The adhesion of hot-filament CVD diamond films on AISI type 316 austenitic stainless steel


*Department of Applied Physics, NSRIM, University of Nijmegen, Toernooiveld 1, 6525 ED Nijmegen, The Netherlands
bDepartment of Solid State Chemistry, NSRIM, University of Nijmegen, Toernooiveld 1, 6525 ED Nijmegen, The Netherlands
cDepartment of Experimental Solid State Physics III, NSRIM, University of Nijmegen, Toernooiveld 1, 6525 ED Nijmegen, The Netherlands
dMetallurgy and Materials Group, Indira Gandhi Centre for Atomic Research, Kalpakkam 603102, India

Abstract

Steel ball indentation and scratch adhesion testing of hot filament chemical vapour deposited diamond films onto AISI type 316 austenitic stainless steel substrates using two different interlayer systems, namely chromium nitride and borided steel, have been investigated. In order to compare the adhesion of these films with that of a well-known and strongly adherent system, detailed adhesion tests were performed on diamond films grown on molybdenum substrates as well. Scanning electron microscopy analysis of various indented regions on the diamond-coated steel and molybdenum samples in combination with the measurement of the acoustic emission signals during loading, indicate that the adhesion of the coatings on the stainless steel substrates with the CrN interlayer is comparable and only slightly less than that of the strongly adhering diamond films on the molybdenum samples. The critical load value derived from the acoustic emission signals at which partial delamination of the diamond films is first observed, is significantly lower for the diamond-coated steel with the boride interlayer than that obtained with the CrN interlayer for the present deposition conditions used. The steel ball indentation tests also show that the hardness and thickness of the interlayer have a strong effect on the penetration depths of the indents. Scratch tests performed on the diamond coated stainless steel specimens with the boride interlayer show no significant coating failure for loads up to 80 N.

Keywords: Chemical vapor deposition; Diamond films; Adhesion; Steel

1. Introduction

With the introduction of chemical vapour deposition (CVD) techniques to grow high-quality diamond films on various types of substrate materials of different shapes, the application of diamond based products became widespread [1,2]. Especially for the mechanical and tribological applications, significant consideration needs to be given to the effect of intrinsic and extrinsic stresses on the adherence between diamond films and all kinds of substrate materials. However, to date only a limited number of substrate materials is known to support the growth of well-adhering diamond films. Among these are WC–Co, Si3N4 and SiC, which are used as successful substrates in the material forming industry [3]. Other substrate materials such as steels have been studied as well, but the adhesion of the diamond films grown on top of these materials was found to be relatively weak. In order to reduce the residual stresses acting on the deposited diamond films and to improve the diamond film adhesion, different kinds of steel substrate modifications have been reported. Most promising results have been obtained if gradient interlayers or multiple interlayer systems are applied. For example, nitrided chromium [4] and diffusion chromized interlayers [5] are reported to be very successful in accommodating the high thermal stresses on ferritic tool steels and show superior diamond film adhesion. However, due to the relatively higher expansion coefficient of austenitic stainless steel substrate materials, the use of these steels generally results in inferior adhesion of the grown diamond coatings. To
date, studies on the adhesion of diamond coatings on austenitic stainless steel substrates are very limited.

Though it is very difficult to quantify the adhesion of hard, thin coatings on top of various substrate materials, several types of experimental techniques are available to qualify the adhesion. Among these are the widely-used indentation and scratch adhesion tests [6]. In earlier work, critical loads for coating delamination were given for various diamond/interlayer/steel substrate systems [5,7]. For example, by means of a 20-nm thick Si buffer layer diamond composite films consisting of diamond particles, hydrogenated amorphous carbon and/or fluorocarbons were grown on carbon steel substrates in a microwave plasma CVD reactor by Ong et al. [7]. Applying scratch adhesion testing, they found a critical load value higher than 68 N for film failure. However, as the critical load is highly dependent on the applied experimental test conditions like the elastic properties of the indentor material, shape and radius of curvature of the indenter tip and loading rate, an absolute value for the critical load of diamond coatings on steel substrates in general is difficult to be deduced.

This work describes the indentation and scratch adhesion tests performed on diamond-coated AISI type 316 stainless steel substrates with boride and physical vapour deposited (PVD) CrN interlayers. CrN has a thermal expansion coefficient close to that of diamond and so its application is expected to result in low residual thermal stresses in the diamond film. However, being an overlay coating, it has two potentially weak interfaces, i.e. diamond/CrN and CrN/steel, at which adhesive failure can occur. Alternatively, although iron borides have a slightly higher thermal expansion coefficient, by virtue of forming a diffusion modified surface layer they result in a gradient microstructure with continuously changing thermal and mechanical properties and thereby they are expected to result in better residual stress accommodation. The objective of the present study is to study the effect of two different types of interlayer structures, i.e. (i) overlay coatings like CrN and (ii) diffusion modified layers formed by boriding for example, on the residual stress and interface adhesion strength of the grown diamond films. In order to evaluate the observed trends, a direct comparison with strongly adhering diamond films on molybdenum substrates is made.

2. Experimental

Approximately 2- to 4-μm thick diamond films are deposited onto AISI type 316 austenitic stainless steel (Ø18 mm; 1 mm in thickness) and pure molybdenum (12×12×0.5 mm^3) substrates in a hot-filament-assisted chemical vapour deposition (HFCVD) reactor. Two types of interlayer systems are used for the diamond film growth onto the stainless steel (SS) samples, i.e. PVD CrN coatings with a thickness of approximately 2 μm [8] and diffusion modified boride surface layers (approx. 20 μm in thickness) as prepared by means of a pack cementation process [9]. The diamond deposition conditions including substrate pretreatment, deposition temperature and methane concentration are optimized for each type of interlayer used on the steel substrate independently. In all deposition runs, a tantalum filament is operated at 2130±20 °C and a pressure of approximately 50 mbar is maintained. Indentation tests have been carried out on the specimens coated with diamond using a methane concentration of 0.5% for 4 h at a substrate temperature of 650 °C for the CrN interlayer and 550 °C for the borided steels. On the CrN coated stainless steel substrates covering diamond films are formed using a steel substrate surface roughness of $R_s = 0.71 \mu m$. The diamond layers produced on these substrates show only a small number of partially delaminated regions (approx. 20–30 μm) due to the high thermal stresses arising during the cooling down from the deposition temperature of 650 °C. Fully continuous diamond films are deposited on the borided stainless steel substrates without delamination when the as-borided surface does not contain the FeB phase [9]. The pure molybdenum substrates are manually pretreated in a diamond slurry followed by ultrasonic impregnation and are subsequently used for diamond deposition at 650 and 550 °C with a 0.5% CH₄/H₂ gas mixture.

The indentation and scratch adhesion tests are performed in the 0–200 N normal load range using a scratch tester (Revetest, CSM instruments) with steel ball (750 μm in diameter) and Rockwell diamond (200 μm tip radius; 120° cone angle) indenter types. The acoustic emission signals are recorded using a resonant detector (Vallen-System type SE150-M) set at 125 dB gain in the 20–500 kHz range. On each specimen a series of indentations is made applying normal loads from 50 to 200 N using a steel ball indenter. Constant indenter loading rates of 50 N min^{-1} are used for the <100 N indents and 100 N min^{-1} for the ≥100 N indents. The steel ball is replaced after each indentation series. Scratch tests are performed on the diamond coated stainless steels with the boride interlayer using both the steel ball and the Rockwell C indenter types with a loading rate of 80 N min^{-1}, a track length of 3 mm and a scan speed of 3 mm min^{-1}. In the indentation tests, the penetration depth, acoustic emission signal and normal load are simultaneously recorded, while in the scratch tests the lateral displacement, penetration depth, acoustic emission signal, coefficient of friction, normal load and tangential force are recorded. Field emission scanning electron microscopy (JEOL JSM 6330 F) and optical microscopy are employed to study the surfaces of the tested samples.
3. Results

3.1. Indentation tests

In Fig. 1, the penetration depths and acoustic emission signals from the diamond coated AISI type 316 stainless steels with the boride and CrN interlayers and the diamond coated molybdenum substrates are displayed as a function of the applied normal load. The typical results from indentation tests using final loads of 100 and 150 N are shown. In the case of the tests with a final load of 150 N, all the specimens showed a similar behaviour up to the first 100 N as compared to the tests performed on the same specimens with a final load of 100 N, indicating a good reproducibility of the tested specimens. The penetration depth profiles of all specimens show a nearly linear dependence with respect to the applied load. However, the penetration depths are significantly less for the diamond coated stainless steel specimen with the boride interlayer (Fig. 1a,b) as compared to the diamond coated steel with the CrN interlayer (Fig. 1c,d) and the coated molybdenum substrate (Fig. 1e,f). For all specimens, the acoustic emission (AE) background signal (arbitrary units) is in the 700–1300 range. The diamond coated stainless steel with the boride interlayer shows a strong AE signal (3395) at 69 N for the indent with a final load of 100 N (Fig. 1a). For the indentation with a final load of 150 N, a series of relatively strong AE signals starting from 68 N is observed for the same specimen. The diamond coated stainless steel with the CrN interlayer does not show any strong AE signal in the indentation scan with a final load of 100 N. However, upon applying a final load of 150 N a relatively strong AE signal (4254) is observed at approximately 100 N. For the diamond coated molybdenum substrates, AE signals are only seen at 135 N and higher.

In Fig. 2, the penetration depths of the indents on the three types of diamond coated substrates are displayed as a function of the applied final normal load. For all specimens, the penetration depth profiles show a nearly linear dependence with respect to the final applied load. The profiles for the molybdenum and CrN coated stainless steel substrates are similar, whereas the penetration depths for the borided steel substrate are smaller.

On all specimens, fine concentric, predominantly intergranular cracks are observed at localized areas within the indented regions for all applied loads. Besides the concentric cracks, a few radial cracks are also observed extending at near right angles from the circumferential cracks. From SEM analysis of the plastically deformed, indented regions on the diamond coated steel specimens with the CrN interlayer, it is derived that the diamond film starts to delaminate in the normal load range of 100–150 N, as for the indents of 50 and 100 N applied load, no delamination or spalling of the diamond coating was observed. Only one strong acoustic emission signal was observed at 99.5 N for the 150 N indent and no significant acoustic emission peak could be detected for the 100 N indent (Fig. 1c,d). From SEM analysis combined with AE monitoring on all specimens, it can be concluded that the strong acoustic emission signal at 100 N is associated with the partial delamination of the diamond film. SEM micrographs of the diamond coated surfaces at various indented regions on the stainless steel with the CrN interlayer and the molybdenum substrates are displayed in Fig. 3. For the 150 N indent partial flaking of the diamond film together with the presence of concentric cracks is observed for the stainless steel with the CrN interlayer (Fig. 3a). Fig. 3b,c display the surface region near the boundary of the indent, where the network of cracks exhibits both inter- and intragranular cracking. At the centre of Fig. 3c, for example, a crack running through the entire {100} crystallite facet of a single diamond grain is displayed. Fig. 3d displays the 150 N indent region exhibiting significant spalling of the diamond coating for the molybdenum substrate. At this load, only 3 radial cracks are observed, while the number of concentric cracks is much higher. In Fig. 3e, a magnified view of the crack network observed at the indent with a final load of 200 N is shown. This figure clearly shows the presence of concentric cracks at the indent region as well as a high number of radial cracks running perpendicular outwards from the indent. The average length of the radial cracks at the 200 N indent is approximately 100–120 µm. A magnified view of a radial crack running almost perpendicular to the outer concentric crack is shown in Fig. 3f.

3.2. Scratch tests

Scratch adhesion tests are applied to the diamond/ borided steel specimens using final loads of 80 N. In Fig. 4a,c, the normal and tangential forces during the scratch tests for both the steel ball and Rockwell C indenter types are displayed as a function of the lateral displacement or track length. For both indenter types, no strong acoustic emission peaks are detected up to 80 N. The tangential forces are proportional to the applied normal forces reaching values of approximately 20 N at normal loads of 80 N. The penetration depth for both indenter types (not shown) also shows a proportional increase with respect to the applied normal load and is in the order of 15–20 µm at the end of the scratch track. The penetration depth after application of a 80 N load is significantly lower in the scratch mode as compared to the indentation. This is because during indentation testing, the same region is exposed to continuously increasing load resulting in cumulative damage. In contrast, in scratch testing, since there is also a dynamic advance of the specimen, a new diamond
Fig. 1. Penetration depths and acoustic emission signals (vertical lines are the AE signals, which are relatively strong with respect to the background signal) as a function of the applied normal loads for the diamond-coated stainless steel with the boride interlayer (a,b), the PVD CrN interlayer (c,d) and the diamond-coated molybdenum substrates (e,f). Measurements (a, c and e) are recorded with a final load of 100 N and (b, d and f) with a final load of 150 N. In all cases a steel ball indenter was used.

The friction coefficient in the case of the scratch performed with the steel ball indenter is in the order of 0.28, while it increases from approximately 0.15 to 0.23 for the Rockwell C indenter. The increase in friction coefficient of the latter can be explained by the change-over from diamond on diamond sliding towards diamond on steel sliding once the diamond film is fully penetrated by the indenter. In Fig. 5, optical images of the scratch channel produced by the steel ball indenter are shown. Fig. 5a displays the scratch channel at a load of approximately 60 N. At this load, the width of the scratch channel is approximately 60 μm. Within the
In general, indentation fracture of brittle layers is caused by the contact stress field, within which cracks evolve. The stress field is determined by geometrical factors such as the radius of curvature of the indenter tip and by the material properties, like hardness, toughness and elastic modulus of both the indenter and specimen. In this study, we have chosen for a blunt indenter type, i.e. a spherical steel ball, for two main considerations. The first was to avoid damage of the commonly applied diamond indenters by the hard diamond films, which can lead to early and frequent failure of these expensive indenters. Further, it has been shown that to suppress non-cohesive failure and to ensure only adhesive failure of the films, it is necessary to use an indenter with a large radius. Particularly for hard coatings on soft substrate materials, the Rockwell C indenter may not have a radius large enough to reliably assess the adhesive failure of the interface [10].

Adhesive failures of hard coatings on soft substrates take place by differential plastic deformation between the substrate and the film resulting in an additional shear strain at the interface. Besides, radial and circumferential cracks are also frequently seen to precede the adhesive failure of hard and brittle coatings. With increasing load during indentation, both the film and substrate deform together up to the point of adhesive failure of the interface, resulting in an indent groove being formed. This leads to an additional bending stress on the diamond film. The bending stress is proportional to both the applied load as well as the radius of curvature of the film. Since the radius of curvature is maximal at the edge of the indent, the bending stress is also usually highest at the contact edge. At a critical load, the bending stress may be sufficiently high to initiate concentric cracks all along the circumference of the contact edge. With increasing load, the depth as well as the diameter of the indent increases and thereby the physical position of the contact edge also moves outward in comparison to the first crack. This results in the formation of a higher number of circumferential cracks nearly concentric to the first one. In the initial stage of crack propagation, a ring is formed around the contact center and upon subsequent loading the ring evolves into a cone crack. The formation of these Hertzian cone cracks can be observed clearly from Fig. 3e. The distance between two circumferential cracks for a fixed indenter radius has been shown to be in the order of the coating thickness [11]. This is in accordance to our present study as can be seen from Fig. 3b. The distance between two adjacent concentric cracks is approximately 3–4 \( \mu \text{m} \) corresponding well to the diamond coating thickness. Above a certain stress, radial cracks are also observed to originate. The radial cracks have their tensile stress peaking just outside the contact zone [12]. Based on stress analysis calculations, the radial and circumferential cracks have been shown to initiate from the coating surface or from a distance above the coating interface and subsequently they grow into a through-thickness crack. Upon further loading, the tensile stress under the indenter expands and when it encompasses the crack tip, crack growth can occur towards the interface by Mode-II shear off, finally leading to interface delamination by Mode-I opening [11]. Both the radius of the first circumferential crack as well as the maximum length of the radial crack has been shown to be a measure of the fracture toughness of the film. It should be noted that the formation of such radial and/or circumferential cracks is common to hard and brittle films. The critical load for adhesive failure should only be taken as the load at which failure of the interface occurs, thereby leading to film delamination, and not

---

**Fig. 2.** Penetration depth as a function of the applied final normal load for the diamond coated stainless steel specimens with the boride and CrN interlayer and the diamond coated molybdenum substrates, respectively. In all cases a steel ball indenter (750-\( \mu \text{m} \) in diameter) was used.
Fig. 3. SEM micrographs of the diamond coatings on the CrN coated stainless steel (a–c) and molybdenum substrates (d–f) at various indent regions. (a) indent region with 150 N final load, (b) magnified view of circumferential cracks at boundary of the 150 N indent, (c) magnified view of circumferential cracks showing intragranular cracking (150 N), (d) indent region with 150 N load, (e) magnified view of 200 N indent region showing lateral and circumferential cracking and (f) magnified view of boundary of 200 N indent showing radial (indicated by white arrow) and circumferential cracking.

the load corresponding to the formation of such radial or circumferential cracks. However, for the ≤200 N normal loads applied in this work, the radial crack length is not yet proportional to the applied load and therefore the fracture toughness cannot be deduced with good accuracy.

As put forward by Belmonte et al. the recording of acoustic emission signals in combination with post-indentation scanning electron microscopy observations allows an accurate study of the adhesion of the diamond film/Si₃N₄ substrate system [13]. However, it is obvious that several acoustic events during the indentation pro-
Fig. 4. Scratch testing of diamond coated borided steel: The normal and tangential forces (a,c) together with the derived friction coefficients (b,d) displayed as a function of the lateral displacement or scratch track length for both the steel ball and Rockwell C indenter types.

cess such as the formation of concentric and radial cracks are detected apart from the subsequent delamination at the interface. Hence, adequate care should be taken in meaningful interpretation of the critical load for adhesive failure from AE signals. In the present study, the recorded AE signals show that the most intensive acoustic events are also related to diamond film spalling on all specimens. The results of the indentation tests shown in Figs. 1 and 3 indicate that, instead of measuring the fracture resistance in the higher load range, an alternative critical load can be assigned to the diamond coating/substrate systems. Applying a

Fig. 5. Optical images of the scratch channel on diamond coated borided stainless steel produced by the steel ball indenter: (a) at a normal load of approximately 60 N and (b) at the end of the scratch track (80 N). The dotted arrows in the upper right-hand side of the figures show the direction of scratching.
series of indentations with stepwise increased normal loads, a critical load value can be derived from the combined observation of the acoustic emission signals and light scattering of the indented regions. Coating detachment is only observed at indentation loads, at which a strong acoustic emission signal is observed as well. For lower loads, only crack initiation but no coating detachment is seen. As derived from Fig. 1, these observations lead to critical load values for coating delamination of approximately 69, 100 and 135 N for the diamond coated stainless steels with the boride and CrN interlayer and the diamond coated molybdenum substrates, respectively. This indicates that the bonding strength between the diamond film and underlying substrate is lowest for the borided steel, medium for the CrN coated steel and highest for the molybdenum substrates. In other work, we have shown that diamond films grown on pure molybdenum substrates at 550 °C result in a critical load value of approximately 75 N [14]. The relatively low value of 69 N for the borided steel specimens in the present work can therefore be ascribed to the lower applied deposition temperature. Further studies to optimize the deposition conditions for the borided steel substrates at higher deposition temperatures are under progress.

In previous studies [8,9,15] it was shown that diamond deposition onto the various substrates leads to interlayer formation due to carbon reaction and inter-diffusion. Diamond deposition onto borided stainless steel substrates does not result in the formation of a significant interlayer [9]. Only relatively low intensity X-ray diffraction signals from the Cr$_7$C$_2$ phase are seen. In the case of a CrN interlayer, the formation of a thick interlayer mainly consisting of the Cr$_7$C$_2$ phase is evident [8]. Diamond formation on molybdenum substrates generally results in the formation of a 1- to 2-$\mu$m thick Mo$_2$C intermediate layer [15]. Based on the present results, it can be concluded that in the case of molybdenum and CrN coated stainless steel the formation of the carbide intermediate layers contributes to better adhesion of the grown diamond film. It is suggested that these carbide interlayers, which are dominated by the strong Cr–C or Mo–C bonds, lead to a strong chemical bonding between the diamond coating and the substrate. The more abrupt diamond/interlayer interface between the diamond phase and borided steel surface most probably does not allow for an optimal chemical bonding or connection. Despite the high thermal stresses acting on the diamond films in the diamond/CrN/steel system [8], the critical load obtained is much higher than that observed for the diamond/borided steel system, which shows little compressive stress [9]. In the case of equal bonding, a film displaying higher residual stress would fail prior to a film showing less internal stress as the presence of stress generally causes degradation of the adhesion [16]. Due to the combination of the low compressive stress and the strong chemical bonding, the present indentation tests show superior adhesion of the diamond films deposited on the molybdenum substrate.

The residual stress in the diamond film influences the cracking behaviour upon loading as well. Upon indentation of the diamond coated stainless steel with the CrN interlayer, a network of concentric cracks with inter- and intragranular components is observed. On the contrary, indentation on the diamond coated molybdenum substrate leads to the formation of a network of both lateral and concentric cracks, which show less intragranular components. The difference in cracking behaviour between the two types of specimens cannot be explained by a difference in penetration depths of the various indents, which is negligibly small. We suggest that the high compressive stresses acting on the diamond film grown on the CrN coated stainless steel (up to $\sim$11 GPa) affect the crack initiation and propagation strongly. The radial cracks, which initiate at the circumference of the indent, result from the large tensile stresses, which are induced at the outer indent region during indentation. The very high compressive stress in the film might aid crack closure and thereby retard the formation of tensile radial cracks. This might explain the lack of radial cracks upon indentation of the diamond coated CrN/ steel system and the presence of a large number of radial cracks in the case of the diamond coated molybdenum (observed for indents with final loads of 75 N and higher). From micro-Raman spectroscopy measurements on the diamond/borided steel system, low residual, compressive stresses are obtained. However, upon indentation no radial cracks are observed on this system. As delamination of the grown diamond layers already occurs at applied loads of approximately 69 N, most of the induced stress is relaxed at the diamond/substrate interface, the stress equivalent of $\leq$69 N being insufficient to cause radial cracks in the diamond film.

As the diamond coatings on all three substrate systems are only approximately 2- to 4-$\mu$m thick, the difference in penetration depths between the various coating/substrate systems (Fig. 2) can be explained by the difference in mechanical properties of the modified steel substrate material. The boriding process results in a borided surface layer of approximately 20-$\mu$m thick and a surface hardness, which is significantly higher than 3000 VHN. The CrN coated steel and molybdenum substrates show surface microhardness values, which are approximately 2000 VHN and 1530 VHN, respectively. The relatively smaller penetration depths upon indentation on the borided steel substrate are, therefore, the result of its higher surface hardness.

In recent work, we have shown that the cohesion and adhesion of HFCVD diamond layers on molybdenum substrates is increasing with increasing deposition tem-
temperature in the 450–850 °C range [14]. The connectivity between individual diamond crystallites as well as the chemical bonding of the crystallites with the underlying substrate are stronger for increasing temperatures. Hence, the critical load for adhesive failure increases with increasing deposition temperature. Based on the critical load of approximately 69 N for diamond film delamination upon indentation, it is surprising that the scratch adhesion test does not result in coating failure outside the scratch channel up to 80 N. As mentioned earlier, the penetration depth is much lower for the scratch test and therefore the bending stresses at the outside of the indenter will be smaller as well. This might explain the absence of coating failure up to 80 N in the scratch test.

To date, only a limited number of critical load values based on scratch and indentation adhesion tests are reported for diamond coatings on steel substrates. The reason for this low number is the difficulty in obtaining adhering and good quality diamond films on steels. For the nitried chromium interlayer system studied by Glozman et al., critical loads in the 1000–1850 N range are reported for commercial carbon chrome alloy steel upon indentation with a Rockwell C indenter [17]. These high values are determined from the loads necessary to induce extensive delamination and fracture of the diamond film. As the Rockwell C indenter is a sharp indenter type and gives rise to highly different contact stress fields, a direct comparison cannot be made. However, in the same study Glozman et al. also described the results of scratch adhesion tests using a commercial Revetet instrument (CSM, Switzerland) as well. From these scratch tests, critical loads from 58 to 72 N are derived for approximately 2-μm thick diamond films. As the instrument equipment as well as the indenter type used by Glozman et al. are similar to those used in the present study, a direct comparison between the scratch test results is plausible. As no significant fracture of the diamond coating is seen on the borided steel specimen up to 80 N, it might be concluded that the adhesion between the diamond film and borided steel is better than that derived for their diamond/ nitried chromium/steel system. However, one should realize that in comparing the individual adhesion test data, additional care has to be taken into account, as the scratch and indentation adhesion tests are only localized probes.

5. Conclusions

Indentation and scratch adhesion tests performed on diamond films on AISI type 316 stainless steel substrates indicate good adhesion characteristics for PVD CrN and borided steel interlayers. Registration of the acoustic emission signals combined with post-indentation surface analysis of the indented regions allows the derivation of critical load values for diamond film detachment. Critical load values of approximately 69 N and 100 N could be derived for the boride and CrN interlayer, the diamond films being deposited at 550 °C and 650 °C, respectively. A direct comparison made with the strongly adhering diamond films on molybdenum substrates indicates only slightly inferior adhesion for the diamond coated stainless steel with the CrN interlayer. Scratch adhesion tests performed on the diamond/borided steel specimen show no significant coating failure up to 80 N. Though the interlayer production and the diamond deposition conditions might be improved even further and though additional tribological tests have to be carried out in the near future, it can be concluded that the use of PVD CrN and boride interlayers is highly promising for the growth of adhering diamond films onto stainless steel substrates.

Acknowledgments

The authors wish to thank Leander Gerritsen for his technical support. This work was performed as part of the research program of the Netherlands Technology Foundation (STW) with financial support from the Netherlands Organization for Scientific Research (NWO).

References