CLAIMS

1. An article comprising:

a substrate; and

a coating on the substrate, wherein the coating comprises a bond layer and an overlying layer comprising at least one oxide, wherein the bond layer comprises between 40 volume percent and 99 volume percent silicon metal and a balance of at least one of a transition metal carbide, a transition metal boride, or a transition metal nitride.

2. The article of claim 1, wherein the bond layer comprises silicon metal and at least one transition metal carbide, and wherein the at least one transition metal carbide comprises at least one of Cr_3C_2, Cr_7C_3, $Cr_{23}C_6$, Mo_2C, NbC, WC, TaC, HfC, or ZrC.

3. The article of claim 1, wherein the bond layer comprises silicon metal and at least one transition metal boride, and wherein the at least one transition metal boride comprises at least one of TaB, TaB_2, TiB_2, ZrB_2, HfB, HfB_2.

4. The article of claim 1, wherein the bond layer comprises silicon metal and at least one transition metal nitride, and wherein the at least one transition metal nitride comprises at least one of TiN, ZrN, HfN, Mo_2N, or TaN.

5. The article of claim 1, wherein the bond layer comprises silicon metal, at least one transition metal carbide, and at least one transition metal boride, wherein the at least one transition metal carbide comprises at least one of Cr_3C_2, Cr_7C_3, $Cr_{23}C_6$, Mo_2C, NbC, WC, TaC, HfC, or ZrC, and wherein the at least one transition metal boride comprises at least one of TaB, TaB_2, TiB_2, ZrB_2, HfB, HfB_2.

6. The article of claim 1, wherein the bond layer comprises silicon metal, at least one transition metal carbide, and at least one transition metal nitride, wherein the at least

one transition metal carbide comprises at least one of Cr_3C_2, Cr_7C_3, $Cr_{23}C_6$, Mo_2C, NbC, WC, TaC, HfC, or ZrC, and wherein the at least one transition metal nitride comprises at least one of TiN, ZrN, HfN, Mo_2N, or TaN.

7. The article of claim 1, wherein the bond layer comprises silicon metal, at least one transition metal boride, and at least one transition metal nitride, wherein the at least one transition metal boride comprises at least one of TaB, TaB_2, TiB_2, ZrB_2, HfB, HfB_2, and wherein the at least one transition metal nitride comprises at least one of TiN, ZrN, HfN, Mo_2N, or TaN.

8. The article of claim 1, wherein the bond layer comprises silicon metal, at least one transition metal carbide, at least one transition metal boride, and at least one transition metal nitride, wherein the at least one transition metal carbide comprises at least one of Cr_3C_2, Cr_7C_3, $Cr_{23}C_6$, Mo_2C, NbC, WC, TaC, HfC, or ZrC, wherein the at least one transition metal boride comprises at least one of TaB, TaB_2, TiB_2, ZrB_2, HfB, HfB_2, and wherein the at least one transition metal nitride comprises at least one of TiN, ZrN, HfN, Mo_2N, or TaN.

9. The article of claim 1, wherein the bond layer comprises a first phase comprising silicon metal and a second phase comprising the at least one of a transition metal carbide, a transition metal boride, or a transition metal nitride.

10. The article of claim 9, wherein the first phase is a substantially continuous phase.

11. The article of claim 1, wherein the overlying layer comprising at least one oxide comprises at least one of a rare earth oxide, a rare earth silicate, or an alkaline earth aluminosilicate.

12. The article of claim 1, wherein the substrate comprises a silicon-based substrate.

13. The article of claim 12, wherein the substrate comprises silicon carbide.

14. The article of claim 13, wherein the substrate comprises a silicon carbide-silicon carbide ceramic matrix composite.

15. The article of claim 1, wherein the bond layer comprises a single layer between the substrate and the overlying layer.

16. A method comprising:

forming a bond layer comprising silicon metal between 40 volume percent and 99 volume percent and a balance of at least one of a transition metal carbide, a transition metal boride, or a transition metal nitride on a substrate; and

forming an overlying layer comprising an oxide on the bond layer.

17. The method of claim 16, wherein the bond layer comprises silicon metal and the transition metal carbide, and wherein forming the bond layer comprises:

depositing a layer comprising a transition metal from a slurry on a bulk surface of a porous substrate preform;

forming the transition metal carbide by exposing the layer including the transition metal to a carbon-containing gas to form a porous layer including the transition metal carbide; and

infiltrating the porous substrate preform and the porous layer including the transition metal carbide with molten silicon to form an article including a ceramic matrix composite substrate and the bond layer comprising silicon metal and the transition metal carbide.

18. The method of claim 17, wherein:

the transition metal comprises at least one of Cr, Mo, Nb, W, Ti, Ta, Hf, or Zr;

the carbon-containing gas comprises at least one of methane or carbon monoxide; and

the transition metal carbide comprises at least one of Cr_3C_2, Cr_7C_3, $Cr_{23}C_6$, Mo_2C, NbC, WC, TiC, TaC, HfC, and ZrC.

19. The method of claim 16, wherein the bond layer comprises silicon metal and the transition metal boride, and wherein forming the bond layer comprises:

depositing a layer comprising a transition metal from a slurry on a bulk surface of a porous substrate preform;

forming the transition metal boride by exposing the layer including the transition metal to a boron-containing gas to form a porous layer including the transition metal boride; and

infiltrating the porous substrate preform and the porous layer including the transition metal boride with molten silicon metal to form an article including a ceramic matrix composite substrate and the bond layer comprising silicon metal and the transition metal boride.

20. The method of claim 16, wherein the bond layer comprises silicon metal and the transition metal nitride, and wherein forming the bond layer comprises:

depositing a layer comprising a transition metal from a slurry on a bulk surface of a porous substrate preform;

forming the transition metal nitride by exposing the layer including the transition metal to a nitrogen-containing gas to form a porous layer including the transition metal nitride; and

infiltrating the porous substrate preform and the porous layer including the transition metal nitride with molten silicon metal to form an article including a ceramic matrix composite substrate and the bond layer comprising silicon metal and the transition metal nitride.