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Novel Composite CBN-TiN Coating: Synthesis and Performance Analysis

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Abstract

Cubic boron nitride (CBN) coating, due to its promising properties, is under development worldwide for machining and other related applications. To synthesize a continuous CBN coating by conventional vapor deposition methods (CVD/PVD), however, poses many challenges, such as metastable CBN phase stabilization, as well as the high levels of intrinsic stress developed during the growth. A novel *combinatorial* approach, which is under development in an effort to develop a CBN composite coating for cutting tools, is reported in this paper. The approach involves a two-step process consisting of electrostatic spray coating (ESC) of CBN particles, followed by chemical vapor infiltration (CVI) of TiN. The process is optimized to deposit a CBN-TiN composite coating with a thickness in excess of 10 μm on tungsten carbide inserts. Such coated tools have been successfully evaluated and tested for machining applications. For production on a commercial scale, the laboratory systems have been upgraded to industrial size. The outcome of scaling up from an experimental to an industrial-sized unit is reported in this paper. The industrial electrostatic spray coating unit, which can coat a batch of about 50 inserts in a couple of minutes, is currently being field tested.

Keywords: *CBN, Cutting Tool Coatings, Tool Inserts*

Introduction

Cubic boron nitride (CBN), a man-made material, is known to be the second hardest material to diamond. Because of their outstanding properties, diamond and CBN compacts have been used in the tool industry for machining applications. Due to the aggressive reaction of diamond with iron at high temperatures typically found in cutting processes, diamond cannot be applied effectively to the machining of ferrous alloys. CBN, on the other hand, has outstanding thermal stability and chemical inertness when used for machining ferrous alloys. Of the total worldwide metal machining market, diamond is a potential candidate for ~25% of the nonferrous market whereas CBN tools are potential candidate for the rest of the ~75% of the ferrous alloy market. Thus, diamond and boron nitride based tools complement each other in machining applications. However, CBN is currently being used as polycrystalline cubic boron nitride (PCBN) compacts, catering to limited applications as a cutting tool for machining ferrous alloys. Due to the structural rigidity and limitations of the forming methods for PCBN compacts, they cannot be manufactured in required complex geometries like chip-breaking cutting tools, rotary tools, and other complex shapes. Successful development of a cubic boron nitride coating technology would allow for the incorporation of such complex shapes and, thus, further broaden the application spectrum. Presently, there is limited success in using conventional vapor coating technologies for depositing continuous and homogenous CBN phase in thin film form. (Mirkarimi et al. 1996; Robertson 1996; Yoshida 1997).

CBN Coated Tools

CBN-composite coated tools can be a significant product, when available commercially, for surface finishing applications in the ferrous metal machining industry and would complement the PCBN compact tools used for coarse machining. Success of a novel combinatorial process, such as the one developed at the Materials and Manufacturing Research Laboratories (MRL) at the University of Arkansas and discussed elsewhere (Malshe et al. 2000, 2001), allows for the possibility of synthesizing such complex shaped carbide inserts with using a composite CBN coating. The process uses two different techniques, namely, electrostatic spray coating (ESC) and chemical vapor infiltration (CVI), to obtain a CBN-

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TiN composite coated tool. The schematic in *Figure 1* explains the scheme.
Because both ESC and CVI are not line-of-sight processes, they can be combined to coat parts of complex shape and/or geometry, or multiple-faced tools.

Hybrid Technology and Composite Coating

The technology discussed in this section is a result of successful collaborative research and development between MRL at the University of Arkansas and Materials Research and Development (MRD) at Valenite, Inc. (Troy, MI), with a common goal of synthesizing a CBN coating for cutting tools. The approach reported here starts with fine micron-sized CBN powder and applies it as a particulate coating instead of growing CBN from the vapor phase (*Figure 1*). An appropriately modified conventional coating method is then used to fix the CBN particles in a matrix and bind them with excellent adhesion to the substrate.

The first step is electrostatic spray coating (ESC), which takes an advantage of insulating CBN powder particles being able to carry a static charge over a distance of a few tens (tenths?) of centimeters. The electrostatic charge is generated on the particles, which are fed through an electrostatic spray gun, by applying a high voltage to a gun electrode (typically a few tens (tenths?) of kilovolts) with respect to the electrically grounded tool substrates. The charged CBN particles follow the electric field lines toward the grounded substrates, which are coated. Because the powder particles follow the field lines emanating from the entire surface of the grounded objects, the spray coating is formed over the entire substrate surface.

A number of process variables, such as powder quantity, particle size, spray gun voltage, distance between gun electrode and substrate, and main air pressure used to pump and fluidize the CBN powder, were considered during initial coating experiments. The electrostatic spray coating process variables were further optimized using a matrix of experiments (Yedave et al. 2001). A cross section of a typical ESC CBN coating layer on a cutting tool appears as shown in *Figure 2*, which shows CBN particles stacked as a continuous layer on the surface of a tool. As seen in *Figure 2*, the stacking of one on top of another is so uniform that a surprisingly smooth layer of particles can be deposited across the surface of the tool. However, these particles are only loosely bound to each other and to the substrate by the electrostatic force of attraction.

Chemical vapor infiltration (CVI) follows as the second step in realizing the composite CBN-TiN coating on a tool substrate. This process is used in many applications in different industries but was developed by MRD, Valenite, Inc., for this particular application. The details of the CVI process are described in elsewhere (Russell et al. 2001). CVI is a controlled process that is closely related to the commonly known chemical vapor deposition (CVD) process. The same equipment is used for both processes (Panitz et al. 1994). The infiltration of titanium ni-

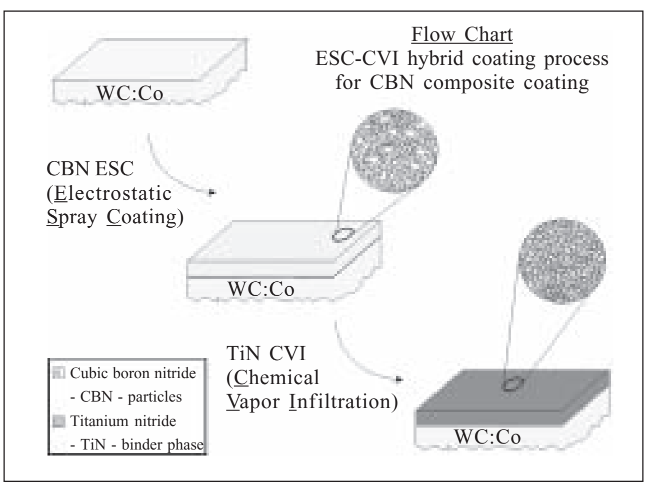

Figure 1
Schematic of ESC-CVI Hybrid Technology for CBN Composite Coating

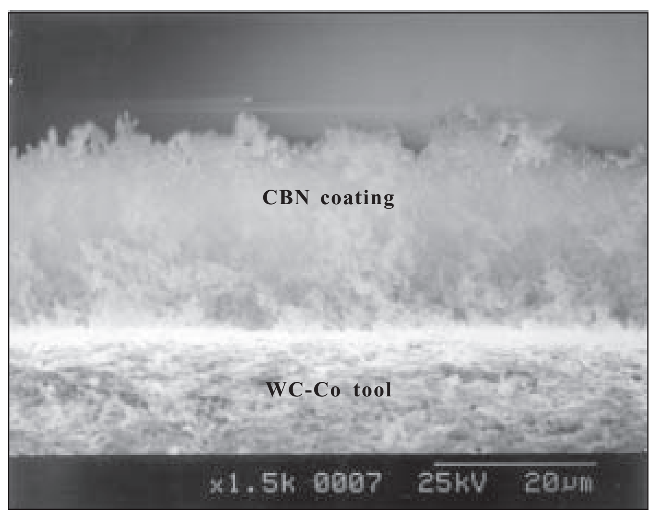

Figure 2
SEM Cross Section of ESC Deposited CBN Particulate Spray Coating on Carbide Tool (1500X)