including, without limitation, at a temperature that is higher than a temperature selected from about 670°C, about 900°C, about 1,000°C, and about 1,500°C.

[0068] In third example, some embodiments of the described methods allow the joint initiator 10 to sufficiently diffuse such that it takes on some of the characteristics of the parts being joined and so that it leaves behind some of the original characteristics that would have prevented it from operating in high-oxidizing environments. In contrast, some traditional brazes may leave behind that original brazing material, which (as described above) is susceptible to oxidation or oxidizing environments, or which may simply weaken, causing the joint to fail, at very high temperatures.

[0069] In a fourth example, the described methods can be much less complex than some traditional brazing and joining techniques. Indeed, while some brazing techniques must be performed in a vacuum and/or non-oxygen environment, some embodiments of the described methods can be completed in air and standard atmospheric pressures—thereby eliminating the need for costly set-ups in vacuum furnace systems. Similarly, unlike many traditional brazing techniques, some embodiments of the current methods do not include chemical treatments of the substrates (*e.g.*, to convert surface free silicon to SiN or SiC) before or as part of the joining process.

[0070] In a fifth example, unlike some traditional brazing techniques that require doped or alloy metals to serve as the brazing material, some embodiments of the described methods use a substantially pure sample of aluminum as the joint initiator. Furthermore, some embodiments of the described methods simply use aluminum foil, aluminum powder, aluminum ink, and/or another inexpensive form of aluminum as the joint initiator.

[0071] In a sixth example, unlike some traditional brazing techniques that require the ceramic substrates to comprise reaction-bonded silicon carbide (RSBC), some embodiments of the present invention do not use such a substrate. Instead, such embodiments use a direct-sintered ceramic carbide (*e.g.*, silicon carbide) or ceramic nitride. Similarly, while some traditional brazing techniques require the use of RSBC with the utilization of a free silicon infiltrant, some embodiments of the described methods do not involve such an infiltrant.

[0072] In a seventh example, while some traditional brazing techniques require that a surface layer (*e.g.*, of silicon) be added to a substrate interface surface before being joined, some embodiments of the describe methods do not involve the addition of a surface layer.

[0073] In an eighth example, unlike some traditional brazing techniques that require metallization of a ceramic substrate surface before that substrate can be joined to another

CLAIMS:

1. A ceramic to ceramic joint comprising:

a first ceramic part, wherein the first ceramic part is a ceramic carbide or a ceramic nitride;

a second ceramic part, wherein the second ceramic part is a ceramic carbide or a ceramic nitride; and

an aluminum-initiated joint region joining the first and second ceramic parts, wherein the joint region comprises chemical species from the first and second ceramic parts diffused within the joint region, wherein the first ceramic part comprises a first joint diffusion zone disposed adjacent to the joint region which comprises aluminum species from the joint region diffused within the first joint diffusion zone, and wherein the second ceramic part comprises a second joint diffusion zone disposed adjacent to the joint region which comprises aluminum species from the joint region diffused within the second joint diffusion zone.

2. The ceramic to ceramic joint according to claim 1, wherein the first ceramic part and second ceramic part comprise SiC.

3. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 50% of a bulk strength of the first and second ceramic parts.

4. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 60% of a bulk strength of the first and second ceramic parts.

5. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 70% of a bulk strength of the first and second ceramic parts.

6. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 80% of a bulk strength of the first and second ceramic parts.

7. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 90% of a bulk strength of the first and second ceramic parts.

8. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than or equal to a bulk strength of the first and second ceramic parts.

9. A ceramic to ceramic joint comprising:

a first ceramic part, wherein the first ceramic part is a ceramic carbide or a ceramic nitride;

a second ceramic part, wherein the second ceramic part is a ceramic carbide or a ceramic nitride; and

an aluminum-initiated joint region joining the first and second ceramic parts characterized by diffusion and counter-diffusion of chemical species between the joint region and the adjoining first and second ceramic parts, wherein the joint region has a joint strength greater than 50% of a bulk strength of the first and second ceramic parts.

10. The ceramic to ceramic joint according to claim 9, wherein the joint region has a joint strength greater than 60% of the bulk strength of the first and second ceramic parts.

11. The ceramic to ceramic joint according to claim 9, wherein the joint region has a joint strength greater than 70% of the bulk strength of the first and second ceramic parts.

12. The ceramic to ceramic joint according to claim 9, wherein the joint region has a joint strength greater than 80% of the bulk strength of the first and second ceramic parts.

13. The ceramic to ceramic joint according to claim 9, wherein the joint region has a joint strength greater than 90% of the bulk strength of the first and second ceramic parts.

14. The ceramic to ceramic joint according to claim 9, wherein the joint region has a joint strength greater than or equal to the bulk strength of the first and second ceramic parts.

15. A method of forming a ceramic to ceramic joint comprising:

obtaining a first ceramic part and a second ceramic part;

positioning a joint initiator within a joint region between and adjacent the first ceramic part and the second ceramic, wherein the joint initiator comprises aluminum; and

heating the joint initiator and the first and second ceramic parts adjacent to the joint initiator to a temperature greater than about 700°C for a time period sufficient to cause diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts.

16. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint initiator and the first and second ceramic parts adjacent to the joint initiator are heated to a temperature greater than about 800°C.

17. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint initiator and the first and second ceramic parts adjacent to the joint initiator are heated to a temperature greater than about 900°C.

18. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint initiator and the first and second ceramic parts adjacent to the joint initiator are heated to a temperature greater than about 1000°C.

19. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint region has a joint strength greater than 50% of a bulk strength of the first and second ceramic parts.

20. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint region has a joint strength greater than 60% of a bulk strength of the first and second ceramic parts.

21. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint region has a joint strength greater than 70% of a bulk strength of the first and second ceramic parts.

22. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint region has a joint strength greater than 80% of a bulk strength of the first and second ceramic parts.

23. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint region has a joint strength greater than 90% of a bulk strength of the first and second ceramic parts.

24. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint region has a joint strength greater than or equal to a bulk strength of the first and second ceramic parts.

25. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint initiator comprises undoped aluminum.

26. The method of forming a ceramic to ceramic joint according to claim 25, wherein the aluminum foil has a thickness less than about 250 μm.

27. The method of forming a ceramic to ceramic joint according to claim 25, wherein the aluminum foil has a thickness less than about 125 μm.

28. The method of forming a ceramic to ceramic joint according to claim 25, wherein the aluminum foil has a thickness greater than about 25 μm.

29. The method of forming a ceramic to ceramic joint according to claim 25, wherein the aluminum foil has a thickness greater than about 5 μm.

30. The method of forming a ceramic to ceramic joint according to claim 25, wherein the aluminum foil has a thickness less than about 30 μm.

31. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint initiator comprises aluminum ink.

32. The method of forming a ceramic to ceramic joint according to claim 15, wherein the joint initiator comprises aluminum powder.

33. The method of forming a ceramic to ceramic joint according to claim 15, further comprising applying a load to the joint region during the heating step.

34. The method of forming a ceramic to ceramic joint according to claim 15, wherein the heating step comprises heating within a thermally insulated container.

35. The method of forming a ceramic to ceramic joint according to claim 15, wherein the heating step comprises localized heating by a torch.

36. The method of forming a ceramic to ceramic joint according to claim 15, wherein the heating step comprises resistive heating.

37. The method of forming a ceramic to ceramic joint according to claim 15, wherein following diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts there is substantially less free aluminum remaining within the joint region.

38. The method of forming a ceramic to ceramic joint according to claim 15, wherein following diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts there is less than 20 mole % free aluminum remaining within the joint region.

39. The method of forming a ceramic to ceramic joint according to claim 15, wherein following diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts there is less than 40 mole % free aluminum remaining within the joint region.

40. The method of forming a ceramic to ceramic joint according to claim 15, wherein following diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts there is less than 60 mole % free aluminum remaining within the joint region.

41. The method of forming a ceramic to ceramic joint according to claim 15, further comprising increasing the joint region's ability to resist oxidation by repeating the heating step and causing additional diffusion and counter-diffusion of the chemical species in the joint region.

including, without limitation, at a temperature that is higher than a temperature selected from about 670°C, about 900°C, about 1,000°C, and about 1,500°C.

[0068] In third example, some embodiments of the described methods allow the joint initiator 10 to sufficiently diffuse such that it takes on some of the characteristics of the parts being joined and so that it leaves behind some of the original characteristics that would have prevented it from operating in high-oxidizing environments. In contrast, some traditional brazes may leave behind that original brazing material, which (as described above) is susceptible to oxidation or oxidizing environments, or which may simply weaken, causing the joint to fail, at very high temperatures.

[0069] In a fourth example, the described methods can be much less complex than some traditional brazing and joining techniques. Indeed, while some brazing techniques must be performed in a vacuum and/or non-oxygen environment, some embodiments of the described methods can be completed in air and standard atmospheric pressures—thereby eliminating the need for costly set-ups in vacuum furnace systems. Similarly, unlike many traditional brazing techniques, some embodiments of the current methods do not include chemical treatments of the substrates (*e.g.*, to convert surface free silicon to SiN or SiC) before or as part of the joining process.

[0070] In a fifth example, unlike some traditional brazing techniques that require doped or alloy metals to serve as the brazing material, some embodiments of the described methods use a substantially pure sample of aluminum as the joint initiator. Furthermore, some embodiments of the described methods simply use aluminum foil, aluminum powder, aluminum ink, and/or another inexpensive form of aluminum as the joint initiator.

[0071] In a sixth example, unlike some traditional brazing techniques that require the ceramic substrates to comprise reaction-bonded silicon carbide (RBSC), some embodiments of the present invention do not use such a substrate. Instead, such embodiments use a direct-sintered ceramic carbide (*e.g.*, silicon carbide) or ceramic nitride. Similarly, while some traditional brazing techniques require the use of RBSC with the utilization of a free silicon infiltrant, some embodiments of the described methods do not involve such an infiltrant.

[0072] In a seventh example, while some traditional brazing techniques require that a surface layer (*e.g.*, of silicon) be added to a substrate interface surface before being joined, some embodiments of the describe methods do not involve the addition of a surface layer.

[0073] In an eighth example, unlike some traditional brazing techniques that require metallization of a ceramic substrate surface before that substrate can be joined to another

CLAIMS:

1. A ceramic to ceramic joint comprising:

a first ceramic part, wherein the first ceramic part is a ceramic carbide;

a second ceramic part, wherein the second ceramic part is a ceramic carbide; and

an aluminum-initiated joint region joining the first and second ceramic parts, wherein the joint region comprises chemical species from the first and second ceramic parts diffused within the joint region, wherein the first ceramic part comprises a first joint diffusion zone disposed adjacent to the joint region which comprises aluminum species from the joint region diffused within the first joint diffusion zone, and wherein the second ceramic part comprises a second joint diffusion zone disposed adjacent to the joint region which comprises aluminum species from the joint region diffused within the second joint diffusion zone, wherein the aluminum-initiated joint region has a thickness less than 125 μm and a thickness greater than 5 μm.

2. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 50% of a bulk strength of the first and second ceramic parts.

3. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 60% of a bulk strength of the first and second ceramic parts.

4. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 70% of a bulk strength of the first and second ceramic parts.

5. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 80% of a bulk strength of the first and second ceramic parts.

6. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than 90% of a bulk strength of the first and second ceramic parts.

7. The ceramic to ceramic joint according to claim 1, wherein the joint region has a joint strength greater than or equal to a bulk strength of the first and second ceramic parts.

8. A ceramic to ceramic joint comprising:

a first ceramic part, wherein the first ceramic part is a ceramic carbide;

a second ceramic part, wherein the second ceramic part is a ceramic carbide; and

an aluminum-initiated joint region joining the first and second ceramic parts characterized by diffusion and counter-diffusion of chemical species between the joint region and the adjoining first and second ceramic parts, wherein the aluminum-initiated joint region has a thickness less than 125 μm and a thickness greater than 5 μm, wherein the joint region has a joint strength greater than 50% of a bulk strength of the first and second ceramic parts.

9. The ceramic to ceramic joint according to claim 8, wherein the joint region has a joint strength greater than 60% of the bulk strength of the first and second ceramic parts.

10. The ceramic to ceramic joint according to claim 8, wherein the joint region has a joint strength greater than 70% of the bulk strength of the first and second ceramic parts.

11. The ceramic to ceramic joint according to claim 8, wherein the joint region has a joint strength greater than 80% of the bulk strength of the first and second ceramic parts.

12. The ceramic to ceramic joint according to claim 8, wherein the joint region has a joint strength greater than 90% of the bulk strength of the first and second ceramic parts.

13. The ceramic to ceramic joint according to claim 8, wherein the joint region has a joint strength greater than or equal to the bulk strength of the first and second ceramic parts.

14. A method of forming a ceramic to ceramic joint comprising:

obtaining a first ceramic part and a second ceramic part;

positioning a joint initiator within a joint region between and adjacent the first ceramic part and the second ceramic, wherein the joint initiator comprises aluminum and has a thickness less than 125 μm and a thickness greater than 5 μm; and

heating the joint initiator and the first and second ceramic parts adjacent to the joint initiator to a temperature greater than about 700°C for a time period sufficient to cause diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts.

15. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint initiator and the first and second ceramic parts adjacent to the joint initiator are heated to a temperature greater than about 800°C.

16. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint initiator and the first and second ceramic parts adjacent to the joint initiator are heated to a temperature greater than about 900°C.

17. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint initiator and the first and second ceramic parts adjacent to the joint initiator are heated to a temperature greater than about 1000°C.

18. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint region has a joint strength greater than 50% of a bulk strength of the first and second ceramic parts.

19. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint region has a joint strength greater than 60% of a bulk strength of the first and second ceramic parts.

20. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint region has a joint strength greater than 70% of a bulk strength of the first and second ceramic parts.

21. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint region has a joint strength greater than 80% of a bulk strength of the first and second ceramic parts.

22. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint region has a joint strength greater than 90% of a bulk strength of the first and second ceramic parts.

23. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint region has a joint strength greater than or equal to a bulk strength of the first and second ceramic parts.

24. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint initiator comprises undoped aluminum foil.

25. The method of forming a ceramic to ceramic joint according to claim 24, wherein the aluminum foil has a thickness of 25 μm ± 5 μm.

26. The method of forming a ceramic to ceramic joint according to claim 24, wherein the aluminum foil has a thickness greater than about 25 μm.

27. The method of forming a ceramic to ceramic joint according to claim 24, wherein the aluminum foil has a thickness less than about 30 μm.

28. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint initiator comprises aluminum ink.

29. The method of forming a ceramic to ceramic joint according to claim 14, wherein the joint initiator comprises aluminum powder.

30. The method of forming a ceramic to ceramic joint according to claim 14, further comprising applying a load to the joint region during the heating step.

31. The method of forming a ceramic to ceramic joint according to claim 14, wherein the heating step comprises heating within a thermally insulated container.

32. The method of forming a ceramic to ceramic joint according to claim 14, wherein the heating step comprises localized heating by a torch.

33. The method of forming a ceramic to ceramic joint according to claim 14, wherein the heating step comprises resistive heating.

34. The method of forming a ceramic to ceramic joint according to claim 14, wherein following diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts there is substantially less free aluminum remaining within the joint region.

35. The method of forming a ceramic to ceramic joint according to claim 14, wherein following diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts there is less than 20 mole % free aluminum remaining within the joint region.

36. The method of forming a ceramic to ceramic joint according to claim 14, wherein following diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts there is less than 40 mole % free aluminum remaining within the joint region.

37. The method of forming a ceramic to ceramic joint according to claim 14, wherein following diffusion and counter-diffusion of chemical species between the joint initiator and the adjoining first and second ceramic parts there is less than 60 mole % free aluminum remaining within the joint region.

38. The method of forming a ceramic to ceramic joint according to claim 14, further comprising increasing the joint region's ability to resist oxidation by repeating the heating step and causing additional diffusion and counter-diffusion of the chemical species in the joint region.