Technology Summary: Diamond Coating on Steel Substrate

Opportunity Statement

Numerous advances have been made in the diamond coating of metals, glass, ceramics, and plastics using various techniques, such as chemical vapor deposition (CVD), plasma-assisted vapor deposition, and ion-beam-enhanced deposition. Particularly in the tooling industry, diamond-coated, hard-alloy tools have been well developed and commercialized. However, one major disadvantage of hard-alloy tools is that the cost may be high compared to other more easily available materials, such as steel.

Alloy steels are among the most commonly used and cost-effective structural materials in modern industry. However, when steel is used for critical wear-resistant components and machining tools in harsh (wear, corrosive and erosive) environments, accelerated damage usually occurs. Well-adhered diamond films deposited on steel surfaces can lead to major improvements in the life and performance of steel tools, resulting in a cost-effective substitute for hard alloys and other expensive tool materials.

Problem

Despite their great industrial potential, the development of diamond-coated steel tools has been limited due to difficulties in achieving satisfactory diamond film adhesion to the steels resulting from several limiting factors. These factors include:

a. The high solubility of carbon in the iron face-centered cubic phase leads to prolonged diamond nucleation times.
b. Iron catalyzes graphite formation at the diamond-steel interfaces during the CVD process.
c. The coefficients of thermal expansion of diamond and steel differ by one order of magnitude, resulting in great stress in the diamond film during the heating and cooling processes.

Therefore, there is a need for a solution that overcomes the challenges of depositing diamond film on steel substrates and provides a cost-effective substitute for diamond-coated, hard-alloy tools.

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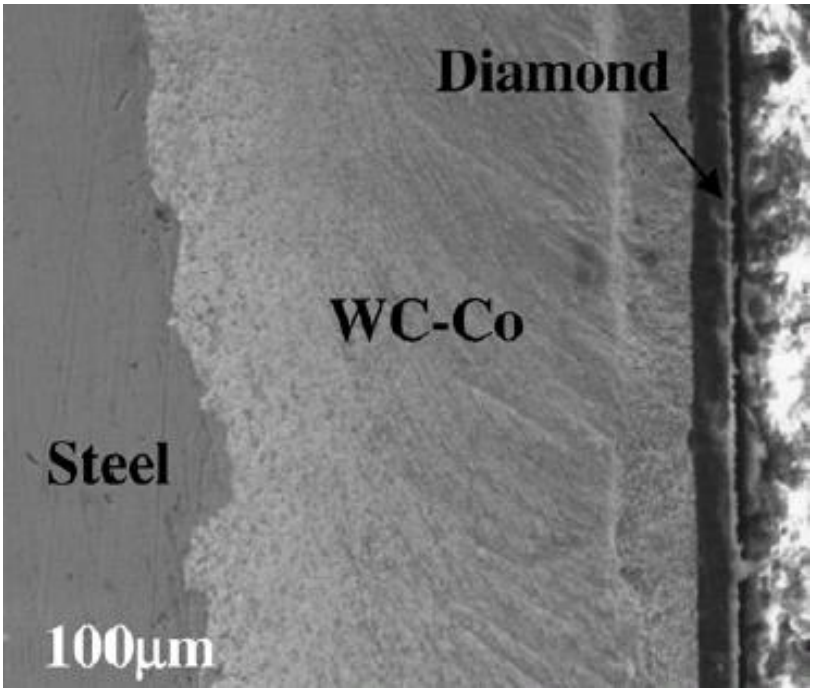
360ip Partner's Solution

360ip's partner for this opportunity is Central South University (CSU), the #1-ranked applied research university in China. The technology developed by CSU uses a tungsten carbide-cobalt (WC-Co) intermediate layer prior to diamond film deposition. The addition of this intermediate layer eliminates the negative effects of diamond-on-steel deposition, increases the hardness and wear-resistance of steel, and reduces the stress caused by the different thermal expansion coefficients of the steel substrate and diamond film. The diamond film-coated steel substrate composite material produced by using the CSU technology has the following characteristics:

a. It is composed of three layers: a steel substrate, a WC-Co intermediate layer (2~100 μm), and a diamond super-hard, wear-resistant outer layer.
b. The WC-Co intermediate layer contains cobalt with a mass ratio of 1~30% with the remainder composed of tungsten carbide.
c. The atomic ratio of W to C in tungsten carbide is from 1:1 to 3:1.
d. The phases included in tungsten carbide include one or several of WC, W2C, W3C and WC1-x (where x is in the range of 0.34~0.43), in which WC takes a mass ratio of 50%~100%, with the remainder as one or several of W2C, W3C and WC1-x.
e. The diamond super-hard, wear-resistant layer has a thickness of 1~300 μm.



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The key advantages associated with this technology include:

- High bonding strength between the diamond film and the steel substrate.
- Steel substrate tools provide overall better mechanical properties.
- Less expensive than tools based on hard alloys or ceramics.
- Effectively enhances the nucleation density of the diamond, and achieves a compact nano-diamond coating.
- The WC-Co intermediate layer is very compact and the particle diameters can be controlled at the nanoscale.

Patents

CSU has filed one patent application on this invention.

Summary

360ip's partner, CSU, has developed a solution that enables the deposition of diamond on steel, resulting in a substitute for diamond-coated, hard-alloy tools that is cost-effective and has better mechanical properties.

360ip is seeking interested parties for the licensing, further development and commercialization of this technology-based solution.

For additional information, contact: licensing@360ip.com