CLAIMS

1. A downhole tool, comprising:

a body made of a metal or metal alloy;

a coating disposed on the body;

wherein the coating includes at least 75 vol % tungsten carbide having an average grain size less than 1.0 μm;

wherein the content of tungsten carbide in the coating with a grain size less than 0.5 μm is between 40 and 64 vol % of the coating.

2. The downhole toolof claim 1, wherein the coating includes about 10 wt % cobalt and about 4 wt % chromium.

3. The downhole toolof claim 1, wherein the tungsten carbide has an average grain size between 0.4 and 0.8 μm.

4. The downhole toolof claim 3, wherein the content of tungsten carbide with a grain size less than 0.5 μm is between 44 and 64 vol % of the coating.

5. The downhole toolof claim 3, wherein the body is made of steel.

6. The downhole toolof claim 3, wherein the coating has a thickness between (about 0.005 cm) 0.002 and 0.020 in (about 0.05 cm).

7. A method for forming a protective coating on a downhole tool, the method comprising:

(a) feeding a metal powder to an HVOF thermal spray system;

(b) injecting the metal powder into a stream of gas to accelerate and at least partially melt the metal powder with the thermal spray system;

(c) depositing the metal powder on the downhole tool after (b) with the thermal spray system to form the coating on the downhole tool, wherein the coating comprises at least 75 vol % tungsten carbide and wherein the content of tungsten carbide in the coating having a grain size less than 0.5 μm between 40 and 64 vol % of the coating;

(d) depositing the metal powder on the downhole tool during (c) until the coating on the downhole tool has a thickness greater than 0.002 in (about 0.005 cm).

8. The method of claim 7, wherein the metal powder comprises about 10 wt % cobalt and about 4 wt % chromium.

9. The method of claim 8, wherein the average grain size of the tungsten carbide in the coating is less than 1.0 μm.

10. The method of claim 9, wherein the average grain size of the tungsten carbide in the coating is between 0.4 and 0.8 μm.

11. The method of claim 9, wherein the content of tungsten carbide in the coating having a grain size less than 0.5 μm is between 44 and 64 vol % of the coating.

12. The method of claim 10, further comprising cryogenically milling the metal powder before (a).

13. The method of claim 12, wherein the downhole tool comprises a mandrel or a bearing.

14. A drilling system, comprising:

a drill string extending downhole from the rig;

a downhole motor coupled to the drillstring, wherein the downhole motor includes a drive section coupled to a bearing assembly; and

a drill bit coupled to the downhole motor;

wherein the bearing assembly includes a housing and a mandrel rotatably supported within the housing;

wherein the mandrel includes a body and a protective coating deposited on an outer surface of the body;

wherein the coating comprises at least 75 vol % tungsten carbide having an average grain size less than 1.0 μm;

wherein the content of tungsten carbide in the coating having a grain size less than 0.5 μm is between 40 and 64 vol % of the coating.

15. The drilling system of claim 14, wherein the coating comprises about 10 wt % cobalt and about 4 wt % chromium.

16. The drilling system of claim 15, wherein the tungsten carbide has an average grain size between 0.4 and 0.8 μm.

17. The drilling system of claim 15, wherein the content of tungsten carbide with a grain size less than 0.5 μm in the coating is between 44 and 64 vol %.

18. The drilling system of claim 15, wherein the body of the mandrel is made of steel.

19. The drilling system of claim 15, wherein the coating has a thickness between 0.002 (about 0.005 cm) and 0.020 in (about 0.05 cm).