Available online at www.sciencedirect.com
ScienceDirect
Diamond & Related Materials 16 (2007) 481–485
DIAMOND AND RELATED MATERIALS
www.elsevier.com/locate/diamond

Deposition and characterization of nanocrystalline diamond films on Co-cemented tungsten carbide inserts

Y.P. Ma *, F.H. Sun, H.G. Xue, Z.M. Zhang, M. Chen

School of Mechanical Engineering, Shanghai Jiao Tong University, Huashan road 1954, Shanghai 200030, P.R. China

Received 8 March 2006; received in revised form 30 August 2006; accepted 25 September 2006
Available online 14 November 2006

Abstract

Nanocrystalline diamond films were deposited on Co-cemented tungsten carbides using bias-enhanced hot filament CVD system with a mixture of acetone, H_2 and Ar as the reactant gas. The effect of Ar concentration on the grain size of diamond films and diamond orientation was investigated. Nanocrystalline diamond films were characterized with field emission scan electron microscopy (FE-SEM), Atomic force microscopy (AFM), Raman spectroscopy and X-ray diffraction spectroscopy (XRD). Rockwell C indentation tests were conducted to evaluate the adhesion between diamond films and the substrates. The results demonstrated that when the Ar concentration was 90%, the diamond films exhibited rounded fine grains with an average grain size of approximately 60–80 nm. The Raman spectra showed broadened carbon peaks at 1350 cm^{-1} and 1580 cm^{-1} assigned to D and G bands and an intense broad Raman band near 1140 cm^{-1} attributed to *trans*-polyacetylene, which confirmed the presence of the nanocrystalline diamond phase. The full width at half maximum of the <111> diamond peak (0.8°) was far broader than that of conventional diamond film (0.28°–0.3°). The Ra and RMS surface roughness of the nanocrystalline diamond film were measured to be approximately 202 nm and 280 nm with 4 mm scanning length, respectively. The Ar concentration in the reactant gases played an important role in the control of grain size and surface roughness of the diamond films. Nanocrystalline diamond-coated cemented tungsten carbides with very smooth surface have excellent characteristics, which made them a promising material for the development of high performance cutting tools and wear resistance components.

Keywords: Nanocrystalline diamond films; Co-cemented tungsten carbides; Surface roughness; Bias-enhanced HFCVD

1. Introduction

At present, the substrate materials of cutting tools, drawing dies, sliding bearings and many kinds of wear resistant components are mostly Co-cemented carbide inserts (WC-Co). These conventional parts are worn seriously and have a short working lifetime, thus they cannot satisfy the demands of high efficiency machining. An effective method for improving these problems is to deposit diamond thin films on Co-cemented carbide inserts. Diamond-coated cemented carbide tools are suitable for high efficiency and precision machining non-ferrous metals and alloys, metal-compound materials, and hard brittle non-metals (e.g. ceramics, graphite, reinforced plastics).The practical application shows that the tool life of diamond-coated cutting tools is increased remarkably in comparison with uncoated ones [1–3]. In contrast with other types of diamond tools, the thin film diamond-coated cutting inserts have great potentialities in the commercial application because of its low costs and high performance. Due to these unique characteristics of diamond films, the CVD diamond films have wide application in the cutting tools and wear resistance components.

However, synthetic diamond films deposited by conventional CVD processes have a very rough surface, which will cause a

Table 1
Typical deposition parameters of nanocrystalline diamond film

Parameters	Nanocrystalline
Acetone concentration	1%
Pressure [Torr]	20
Substrate temperature [°C]	850
Filament temperature [°C]	2100±200
Bias current [A]	About 3 A
Ar concentration	40–90%
Deposition time [h]	4

* Corresponding author.
E-mail address: yupingma@sjtu.edu.cn (Y.P. Ma).

0925-9635/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.diamond.2006.09.020

large effect on the machining precision and are not appropriate for many applications. In order to improve the surface roughness of diamond films, it would be better to concentrate on growing naturally smooth films on Co-cemented carbide inserts. Nanocrystalline diamond films have been taken into much consideration because of their smooth surface. Compared with the conventional diamond films, nanocrystalline diamond films have many outstanding properties, such as fine grains, very smooth and uniform surface, low friction coefficient, which make them a promising candidate for applications including, tribological devices, wear resistant, fine machining tools and drawing dies, etc.

Extensive study on deposition of nanocrystalline diamond films has been carried out. Plenty of studies on the nanocrystalline diamond films grown on N-type Si wafers, P-type Si single crystal wafers, Si_3N_4 substrates using CH_4/H_2/Ar gas mixture were also carried out. The grain size ranged from 3 nm to 30 nm and the Ra or RMS surface roughness was less than 40 nm [4–15].

Although many researchers have studied the deposition of nanocrystalline diamond films and their quality and tribological performance, the substrates were mostly Si wafers, sintered SiC, Si_3N_4, quartz, etc and the application was in optical, tribological or micro-electrical fields [4,11–18]. Little study on deposition

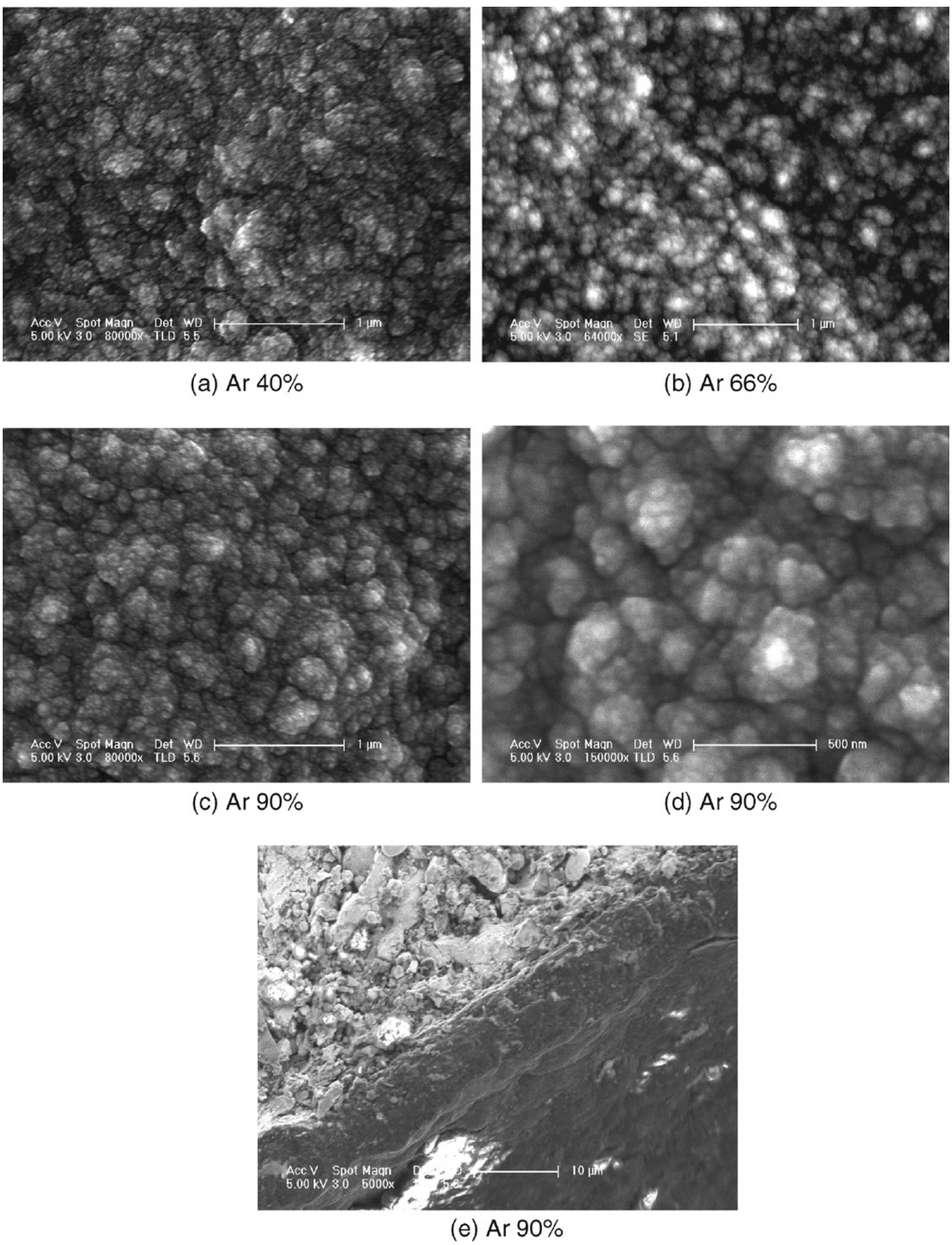

Fig. 1. Surface and cross-sectional FE-SEM morphologies of diamond films as a function of Ar concentration in the processing gases with acetone concentration kept at 1%.