

APPLICATION OF INDENTATION FRACTURE MECHANICS APPROACH FOR DETERMINATION OF FRACTURE TOUGHNESS OF DLC COATING CERAMICS MATERIALS

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Introduction

Thin coatings have become a key technology in a wide range of industries for a vast range of engineering purposes. The successful performance and reliability of thin coatings is often limited by their mechanical properties. Generally, harder coatings are more brittle and easily damaged by shock loads in practical applications. A necessary criterion for evaluating brittleness of thin coatings is to measure fracture toughness of the coatings. Amorphous carbon coatings, often called diamond-like carbon (DLC) coatings, have lots of interesting properties such as very high hardness and elastic modulus, high electric resistivity, high optical transparency and chemical inertness, which are close to those of diamond. These coatings have a wide range of uses including optical, electronic, thermal management (heat sinks), and biomedical applications. In certain applications, there is a need for thin coatings to improve friction and wear performance. Intensive research has been done on the measurement of hardness and elastic modulus of such thin DLC coatings deposited by different deposition techniques [1]. However, very little is understood on their fracture toughness. Although, different conventional techniques are proposed to evaluate K_{IC} of brittle materials, as the chevron notch bar (CNB) technique [2], the single-edge precracked beam (SEPB) [3], the single-edge notched beam (SENB) [4], the double cantilever beam (DCB) and the edge loaded split (ELS) beam. Besides these methods, the Vickers Indentation Fracture (VIF) technique is probably the most often employed due to its simplicity. The objective of this study was to deposit a thin coating of DLC on a ceramic substrate followed by evaluating their

fracture toughness using the methodology recently developed based on the energy release.

Experimental

Comparing to other chemical vapor deposition (CVD) process, one of the main advantages of plasma-enhanced chemical vapor deposition (PECVD) is that the process can be operated in low temperature while the deposition rate is comparable to other CVD process. The thin films being deposited also have low mechanical stress. This can prevent the films being deformed and become non-uniform because of the uneven mechanical stress on the films. Therefore, in this study, a thin (2 μm thick) amorphous carbon coating on Al_2O_3 substrate deposited by PECVD. Vickers hardness measurements were made with a normal-load hardness tester at load levels ranging from 1 to 50 kg and at a constant indenter dwell time of 15 s. After indentation, the length of each of the two diagonals of the square-shaped Vickers indentation was immediately measured by optical microscopy. Three indentations are performed for each load applied on the surface

The Vickers diamond pyramid hardness number, H_V , is defined as the ratio of the applied load, P , to the pyramidal contact area, A , of the indentation:

$$H_V = P/A = \alpha P/d^2 \quad (1)$$

Where, d is the length of the diagonal of the resultant impression, and $\alpha=1.8544$ for Vickers indenter.

The length of radial cracks propagating from the corners is used to estimate the fracture toughness of the DLC coating according to the flowing equation [5].

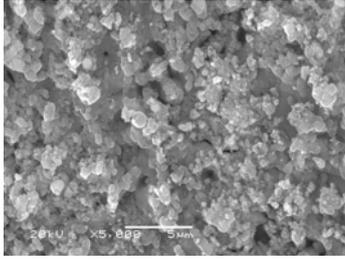
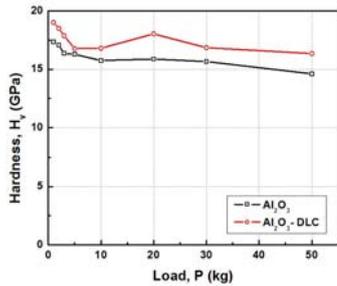


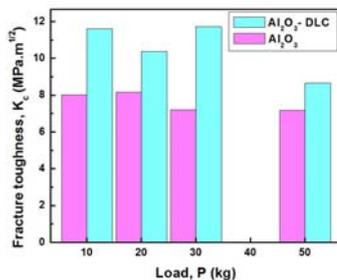
Fig. 1: Surface morphology of plasma sprayed DLC coating.

Fig. 2: Vickers hardness as functions of applied



load for Al₂O₃ and Al₂O₃-DLC coating.

Fig. 3: Fracture toughness as functions of applied



load for Al₂O₃ and Al₂O₃-DLC coating.

$$K_c = \chi(E/H)^{1/2} \cdot (P/a^{3/2}) \quad (2)$$

where P is the applied load, E Young's modulus, H the Vickers hardness, a the radial crack length measured from the center of the indent, and χ an empirically determined "calibration" constant taken to be $0.016 \pm 0.004.2$.

Results and Discussions

Fig. 1 shows the surface morphology of DLC coating surface. From this figure it is observed that carbon grains are well spread throughout the surface making sp^3 bond which gives high hardness for coating surface.

Fig. 2 shows the dependence of the microhardness for DLC coating on the indentation loads ranges from 1 to 50 kg. In the first stage, when load is below 5 kg, the curve declines sharply in both coating and substrate materials. When the load over 5 kg, work hardening degree tends to decrease slowly. However, DLC coating hardness is always higher than that of substrate materials.

Fracture toughness of Al₂O₃ and DLC coated Al₂O₃ is presented in Fig. 3. This figure tells us that K_c values for coating materials are higher than that of base materials for same applied load. Fracture toughness for DLC coating ranging between 8.6 to 11.6 MPa. m^{1/2} while for Al₂O₃ it stands from 7.1 to 8.16 MPa. m^{1/2}.

Conclusions

Vickers indentation tests were performed to evaluate the critical fracture toughness of DLC coatings substrate. The indentation size effect in Vickers hardness for brittle ceramics should be explored over a relatively wider range of applied test load, in order to obtain a complete understanding of this phenomenon. It was found that fracture toughness for DLC coating ranging between 8.6 to 11.6 MPa. m^{1/2}.

Acknowledgements

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