

# Cutting performance of CrAlSiN- coated router on the PCB board

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**Abstract.** The machining performance of the CrAlSiN coating deposited on the micro router was evaluated by cutting printed circuit board (PCB). Two CrAlSiN coating systems, including commercial one and the one by pulsed cathodic arc evaporation (CAE) technology were deposited. The arc source current input is set by modulating the arc source current in the range of 90 and 120A, as compared to the constant current of 90A. CrAlSiN coating with the pulsed current input presents the highest hardness which is triple times higher than that of tool material. After the cutting PCB in dry condition, the microtool with CrAlSiN coating deposited by pulsed arc current exhibited the best cutting performance related to the cutting distance.

## 1. Introduction

In the past decades, CrAlSiN coatings known with unique composite structure and excellent mechanical properties have attracted an increasing interest in fields of machining applications [1]. CrAlSiN coating featured with high hardness and better oxidation resistance is widely applied to the cutting tools. One of the advantages of CrAlSiN is attributable to the formation of protective phases of Al<sub>2</sub>O<sub>3</sub>, Cr<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub> above the surface retarding the oxidation of the coating [2-6].

Under increasing demand to further improve the efficiency of cutting tool, searching for modified coating materials and the coating synthesis process is progressive until now. The pulsed cathodic arc deposition technology is one of the most efficient cathodic arc evaporation (CAE) techniques to modify hard coatings for cutting tools [7-14]. A novel concept of pulsed current input of the sources has been developed with the advantages of higher ionization and deposition rate as compared with conventional arc deposited coatings. The cutting tool for machining printed circuit board (PCB) is gaining interest among the research groups. Therefore, the aim of the research presented here is to show the excellent performance of the CrAlSiN coating on the micro router. By using the above-mentioned pulsed current concept of the CAE technology, the CrAlSiN coatings were investigated to further improve the machining performance.

## 2. Experimental

CrAlSiN coating deposited on microtool specimens made of tungsten carbide was carried out by using CAE technology. The microtool is so called router which is used to trench the PCB. The micro router dimension of the blade area used in this study is 1.2 mm in diameter and 10 mm long, as shown in Fig. 1. The CAE system consists of two sets of standard cathodic arc ion evaporators, auxiliary a circular substrate holder connected with bias power supply. Chromium targets (purity: 99.9%) and Cr<sub>30</sub>Al<sub>60</sub>Si<sub>10</sub> ((purity: 99.9 at.%) targets were used as source materials, respectively. The samples were thus coated

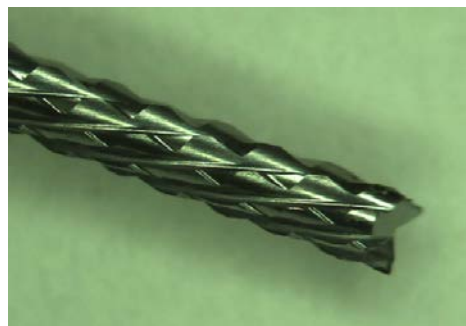


with one commercial process and the other one coated by pulsed CAE process. The pulsed arc source input is set by modulating the current in the range of 90 and 120A.

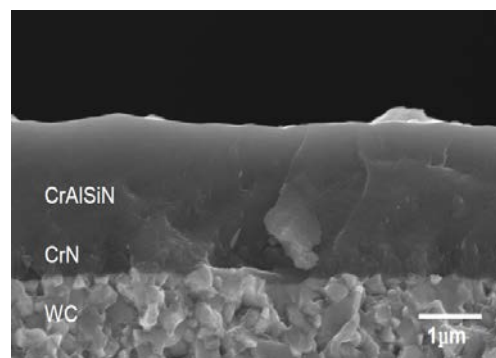
The surface morphologies of the coatings were observed by scanning electron microscopy (FE-SEM, model JOEL JSM-5600) and the thickness of the films were measured from fractured tool by observation of cross section area. The composition of the coatings is analyzed by using energy dispersive spectrometer (EDS). The hardness of coatings was measured in a Vicker's indentation equipment with the applied load 25g. Three kinds of the samples were compared by machining the PCB in dry condition. One is blank tool which has no coating on top. The other two are one coated with commercial CrAlSiN coating and the other one coated by above mentioned pulsed CAE technology. After the cutting test, the PCB boards were to be compared via the cutting distance observed by optical microscope.

### 3. Results and Discussion

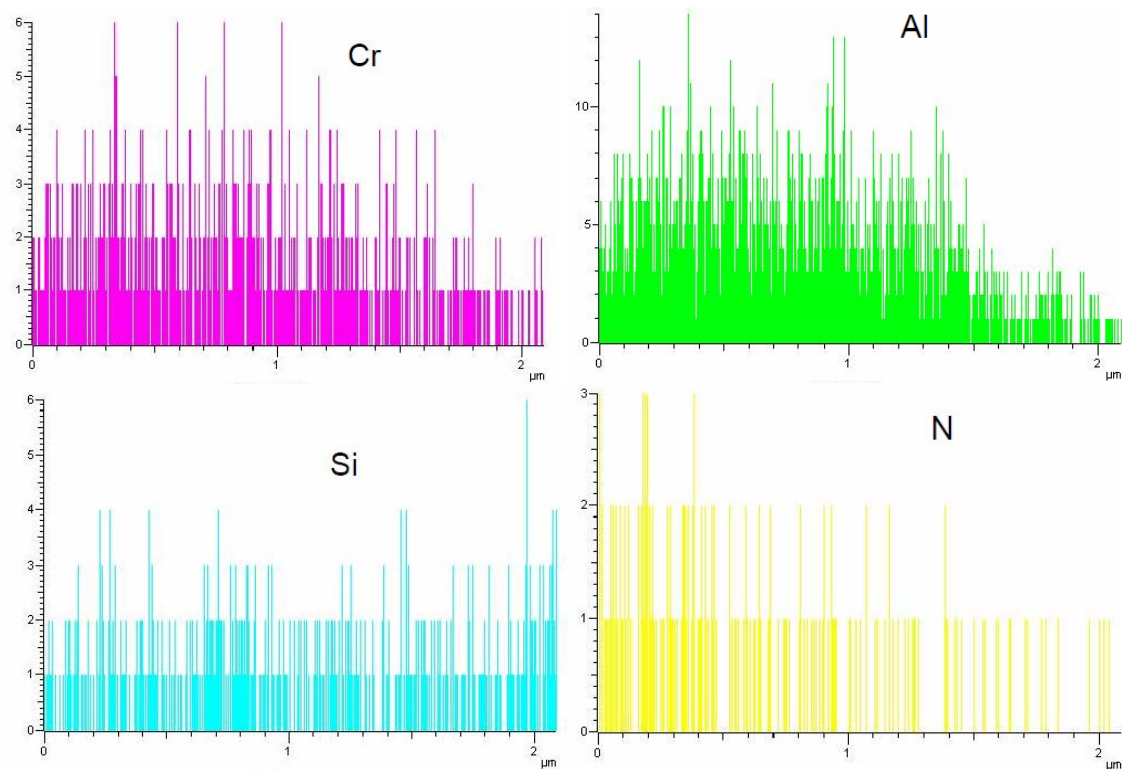
Fig. 2 shows the cross-section area observation of the CrAlSiN coating which reveals the thickness of the coatings about 2.1  $\mu\text{m}$ . The SEM micrographs of the coating shows a columnar morphology of CrN bond layer and a much dense morphology of CrAlSiN top layer as compared to the CrN. Previous works of the others [7-9], comparison of the d.c. and the pulsed processes, using the modified pulsed arc technique led higher ion current density related to the d.c. process. Therefore, pulsed CAE leads to the denser structure of the CrAlSiN top layer. The presence of CrAlSiN layer was verified by EDS scanning analysis showing the composition of the coating (Fig. 3). The composition ratio of the CrAlSiN is 18.2 of Cr, 31.1 of Al, 5.5 of Si and 45.2 of N ( at.%), respectively. The rich Cr and Al element profiles confirm the CrAlSiN top layer. The metal / total ratio is about 50% which means FCC structure preferable. The hardness of the pulsed CrAlSiN coating is about HV3300 which is slightly higher than that of commercial CrAlSiN coating and about triple times of that of tungsten carbide substrate. The advantage of the modified pulsed arc process results in increasing of the coating hardness.



**Figure 1 .** Optical microscope observation of the microtool (router) with 1.2 mm in diameter and 10 mm long

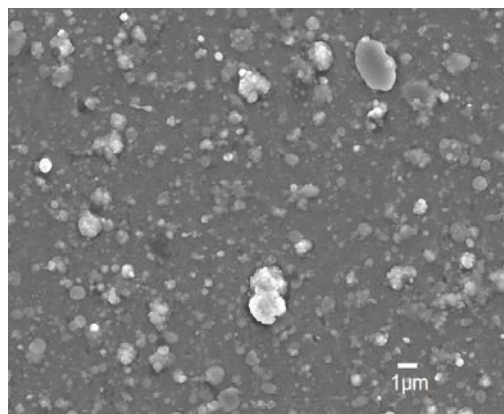


**Figure 2 .** SEM observation of fractured CrAlSiN coating on tungsten carbide substrate

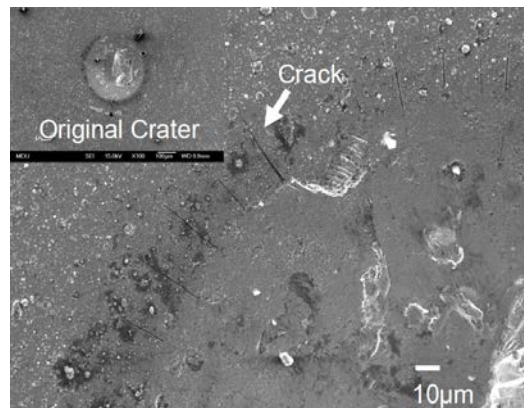


**Figure 3.** The EDS analysis of the CrAlSiN coating

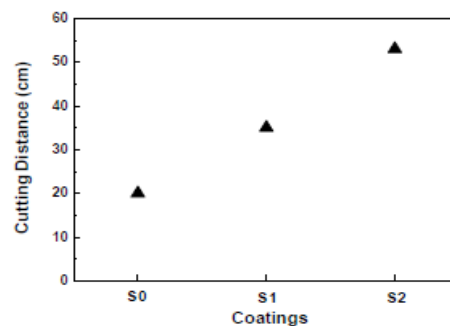
Surface morphology of the CrAlSiN coating examined by SEM was shown in Fig. 4. Due to the disadvantage of the cathodic arc deposition method, the droplets formed during deposition from the CrAlSi cathode are randomly distributed on the coating surface in small sizes, varying from a fraction of a micrometer to 3  $\mu\text{m}$ . The presence of these droplets leads to rougher surface of about  $R_a$  0.21  $\mu\text{m}$  of conventional CrAlSiN coating. However, better surface roughness of pulsed CrAlSiN coating of  $R_a$  0.16  $\mu\text{m}$  was obtained. The adhesion of the coating was checked by using Rockwell indentation test with the indented crater depth which is larger than that of film thickness. In general, poor adhesion of coating was occurred by peeling the coating around the crater edge. However, the indented crater only shown radial crack around the crater, the result confirmed the excellent adhesion of the pulsed coating on the substrate (Fig. 5).



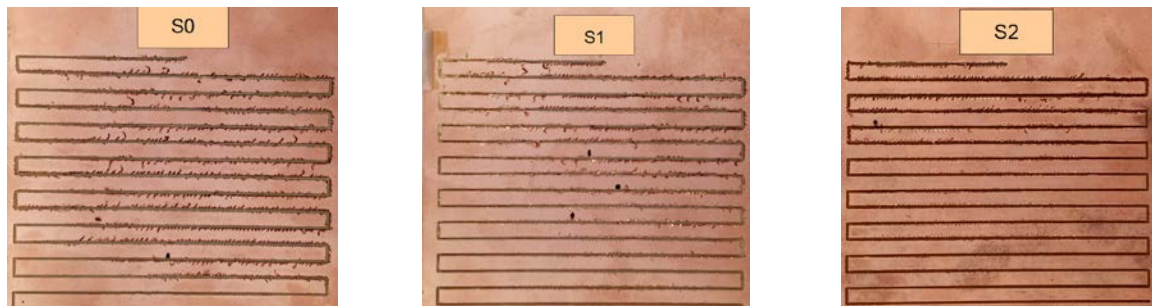
**Figure 4 .** SEM observation of the surface morphology of the CrAlSiN coating



**Figure 5.** The Rockwell indentation test of the CrAlSiN coating



**Figure 6.** Cutting tests for the CrAlSiN-coated microtool against PCB in dry condition



**Figure 7.** Optical microscope observation of the PCB cut tracks

The cutting tests for the CrAlSiN-coated microtool against PCB are shown in Fig. 6. Three kinds of tools were tested including blank tool (S0), tool with commercial CrAlSiN coatings deposited under the d.c. 90A current (S1) and CrAlSiN coatings deposited under pulsed 90/120A current (S2), respectively. The cutting failure is definite in the mode of copper debris built up along PCB trench under normal force. In case of blank tool, the shorter cutting distance was seen. In contrast, S1 samples exhibit the slightly longer cutting distance, increasing 75% of distance. The S2 samples deposited under pulsed 90/120A current exhibited the longest cutting distance under more stable state, as compared to the other samples increasing 165% of distance. The effect of the pulsed CrAlSiN coating on the cutting distance of router against PCB is remarkable. To investigate cutting performance, optical microscope was used to observe the cut tracks on PCB (Fig. 7). The cut tracks of the three samples showed similar phenomena with observable copper debris built up parallel to the cutting direction after different cutting distance. The blank-tool caused severe adhered with debris along the cutting direction in shorter distance, which could be related to the worn out of the tool. This suggests that less hardness and higher friction coefficient of blank tool had caused the speedy worn out

during the cutting contact. The tool with pulsed CrAlSiN coating presented a longest life which could be attributed to higher hardness and lower friction coefficient contacting PCB during test.

#### 4. Conclusions

CrAlSiN coatings were obtained by using pulsed cathodic arc deposition technique with Cr and CrAlSi dual targets. As compared to the tungsten carbide substrate, the hardness of CrAlSiN coating with the pulsed current input present the triple times improvement. After the cutting PCB test in dry condition, the microtool with CrAlSiN coating deposited by CAE of pulsed arc current exhibited the best cutting performance related to the cutting distance.

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