A method of coating metalworking tools with a thin uniform adherent layer of refractory carbide, e.g., titanium carbide, is disclosed. Such coating is applied by triode sputter deposition using a refractory carbide cathode and a tool substrate.

The invention described herein was made in the course of or under a contract with the United States Atomic Energy Commission.

BACKGROUND OF THE INVENTION

The coating of metalworking tools with titanium carbide greatly improves cutting, extruding and stamping properties of the tools. In use, these coated tools result in a reduction of cutting force and temperature rise which mean less wear and better surface finish. The high hardness and thermal conductivity of titanium carbide and other refractory carbides also contribute to superior cutting properties.

A conventional method of applying such a refractory carbide coating is that of chemical vapor deposition. For example, titanium tetrachloride is reacted with methane to produce titanium carbide and hydrochloric acid. The titanium carbide so formed is deposited out on the cutting tool surface. While providing an adherent coating of the refractory carbide on the cutting tool, the chemical vapor deposition process has some drawbacks. Hydrochloric acid is a by-product of the process and presents a serious corrosion problem. The substrate is known to pick up hydrogen and for many metals this can cause embrittlement. The process requires the cutting tool substrate to be maintained at temperatures of 900 to 1200° C. which limits the materials which can be coated. Also, the process takes a relatively long period of time, e.g., 8-10 hours.

It is an object of the present invention to provide a method of coating metalworking tools with a thin, uniform, adherent refractory carbide.

It is a further object of the present invention to provide a method of coating refractory carbides on tools which avoids the hydrochloric acid by-product, reduces hydrogen pickup, operates at lower temperatures and shorter times.

THE INVENTION

The present method is based upon the discovery that refractory carbides, such as titanium carbide, can be effectively coated on metalworking tool substrates by triode sputter deposition. Uniform adherent coatings on the order of from about 2 to about 10 microns can be applied to the tools using the present technique employing temperatures of from about 400-800° C. and times of about 2 to about 6 hours.

The present process involves providing, in a vacuum chamber, a refractory carbide target cathode, a metalworking tool substrate and a thermionic electrode; degassing the tool substrate; sputter cleaning the substrate and target cathode surfaces; and sputter depositing the target material onto the cutting tool substrate.

The figure is a drawing of one embodiment of equipment that can be utilized in the present method.

The metalworking tool substrate may be any particular tool used to cut or otherwise plastically deform materials. Such tools include tool bits, drill bits, cutting tool inserts, stamping tools and dies, extruding tools and dies, forming tools and dies, blades, files, and planes. Conventionally such tools are made from various tool steels or tungsten carbide. When tungsten carbide is used as a cutting tool substrate it is preferred that a post deposition heat treatment be carried out on such tools to stress relieve the coating.

In carrying out the present method the target cathode and substrate are positioned within a metal vacuum chamber opposite each other with the thermionic electrode disposed therebetween. Usually the target cathode is in the form of a rectangular or circular plate and the thermionic electrode in the form of a wire positioned between or about the target cathode and the tool substrate.

After a vacuum is drawn on the chamber containing the electrodes, the thermionic electrode is heated by applying a potential across the wire. A positive electrical bias is applied to the tool substrate to cause electrons from the heated electrode to bombarding heat the substrate. The cutting tool substrate is heated to a temperature of from about 400-800° C. whereby gases are removed from the tool. This step is carried out to enhance the adhesion between the cutting tool and the subsequently deposited cathode material.

Following the degassing process a low pressure gas is introduced into the chamber. A gas which is inert, i.e., unreactive with the materials of the cathode, substrate and thermionic electrode can be employed. A typical gas is argon.

The surfaces of the target cathode and substrate are then cleaned by applying a negative bias to the target cathode and the substrate, creating anions of the gas, and causing the gas anions to bombard the target cathode and substrate surfaces removing the surface layers. The amount of negative bias is preferably from about 1 to about 3 kilovolts. After the cleaning operation the amount of gas entering the chamber is reduced from about 10 to about 20 microns down to about 1 to about 5 microns. Such gas is ionized by electrons emitted from the thermionic electrode. A negative bias is now applied only to the target cathode, with the vacuum chamber at ground potential, to cause deposition of the refractory carbide on the cutting tool substrate. A negative bias is applied to the thermionic electrode. Preferably, the negative bias on the target cathode is from about 0.5 to about 2 kilovolts and the negative bias on the thermionic electrode is from about 50 to about 100 volts. A bias can be applied to the substrate for control of the structure of the coating.

As noted, where tungsten carbide is the substrate material it is advantageous to heat treat the coated cutting tool by, for example, applying a positive bias to the coated substrate to cause electrons from the thermionic electrode to bombarding the coated substrate. Heating the coated material for about one-half hour at 400-800° C. stress relieves the coating.

Cutting tools when treated in the prescribed manner have excellent cutting properties of wear resistance, tool force and surface finish. A uniform adherent coating of refractory carbide is achieved.

The figure describes an apparatus which can be employed in the present method. Such apparatus comprises a vacuum chamber 1 with a cover 2 sealed by gasket 3 and openings for gas inlet and vacuum control
A vacuum chamber similar to the one depicted in the figure was built with open ends for introduction of the ionizable gas and electrodes. A 6 inch diameter titanium carbide target was fitted into an opening in the top of the vacuum chamber with connections to a power supply and cooling system. Disposed below the titanium carbide target were several cutting tools placed on a substrate holder which was connected to a power supply. The metal vacuum chamber was used as the anode at ground potential during the deposition. A circular tungsten filament was inserted between the titanium carbide target and the cutting tool substrate. Both tungsten carbide and hardened tool steel were employed as substrate materials. A sputter deposition of about 1 to about 2 microns per hour.

In like manner other refractory carbides can be sputter deposited on various cutting tool surfaces. Such refractory carbides include silicon carbide, vanadium carbide, chromium carbide, zirconium carbide, molybdenum carbide, tantalum carbide, and other heavy metal and earth metal carbides. Also, other metal alloys possessing desirable cutting properties can be sputter deposited on cutting tool surfaces.

What is claimed is:

1. A method of coating a refractory carbide on a metalworking tool substrate which comprises:
   (a) positioning within a vacuum chamber a refractory carbide target cathode and a metalworking tool substrate in oppositely disposed spaced relationship, and disposed therebetween a thermionic electrode;
   (b) heating the thermionic electrode;
   (c) applying a positive bias to the substrate anode to cause electrons from the heated electrode to bombard and heat the substrate, thereby degassing the substrate;
   (d) introducing a low pressure gas into the chamber after turning off the thermionic electrode;
   (e) sputtering the surfaces of the target cathode and the substrate by applying a negative bias to said cathode and substrate to create gas anions and to cause the gas anions to bombard the cathode and substrate surfaces;
   (f) reducing the amount of gas entering the chamber;
   (g) reheating the thermionic electrode and applying a negative bias to said electrode;
   (h) ionizing the incoming gas by electrons emitted from the negatively biased thermionic electrode; and
   (i) applying a negative bias on the cathode with the vacuum chamber at ground potential to sputter deposit a coating of refractory carbide on the cutting tool substrate.

2. The method of claim 1 wherein the refractory carbide is titanium carbide.

3. The method of claim 1 wherein the thermionic electrode is tungsten.

4. The method of claim 1 wherein low pressure gas is argon.

5. The method of claim 1 wherein in step (c) the positive bias applied to the substrate is from about 0.5 to about 3 kilovolts.

6. The method of claim 1 wherein in step (d) the gas is introduced at a pressure in an amount of from about 10 to about 20 microns.

7. The method of claim 1 wherein in step (e) the negative bias applied to the substrate is from about 1 to about 2 kilovolts and to the target cathode is from about 2 to about 3 kilovolts.

8. The method of claim 1 wherein in step (f) the gas is reduced to a pressure of about 1 to about 3 microns from a pressure of about 10 to 20 microns.

9. The method of claim 1 wherein in step (i) the negative bias on the thermionic electrode is from about 50 to about 100 volts.

10. The method of claim 1 wherein in step (i) the negative bias on the target cathode is from about 0.5 to about 2 kilovolts.

11. The method of claim 1 wherein the coating of refractory carbide on the tool substrate has a thickness of from about 5 to about 10 microns.

12. The method of claim 1 wherein the tool substrate is made of tungsten carbide and including the additional step of heat treating the coated substrate by applying a positive bias to the coated substrate to cause electrons from the heated electrode to bombard the coated substrate.

References Cited

UNITED STATES PATENTS
3,021,271 2/1967 Wehner 204—192
3,451,917 6/1969 Moisson 204—192

OTHER REFERENCES


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