CLAIMS

What is claimed is:

1. A polycrystalline compact, comprising:

a hard polycrystalline material, comprising:

a first region, comprising:

a first plurality of grains of hard material having a first average grain size;

a second plurality of grains of hard material having a second average grain size smaller than the first average grain size, the grains of the first plurality of grains of hard material and of the second plurality of grains of hard material being interspersed and inter-bonded; and

catalyst material for catalyzing the formation of inter-granular bonds between the grains of the first plurality of grains of hard material and of the second plurality of grains of hard material, the catalyst material disposed in interstitial spaces between the inter-bonded grains of hard material of the first plurality of grains of hard material and of the second plurality of grains of hard material; and

a second region disposed adjacent and directly bonded to the first region along an interface between the first region and the second region, the second region comprising a third plurality of grains of hard material having a third average grain size, the grains of the third plurality of grains of hard material being interspersed and inter-bonded, wherein interstitial spaces between the inter-bonded grains of the third plurality of grains of hard material are at least substantially free of catalyst material for catalyzing the formation of inter-granular bonds between the grains of the third plurality of grains of hard material.

2. The polycrystalline compact of claim 1, wherein each of the first average grain size and the third average grain size is at least about 50 times greater than the second average grain size.

3. The polycrystalline compact of claim 2, wherein each of the first average grain size and the third average grain size is at least about 100 times greater than the second average grain size.

4. The polycrystalline compact of claim 3, wherein each of the first average grain size and the third average grain size is at least about 150 times greater than the second average grain size.

5. The polycrystalline compact of any one of claims 1 through 4, wherein the first average grain size is equal to the third average grain size.

6. The polycrystalline compact of any one of claims 1 through 4, wherein the first plurality of grains of hard material and the second plurality of grains of hard material together comprise between about ninety-two percent by volume (92 vol%) and about ninety-nine percent by volume (99 vol%) of the first region.

7. The polycrystalline compact of claim 6, wherein the third plurality of grains of hard material comprises between about eighty percent by volume (80 vol%) and about ninety-one percent by volume (91 vol%) of the second region.

8. The polycrystalline compact of claim 7, wherein the third plurality of grains of hard material comprises between about eighty-five percent by volume (85 vol%) and about eighty-eight percent by volume (88 vol%) of the second region.

9. The polycrystalline compact of any one of claims 1 through 4, wherein a first mean free path within the interstitial spaces between the inter-bonded grains of hard material of the first plurality of grains of hard material and the second plurality of grains of hard material in the first region is about ninety percent (90%) or less of a second mean free path within the interstitial spaces between the inter-bonded grains of hard material of the third plurality of grains of hard material in the second region.

10. The polycrystalline compact of claim 9, wherein the first mean free path is about seventy-five percent (75%) or less of the second mean free path.

11. The polycrystalline compact of claim 10, wherein the first mean free path is about fifty percent (50%) or less of the second mean free path.

12. The polycrystalline compact of any one of claims 1 through 4, wherein the hard material of at least one of the first plurality of grains of hard material, the second plurality of grains of hard material, and the third plurality of grains of hard material comprises diamond.

13. An earth-boring tool, comprising:

a tool body; and

at least one cutting element attached to the tool body, the at least one cutting element comprising a polycrystalline compact as recited in any one of claims 1 through 4.

14. A method of forming a polycrystalline compact, comprising:

forming an unsintered compact preform, comprising:

mixing a first plurality of grains of hard material having a first average grain size with a second plurality of grains of hard material having a second average grain size smaller than the first average grain size to form a first particulate mixture; and

positioning a third plurality of grains of hard material having a third average grain size adjacent the first particulate mixture within a container;

sintering the compact preform at a pressure greater than about five gigapascals (5.0 GPa) and a temperature greater than about 1,300°C in the presence of a catalyst material for catalyzing the formation of inter-granular bonds between the grains of hard material of the first plurality of grains of hard material, the second plurality of grains of hard material, and the third plurality of grains of hard material, sintering the unsintered compact preform comprising forming a hard polycrystalline material having a first region comprising interbonded grains of hard material formed from the first plurality of grains of hard material and the second plurality of grains of hard material, and a second region comprising interbonded grains of hard material formed from the third plurality of grains of hard material, the first region having a first density of the hard material higher than a second density of the hard material in the second region; and

removing catalyst material from interstitial spaces within the second region of the hard polycrystalline material without entirely removing catalyst material from interstitial spaces within the first region of the hard polycrystalline material.

15. The method of claim 14, wherein removing catalyst material from the interstitial spaces within the second region of the hard polycrystalline material without entirely removing catalyst material from the interstitial spaces within the first region of the hard polycrystalline material further comprises impeding the flow of the fluid through the first region of the hard polycrystalline material between the grains of the first plurality of hard material using grains of the second plurality of grains of hard material in the first region of the hard polycrystalline material as a barrier to the leaching fluid.

16. The method of claim 14 or claim 15, wherein forming the unsintered compact preform further comprises mixing particles of the catalyst material with the third plurality of grains of hard material prior to positioning the third plurality of grains of hard material adjacent the first particulate mixture within the container.

17. The method of any one of claims 14 through 16, wherein sintering the compact preform at a pressure greater than about five gigapascals (5.0 GPa) and a temperature greater than about 1,300°C comprises sintering the compact preform at a pressure greater than about six and one-half gigapascals (6.5 GPa).

18. The method of claim 17, wherein sintering the compact preform further comprises sintering the compact preform for less than about two minutes (2.0 min).

CLAIMS

What is claimed is:

1. A polycrystalline compact, comprising:

a hard polycrystalline material, comprising:

a first region adjacent a substrate and comprising:

a first plurality of grains of hard material having a first average grain size;

a second plurality of grains of hard material having a second average grain size smaller than the first average grain size, the grains of the first plurality of grains of hard material and of the second plurality of grains of hard material being interspersed and inter-bonded; and

catalyst material for catalyzing the formation of inter-granular bonds between the grains of the first plurality of grains of hard material and of the second plurality of grains of hard material, the catalyst material disposed in interstitial spaces between the inter-bonded grains of hard material of the first plurality of grains of hard material and of the second plurality of grains of hard material; and

a second region adjacent and directly bonded to the first region along an interface between the first region and the second region, the second region having a smaller volume percentage of hard material than the first region and comprising a third plurality of grains of hard material having a third average grain size, the grains of the third plurality of grains of hard material being interspersed and inter-bonded, wherein interstitial spaces between the inter-bonded grains of the third plurality of grains of hard material are at least substantially free of catalyst material for catalyzing the formation of inter-granular bonds between the grains of the third plurality of grains of hard material.

2. The polycrystalline compact of claim 1, wherein each of the first average grain size and the third average grain size is at least about 50 times greater than the second average grain size.

3. The polycrystalline compact of claim 2, wherein each of the first average grain size and the third average grain size is at least about 100 times greater than the second average grain size.

4. The polycrystalline compact of claim 3, wherein each of the first average grain size and the third average grain size is at least about 150 times greater than the second average grain size.

5. The polycrystalline compact of claim 2, wherein the first average grain size is equal to the third average grain size.

6. The polycrystalline compact of claim 1, wherein each of the first average grain size and the third average grain size is at least about five microns (5 μm), and the second average grain size is about five hundred nanometers (500 nm) or less.

7. The polycrystalline compact of claim 6, wherein the second average grain size is about two hundred nanometers (200 nm) or less.

8. The polycrystalline compact of claim 1, wherein each of the first average grain size and the third average grain size is between about one micron (1 μm) and about five microns (5 μm), and the second average grain size is about five hundred nanometers (500 nm) or less.

9. The polycrystalline compact of claim 1, wherein each of the first average grain size and the third average grain size is between about five microns (5 μm) and about forty microns (40 μm), and wherein the second average grain size is between about six nanometers (6 nm) and about one hundred fifty nanometers (150 nm).

10. The polycrystalline compact of claim 1, wherein the first plurality of grains of hard material and the second plurality of grains of hard material together comprise between about ninety-two percent by volume (92 vol%) and about ninety-nine percent by volume (99 vol%) of the first region.

11. The polycrystalline compact of claim 10, wherein the third plurality of grains of hard material comprises between about eighty percent by volume (80 vol%) and about ninety-one percent by volume (91 vol%) of the second region.

12. The polycrystalline compact of claim 11, wherein the third plurality of grains of hard material comprises between about eighty-five percent by volume (85 vol%) and about eighty-eight percent by volume (88 vol%) of the second region.

13. The polycrystalline compact of claim 12, wherein a remainder of the volume of the first region is at least substantially comprised by the catalyst material.

14. The polycrystalline compact of claim 13, wherein a remainder of the volume of the second region is at least substantially comprised by voids.

15. The polycrystalline compact of claim 1, wherein a first mean free path within the interstitial spaces between the inter-bonded grains of hard material of the first plurality of grains of hard material and the second plurality of grains of hard material in the first region is about ninety percent (90%) or less of a second mean free path within the interstitial spaces between the inter-bonded grains of hard material of the third plurality of grains of hard material in the second region.

16. The polycrystalline compact of claim 15, wherein the first mean free path is about seventy-five percent (75%) or less of the second mean free path.

17. The polycrystalline compact of claim 16, wherein the first mean free path is about fifty percent (50%) or less of the second mean free path.

18. The polycrystalline compact of claim 1, wherein the second region comprises a leached region of the hard polycrystalline material.

19. The polycrystalline compact of claim 1, wherein the catalyst material comprises cobalt or a cobalt-based alloy.

20. The polycrystalline compact of claim 1, wherein the hard material of at least one of the first plurality of grains of hard material, the second plurality of grains of hard material, and the third plurality of grains of hard material comprises diamond.

21. A polycrystalline compact, comprising:

a volume of polycrystalline diamond, comprising:

a first region adjacent a substrate and comprising:

a first plurality of diamond grains;

a second plurality of diamond grains having an average grain size of about five hundred nanometers (500 nm) or less disposed and interspersed between the grains of the first plurality of diamond grains, the first plurality of diamond grains and the second plurality of diamond grains being interspersed and inter-bonded; and

a catalyst material for catalyzing the formation of inter-granular diamond bonds disposed in interstitial spaces between the inter-bonded grains of the first plurality of diamond grains and the second plurality of diamond grains; and

a leached second region adjacent and directly bonded to the first region, the leached second region having a greater volume percentage of interstitial spaces than the first region and comprising inter-bonded diamond grains, the inter-bonded diamond grains of the leached second region comprising between about eighty percent (80%) and about ninety-two percent (92%) of a volume of the leached second region, voids in the interstitial spaces between the inter-bonded diamond grains of the leached second region at least substantially comprising a remainder of the volume of the leached second region.

22. A cutting element, comprising:

a cutting element substrate; and

a polycrystalline compact bonded to the cutting element substrate, the polycrystalline compact comprising:

a hard polycrystalline material, comprising:

a first region adjacent the cutting element substrate and comprising:

a first plurality of grains of hard material having a first average grain size;

a second plurality of grains of hard material having a second average grain size smaller than the first average grain size, the grains of the first plurality of grains of hard material and of the second plurality of grains of hard material being interspersed and inter-bonded; and

catalyst material for catalyzing the formation of inter-granular bonds between the grains of the first plurality of grains of hard material and of the second plurality of grains of hard material, the catalyst material disposed in interstitial spaces between the inter-bonded grains of hard material of the first plurality of grains of hard material and of the second plurality of grains of hard material; and

a second region adjacent and directly bonded to the first region along an interface between the first region and the second region, the second region having a smaller volume percentage of hard material than the first region and comprising a third plurality of grains of hard material having a third average grain size, the grains of the third plurality of grains of hard material being interspersed and inter-bonded, wherein interstitial spaces between the inter-bonded grains of the third plurality of grains of hard material are at least substantially free of catalyst material for catalyzing the formation of inter-granular bonds between the grains of the third plurality of grains of hard material.

23. An earth-boring tool, comprising:

a tool body; and

at least one cutting element attached to the tool body, the at least one cutting element comprising:

a polycrystalline compact comprising:

a hard polycrystalline material, comprising:

a first region adjacent the tool body and comprising:

a first plurality of grains of hard material having a first average grain size;

a second plurality of grains of hard material having a second average grain size smaller than the first average grain size, the grains of the first plurality of grains of hard material and of the second plurality of grains of hard material being interspersed and inter-bonded; and

catalyst material for catalyzing the formation of inter-granular bonds between the grains of the first plurality of grains of hard material and of the second plurality of grains of hard material, the catalyst material disposed in interstitial spaces between the inter-bonded grains of hard material of the first plurality of grains of hard material and of the second plurality of grains of hard material; and

a second region adjacent and directly bonded to the first region along an interface between the first region and the second region, the second region having a smaller volume percentage of hard material than the first region and comprising a third plurality of grains of hard material having a third average grain size, the grains of the third plurality of grains of hard material being interspersed and inter-bonded, wherein interstitial spaces between the inter-bonded grains of the third plurality of grains of hard material are at least substantially free of catalyst material for catalyzing the formation of inter-granular bonds between the grains of the third plurality of grains of hard material.

24. A method of forming a polycrystalline compact, comprising:

forming an unsintered compact preform, comprising:

mixing a first plurality of grains of hard material having a first average grain size with a second plurality of grains of hard material having a second average grain size smaller than the first average grain size to form a first particulate mixture; and

positioning a third plurality of grains of hard material having a third average grain size adjacent the first particulate mixture within a container;

sintering the compact preform at a pressure greater than about five gigapascals (5.0 GPa) and a temperature greater than about 1,300°C in the presence of a catalyst material for catalyzing the formation of inter-granular bonds between the grains of hard material of the first plurality of grains of hard material, the second plurality of grains of hard material, and the third plurality of grains of hard material, sintering the unsintered compact preform comprising forming a hard polycrystalline material having a first region comprising inter-bonded grains of hard material formed from the first plurality of grains of hard material and the second plurality of grains of hard material, and a second region having a smaller volume percentage of hard material than the first region and comprising inter-bonded grains of hard material formed from the third plurality of grains of hard material, the first region having a first density of the hard material higher than a second density of the hard material in the second region; and

removing catalyst material from interstitial spaces within the second region of the hard polycrystalline material without entirely removing catalyst material from interstitial spaces within the first region of the hard polycrystalline material.

25. The method of claim 24, wherein removing catalyst material from the interstitial spaces within the second region of the hard polycrystalline material without entirely removing catalyst material from the interstitial spaces within the first region of the hard polycrystalline material comprises leaching the catalyst material from the interstitial spaces within the second region of the hard polycrystalline material using a leaching fluid.

26. The method of claim 25, wherein removing catalyst material from the interstitial spaces within the second region of the hard polycrystalline material without entirely removing catalyst material from the interstitial spaces within the first region of the hard polycrystalline material further comprises impeding the flow of the leaching fluid through the first region of the hard polycrystalline material between the grains of the first plurality of hard material using grains of the second plurality of grains of hard material in the first region of the hard polycrystalline material as a barrier to the leaching fluid.

27. The method of claim 25, further comprising leaving the catalyst material within at least substantially all of the interstitial spaces within the first region of the hard polycrystalline material.

28. The method of claim 24, wherein forming the unsintered compact preform further comprises mixing particles of the catalyst material with the third plurality of grains of hard material prior to positioning the third plurality of grains of hard material adjacent the first particulate mixture within the container.

29. The method of claim 24, wherein sintering the compact preform at a pressure greater than about five gigapascals (5.0 GPa) and a temperature greater than about 1,300°C comprises sintering the compact preform at a pressure less than about six gigapascals (6.0 GPa).

30. The method of claim 24, wherein sintering the compact preform at a pressure greater than about five gigapascals (5.0 GPa) and a temperature greater than about 1,300°C comprises sintering the compact preform at a pressure greater than about six and one-half gigapascals (6.5 GPa).

31. The method of claim 30, wherein sintering the compact preform further comprises sintering the compact preform for less than about two minutes (2.0 min).