the valve. Similar problems can arise when insufficient fluid impermeability, wear resistance and lubrication are created along one or more sealing surfaces of a ball valve.

[0008] In view of the drawbacks of conventional coatings, there is an unmet need for an improved fully-dense coating system that offers superior performance over conventional coating materials for gate and seat components, including improved wear resistance, lubricity and sealing properties over a wide range of operating pressures and temperatures.

Summary of the Invention

[0009] The invention may include any of the following aspects in various combinations and may also include any other aspect of the present invention described below in the written description.

[0010] In a first aspect, fully-dense, fluid tight, low friction coating system, comprising: a substrate; a thermal spray-fused underlying layer on the substrate, said thermal spray-fused underlying layer produced from a blend comprising a tungsten carbide-based material and a self-fluxing alloy (SFA), wherein said tungsten carbide-based material is in an amount no greater than 70 wt.% based of a total weight of the underlying layer, with the balance SFA, said fully dense, fluid tight low friction coating system characterized by an absence of a polymeric or non-polymeric sealant, and further wherein said fully-dense coating system is characterized by a substantial absence of a visually detectable interconnected porosity; and a low friction layer comprising a diamond-like carbon (DLC) material extending above said thermal spray-fused underlying layer.

[0010a] In another aspect, there is provided a fully-dense, fluid tight, low friction coating system without a sealant comprising a substrate; a thermal spray-fused underlying layer on the substrate, said thermal spray-fused underlying layer produced from a blend comprising a tungsten carbide-based material and a self-fluxing alloy (SFA), said SFA being silicon-boron containing; wherein said tungsten carbide-based material is in an amount no greater than 70 wt% based on a total weight of the thermal spray-fused underlying layer, with a balance of the thermal spray-fused underlying layer comprising substantially SFA, wherein said fully dense, fluid tight low friction coating system has a fluid tightness that is characterized by a substantial absence of a visually detectable interconnected porosity as determined by a scanning electron microscope (SEM) at a magnification of 5000X, wherein said absence of the visually detectable interconnected porosity is sufficient to prevent fluid leakage at an applied pressure of 10,000 psi after a duration of 10 minutes ; and a low friction layer extending above said thermal spray-fused underlying layer.

[0011] In a second aspect, a surface treated apparatus comprising: a gate or ball valve including two seats and a gate or ball; said gate or ball having an contact surface that engages with a corresponding face of said seats; wherein at least one of said engaging face of said gate or ball and said seat is coated with a fully dense gas tight low friction coating system comprising (i) thermal sprayed and fused coating deposited from a composition of blended tungsten carbide-based and self-fluxing alloy (SFA) powders; (ii) and a diamond-like carbon (DLC) layer extending onto an outer portion of said coating wherein said coating is characterized by an absence of a polymeric or non-polymeric sealant, and further wherein said fully-dense coating is characterized by a substantial absence of a visually detectable interconnected porosity.

[0011a] In yet another aspect, there is provided a surface treated apparatus comprising a gate or ball valve including a first seat and a second seat, and a gate or ball; said gate or ball having a contact surface that engages with a corresponding face of at least one of said first and second seat; wherein at least one of said engaging face of said gate or ball and said corresponding face of the at least one of said first or second seat is coated with a fully dense gas tight low friction coating system comprising (i) thermal sprayed and fused coating deposited from a composition of blended tungsten carbide-based and self-fluxing alloy (SFA) powders, said SFA powders being silicon-boron containing; (ii) and a diamond-like carbon (DLC) layer extending onto an outer portion of said coating, wherein said fully-dense, gas tight, low friction coating system has a fluid tightness that is characterized by a substantial absence of a visually detectable interconnected porosity as determined by a scanning electron microscope (SEM) at a magnification of 5000X, wherein said absence of the visually detectable interconnected porosity is sufficient to prevent fluid leakage at an applied pressure of 10,000 psi after a duration of 10 minutes.

[0012] In a third aspect, a fully-dense, fluid tight, low friction coating system comprising: a substrate; a thermal spray-fused underlying layer on the substrate, said thermal spray-fused underlying layer deposited from a powder blend comprising a tungsten carbide-based material and a self-fluxing alloy (SFA) material; a low friction layer comprising a diamond-like carbon (DLC) material above said thermal spray-fused underlying layer; said fully dense, fluid tight low friction coating system further characterized by an absence of a polymeric or non-polymeric sealant, and further

wherein said fully-dense coating system is characterized by a substantial absence of a visually detectable interconnected porosity.

[0012a] In another aspect, there is provided a fully-dense, fluid tight, low friction coating system without a sealant comprising a substrate; a thermal spray-fused underlying layer on the substrate, said thermal spray-fused underlying layer derived from a powder blend comprising a tungsten carbide-based material and a self-fluxing alloy (SFA) material said SFA material being silicon-boron containing, wherein a weight ratio of the tungsten carbide-based material to the SFA material is not greater than 3:2; and a low friction layer comprising a diamond-like carbon (DLC) material above said thermal spray-fused underlying layer; wherein said fully-dense coating system has a fluid tightness that is characterized by a substantial absence of a visually detectable interconnected porosity as determined by a scanning electron microscope (SEM) at a magnification of 5000X, wherein said absence of the visually detectable interconnected porosity is sufficient to prevent fluid leakage at an applied pressure of 10,000 psi after a duration of 10 minutes.

[0013] In a fourth aspect, a fully-dense and fluid tight, coating comprising: a substrate; a thermal spray-fused underlying layer on the substrate, said thermal spray-fused underlying layer deposited from a powder blend comprising a tungsten carbide-based material and a self-fluxing alloy (SFA) material said fully dense, fluid tight low friction coating system further characterized by an absence of a polymeric or non-polymeric sealant, and further wherein said fully-dense coating system is characterized by a substantial absence of a visually detectable interconnected porosity, thereby creating substantial fluid impermeability.

[0013a] In yet another aspect, there is provided a fully-dense and fluid tight, coating system, without a sealant comprising: a substrate; a thermal spray-fused underlying layer on the substrate, said thermal spray-fused underlying layer deposited derived from a powder blend comprising a tungsten carbide-based material and a self-fluxing alloy (SFA) material, said SFA material being silicon-boron containing; further wherein said fully dense, fluid tight low friction coating system further characterized by an absence of a polymeric or non-polymeric sealant, and further wherein said fully-dense coating system has a fluid tightness that is characterized by a substantial absence

of a visually detectable interconnected porosity as determined by a scanning electron microscope (SEM) at a magnification of 5000X, thereby creating substantial fluid impermeability, as measured by an absence of fluid leakage at an applied pressure of 10,000 psi after a duration of 10 minutes

[0014] Other aspects, features and embodiments of the disclosure will be more fully apparent from the ensuing description and appended claims.

Claims

1. A fully-dense, fluid tight, low friction coating system without a sealant comprising:

a substrate;

a thermal spray-fused underlying layer on the substrate, said thermal spray-fused underlying layer produced from a blend comprising a tungsten carbide-based material and a self-fluxing alloy (SFA), said SFA being silicon-boron containing; wherein said tungsten carbide-based material is in an amount no greater than 70 wt% based on a total weight of the thermal spray-fused underlying layer, with a balance of the thermal spray-fused underlying layer comprising substantially SFA, wherein said fully dense, fluid tight low friction coating system has a fluid tightness that is characterized by a substantial absence of a visually detectable interconnected porosity as determined by a scanning electron microscope (SEM) at a magnification of 5000X, wherein said absence of the visually detectable interconnected porosity is sufficient to prevent fluid leakage at an applied pressure of 10,000 psi after a duration of 10 minutes ; and

a low friction layer extending above said thermal spray-fused underlying layer.

2. The fully-dense, fluid tight, low friction coating system of claim 1, said thermal spray fused underlying layer having a sufficient microhardness to support said low friction layer above said thermal spray-fused underlying layer.

3. The fully-dense, fluid tight, low friction coating system of claim 1, wherein said tungsten carbide-based material is distributed in a metallic alloy matrix.

4. The fully-dense, fluid tight, low friction coating system of claim 3, wherein said SFA is in a range of about 30 to about 90 wt.,% based on the total weight of the thermal spray-fused underlying layer and said tungsten carbide-based material is in a range of about 10-70 wt% based on the total weight of the thermal spray-fused underlying layer.

5. The fully-dense, fluid tight, low friction coating system of claim 1 derived from a powder blend of said SFA and said tungsten carbide-based material that is thermally sprayed onto the substrate.

6. The fully dense, fluid tight, low friction coating system of claim 1, wherein said low friction layer comprises a diamond-like carbon (DLC) layer.

7. The fully dense, fluid tight, low friction coating system of claim 1, wherein said substrate comprises one or more sealing surfaces of a gate/ball component or a seat component of a gate/ball valve.

8. The fully dense, fluid tight, low friction coating system of claim 1, wherein said tungsten carbide-based material is derived from a powder; said powder blended with the SFA material.

9. The fully dense, fluid tight, low friction coating system of claim 1, wherein said tungsten carbide-based material is selected from the group consisting of tungsten carbide cobalt chromium (WC-CoCr), tungsten carbide cobalt (WC-Co), and tungsten carbide nickel (WC-Ni).

10. The fully dense, fluid tight, low friction coating system of claim 1, wherein said low friction layer has a thickness of 1 to 5 microns.

11. The fully dense, fluid tight, low friction coating system of claim 1, wherein said fully dense, fluid tight, low friction coating system is capable of withstanding contact stress at least 20,000 psi and a temperature of up to about 600 ^{o}F.

12. A surface treated apparatus comprising:

a gate or ball valve including a first seat and a second seat, and a gate or ball; said gate or ball having a contact surface that engages with a corresponding face of at least one of said first and second seat;

wherein at least one of said engaging face of said gate or ball and said corresponding face of the at least one of said first or second seat is coated with a fully dense gas tight low friction coating system comprising (i) thermal sprayed and fused coating deposited from a composition of blended tungsten carbide-based and

self-fluxing alloy (SFA) powders, said SFA powders being silicon-boron containing; (ii) and a diamond-like carbon (DLC) layer extending onto an outer portion of said coating

wherein said fully-dense, gas tight, low friction coating system has a fluid tightness that is characterized by a substantial absence of a visually detectable interconnected porosity as determined by a scanning electron microscope (SEM) at a magnification of 5000X, wherein said absence of the visually detectable interconnected porosity is sufficient to prevent fluid leakage at an applied pressure of 10,000 psi after a duration of 10 minutes.

13. The surface treated apparatus of claim 12, wherein said fully dense coating system is characterized by a coefficient of friction below 0.1 at contact pressures at least at 20,000 psi and substantial fluid impermeability at an elevated temperate up to about 600 ^{o}F.

14. The surface treated apparatus of claim 12, wherein each of said engaging surfaces of said gate or ball and said seats is coated with said fully dense coating system.

15. The surface treated apparatus of claim 12, wherein said tungsten carbide is distributed in a metallic alloy matrix and further wherein said SFA is in a range of about 30 to about 90 wt% based on the total weight of the thermal sprayed and fused coating and said WC is in a range of about 10-70 wt% based on the total weight of the thermal sprayed and fused coating.

16. A fully-dense, fluid tight, low friction coating system without a sealant comprising:

a substrate;

a thermal spray-fused underlying layer on the substrate, said thermal spray-fused underlying layer derived from a powder blend comprising a tungsten carbide-based material and a self-fluxing alloy (SFA) material said SFA material being

silicon-boron containing, wherein a weight ratio of the tungsten carbide-based material to the SFA material is not greater than 3:2; and

a low friction layer comprising a diamond-like carbon (DLC) material above said thermal spray-fused underlying layer;

wherein said fully-dense coating system has a fluid tightness that is characterized by a substantial absence of a visually detectable interconnected porosity as determined by a scanning electron microscope (SEM) at a magnification of 5000X, wherein said absence of the visually detectable interconnected porosity is sufficient to prevent fluid leakage at an applied pressure of 10,000 psi after a duration of 10 minutes.

17. The fully dense, fluid tight, low friction coating system of claim 16, wherein said SFA is in a range of 30 to about 90 wt% based on the total weight of the thermal sprayed and fused underlying layer and said tungsten carbide-based material is in a range of 10-70 wt% based on the total weight of the thermal sprayed and fused underlying layer

18. The fully dense, fluid tight, low friction coating system of claim 16, further characterized by an absence of fluid leakage at pressures of 30,000 psi or greater and temperatures up to about 600F.

19. The fully dense, fluid tight, low friction coating system of claim 16, wherein the low friction coating system is characterized by a coefficient of friction no greater than 0.1.

20. A fully-dense and fluid tight, coating system, without a sealant comprising:

a substrate;

a thermal spray-fused underlying layer on the substrate, said thermal spray-fused underlying layer derived from a powder blend comprising a tungsten carbide-based material and a self-fluxing alloy (SFA) material, said SFA material being silicon-boron containing;

further wherein said fully-dense coating system has a fluid tightness that is characterized by a substantial absence of a visually detectable interconnected porosity as determined by a scanning electron microscope (SEM) at a magnification of 5000X, thereby creating substantial fluid impermeability, as measured by an absence of fluid leakage at an applied pressure of 10,000 psi after a duration of 10 minutes.

21. The fully dense and fluid tight coating of claim 20, said coating characterized by an absence of structural defects, including cracks of a size sufficient to lower the substantial fluid impermeability.