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ADHESION STRENGTH OF DIAMOND COATED WC-Co TOOLS USING MICROWAVE PLASMA CVD

Nobumichi KIYAMA*, Yukihiro SAKAMOTO and Matsufumi TAKAYA****

Chiba Institute of Technology, Graduate School,*
*Chiba Institute of Technology***

ABSTRACT

To apply the CVD diamond film to coated tools, it is necessary to make adhesion strength between diamond film and substrate stronger. So adhesion strength of diamond coated WC-Co tools using Microwave Plasma CVD and cutting test of Al-18mass%Si alloy using diamond cutting tools were studied.

Diamond coating was carried out using Microwave Plasma CVD apparatus. Reaction gas was used mixture of methane and hydrogen. Substrate temperature were varied from 673K to 1173K by control of microwave output power and reaction pressure.

By observation of SEM, grain size became larger and larger as substrate temperature became higher and higher. Also all deposits were covered with clear diamond crystals. XRD results, the deposits were identified to cubic diamond. An analysis using Raman spectroscopy, the deposit synthesized at lower substrate temperature (673K) showed higher quality than deposit synthesized at higher substrate temperature (1173K). As a result of scratch adhesion strength test, from 873K to 1173K adhesion strength decreased by rising of substrate temperature. The deposit synthesized at 873K showed best adhesion strength. In the cutting test of Al-18mass%Si alloy using diamond coated tools and the surface machinability of Al-Si works turned with diamond coating tools which synthesized at 873K presented uniform roughness.

Cutting performance of Al-18mass%Si alloys using diamond coated WC-Co tools related to the adhesion strength.

INTRODUCTION

Diamond has special properties such as high hardness, good thermal conductivity, and chemical stability which suitable for cutting tools. The problem for application of CVD diamond is low adhesion strength between diamond film and substrate[1-3].

In this paper, investigation was carried out on improvement adhesion strength of CVD diamond coated tool. Diamond synthesized on WC-Co substrates in the range of from 673K to 1173K substrate temperature and growth state were estimated. Also adhesion strength of diamond coated WC-Co tools and cutting performance test of Al-18mass%Si alloy using diamond coated cutting tools were studied.

EXPERIMENTAL PROCEDURE

Diamond was deposited by microwave Plasma CVD. Reaction gas was used mixture of methane and hydrogen. WC-6mass%Co (Ra=0.3㎛) was used for substrate materials. For pretreatment scratch treatment in the supersonic wave bath after Co removal in the 50vol%HNO_3-H_2O solution for 10 minutes. Substrate temperature were varied from 673K to 1173K by control of microwave output power and reaction pressure. Film thickness were deposited to 1㎛ and 2㎛ control of reaction time. Table 1 shows experimental condition for diamond de8position. The surface morphology of diamond deposits were estimated by scanning electron microscopy, these structure were characterized with X-ray diffraction and Raman spectroscopy. The adhesion strength of the diamond films were determined by a scratch tester[4]. Table 2 shows experimental condition for scratch test. Critical load (Lc) point was determined by observation of microscope and calculated from the length of scratched mark. Diamond coated WC-Co tools synthesized at 673K, 873K, and 1173K substrate temper ature, non coated WC-Co tools, and diamond compact tool were used in cutting performance test of Al-18mass%Si alloys. After cutting test, peeling state of diamond film, wear oftools, and surface roughness of cutting works were estimated. Chemical components of cutting works are showed in Table 3 and cutting condition is showed in Table 4, respectively.

Table 1 Experimental condition for diamond deposition.

Substrate material	WC-6%Co(TH-10)
Surface roughness	0.3㎛Ra
Pretreatment	Co removal, Scratch
Methane flow rate(SCCM)	2, 4
Hydrogen flow rate(SCCM)	100, 196
Microwave power(W)	280~500
Pressure(Pa)	$1.3\sim6.7\times10^3$
Substrate temperture(K)	673~1173
Reaction time(h)	1.5~40

Table 2 Experimental condition for scratch test

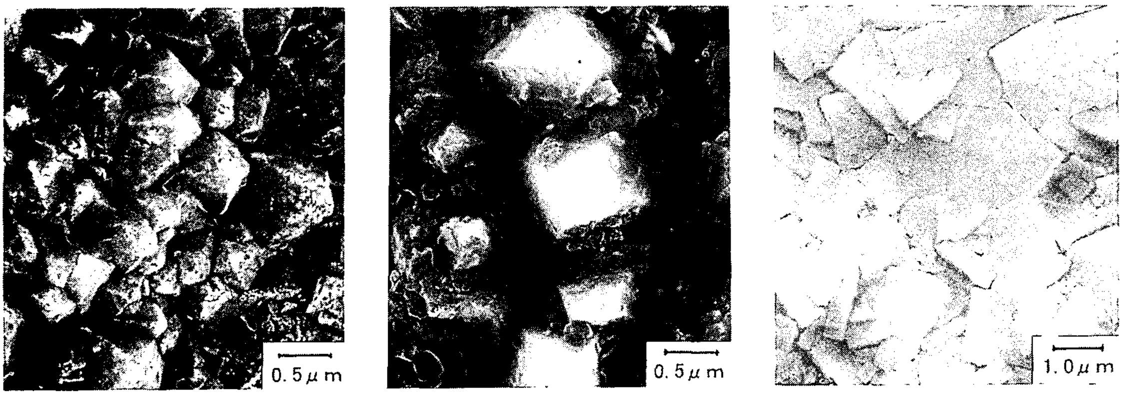
Z axis scratch speed(mm/min.)	5
Z axis load Speed(N/min.)	98
Y axis scratch speed(mm/min.)	5

Table 3 Chemical component of cutting work.

	Chemical component(%)				
	Si	Cu	Ni	Mg	Al
AC9B	18 ~ 20	0.50 ~ 1.5	0.50 ~ 1.5	0.50 ~ 1.5	Rest

Table 4 Cutting condition for A1-18mass% Si alloy

Cutting speed(m/min.)	200
Feed rate(mm/rev.)	0.1
Depth of cut(mm)	0.5
Cutting fiuld	Dry
Work	AC9B-T6(JIS)



(a) (b) (c)

Fig. 1 SEM images of defopsits on the WC-Co substrates with each substrate temperatures.
(a) 673K, (b) 873K, (c) 1173K

RESULT AND DISCUSSION

Diamond synthesize

SEM images of the deposits on the scraxtched WC-Co substrate with each subsxtrate temperatures were showed in figure 1. (a) is 40 hours reaction time at 673K, (b) is 17 hours at 873K, and (c) is 3 hours at 1173K, respectively. These thickness of diamond films were about 2㎛. On the each substrate temperatures, diamond films which covered with clear diamond crystals. Grain size of films became larger and larger as substrate temperature became higher and higher. In the deposits which synthesized from 673K to 1073K substrate temperature appearance planes are diamond (111), but the deposit at 1173K showed preferential orientation to diamond (100).

Figure 2 shows XRD patterns of the deposit on the WC-Co substrate. Diamond (111), (220), (311), and (400) peaks with WC peaks are detected in the XRD patterns of the deposits at each substrate temperature.

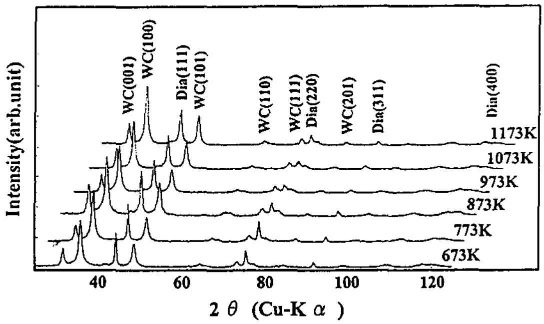


Fig. 2 XRD patterns of the deposits on the WC-Co sub strates with each each substrate temperature.

Figure 3 shows Raman Spectra of the deposits on the WC-Co substrate. Diamond peak at 1333cm^{-1}, graphite peak, and α-C peak are obtained from synthesized at 1173K. Diamond peak and broad DLC peak are obtained from the deposits at 673K and 873K. However, the quality of deposit at 673K is better than the deposit at 873K, because diamond peak is sharp as back ground of spectrum is low. This phenomena may be causing by diffusion of Co to diamond sub-

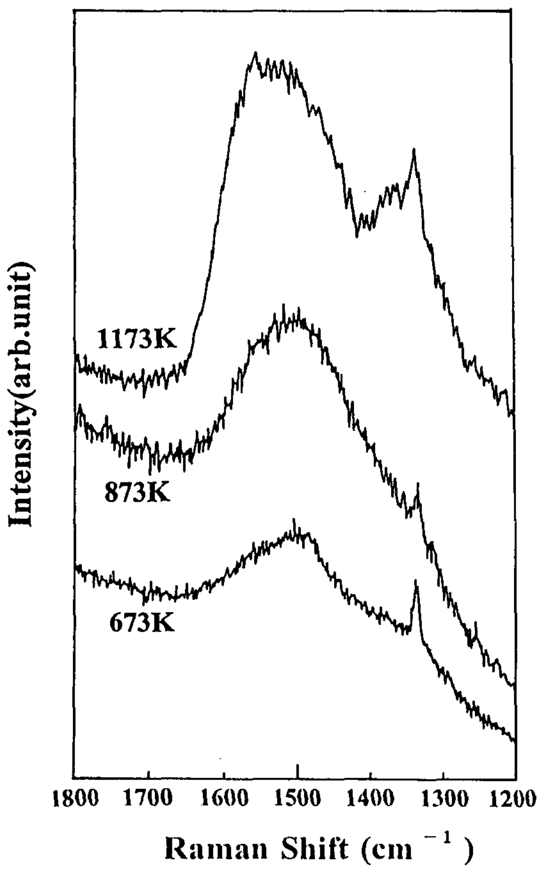


Fig. 3 Raman spectra of the deposits on the WC-Co substrates with substrate temperature

strate interface accompanied with rising substrate temperature.

Adhesion strength of diamond film

Figure 4 shows relationship between substrate temperature during synthesize and adhesion strength. Both 1μm and 2μm film thickness, adhesion strength of the deposit at 873K showed best. Adhesion strength between diamond film and substrate synthesized at near 873K is two times higher than that of synthesized at 1173K.

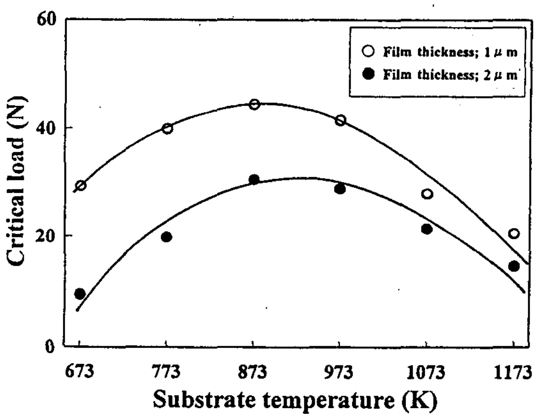


Fig. 4 Relationship between substrate temperature and adhesion strengh.

Cutting performance of diamond coated WC-Co tools

Figure 5 shows SEM images of diamond coated tools after 800m cutting. (a) is nose of the tool deposited at 673K, (b) at 873K, and (c) at 1173K. Peeling off of diamond film at the nose observed in (a), but cutting test could be continued. However, no peeling off was observed in (b). In (c) image is observed sticking of works after peeling off of diamond.

Figure 6 shows surface roughness of cutting works machined with each diamond coated tools. Surface roughness machined with the tool deposited at 673K shows 3.2μmRmax, at 873K shows same at 673K of 3.2μmRmax, these graphical shape of the roughness is regular and unified. Therefore, surface roughness machined with the tool deposited at 1173K become worse at 4.0μmRmax.

As result, diamond coated tools synthesized at 873K showed best cutting performance and the surface machinability of Al-18mass%Si works turned with diamond coating tools which synthesized at 873K presented

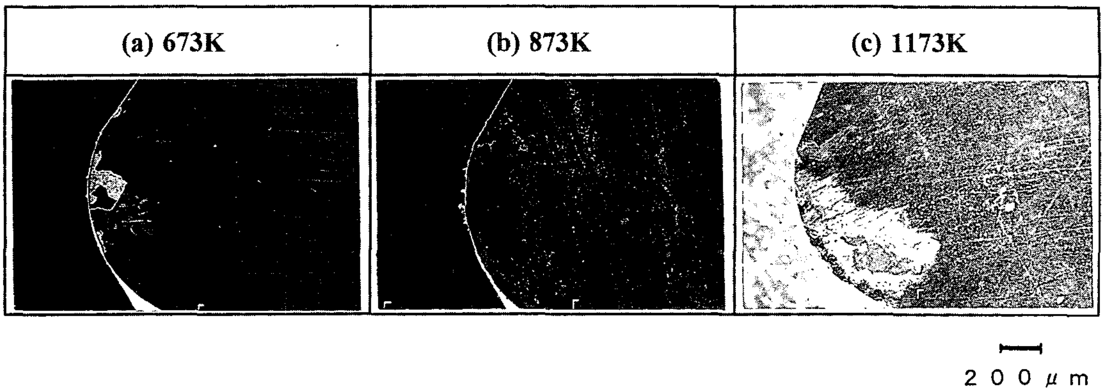


Fig. 5 i1<SEM images of the diamond coated WC-Co tools after 800m cutting. (a) 673K, (b) 873K, and (c) 1173k

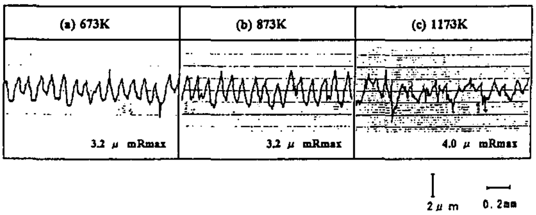


Fig. 6 Fig. 6 Surface roughness of the cutting works machined by diamond coated tools after 800m cutting. (a) 673K, (b) 873K, and (c) 1173K

uniform roughness. Cutting performance of Al-18mass%Si alloys using diamond coated WC-Co tools related to the adhesion strength.

CONCLUSIONS

Investigation results of diamond synthesize on the WC-Co substrate using microwave plasma CVD, measurement of adhesion strength by scratch tester, and cutting test of Al-18mass%Si alloys are follows,

1) Diamond film which covered with clear diamond crystals can be synthesized on WC-Co substrate.

2) Grain size of diamond films synthesized at low temperature became small.

3) Diamond film synthesized at 873K showed best adhesion strength.

4) Cutting performance of Al-18mass%Si alloys using diamond coated WC-Co tools related to the adhesion strength.

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