Properties of ta-C-Films on Tools and Machinery Parts

F. Präßler*, INOVAP GmbH, Bautzner Landstr. 45, 01454 Großerkmannsdorf
W. Grimm, INOVAP GmbH, Bautzner Landstr. 45, 01454 Großerkmannsdorf
T. Chudoba, ASMEC GmbH, Bautzner Landstr. 45, 01454 Großerkmannsdorf

1. Introduction

In the past years carbon coatings found many applications for wear resistive coatings of tools and machinery parts. In industrial applications aC:H Carbon coatings are widely spread. Because of its high hardness carbon coatings of type ta-C are interesting for tool coating. For the following analyses ta-C carbon films were deposited on highly polished round blanks of high speed steel (HSS).

2. Experimental details

A calotte grinding device was used for the measurements of coating thickness and of wear coefficient. At constant rotational speed (500 / min-1) 10 grindings of different depth were rotated automatically into the coatings. The calotte dimensions were evaluated microscopic.
The determination of indentation hardness was accomblished using a Berkovich indenter and indentation forces with up to 50 mN. The indentations followed the international standard [5]. After a quadratic indentation force increased by 8 seconds and a creep time of 5 seconds followed an unloading of 4 seconds. A detailed description can be found in [4]. Additionally, the Quasi Continuous Stiffness Measurement (QCSM) was applied. Thereby stiffness, indentation hardness and Young's modulus can be determined as a function of depth.
Furthermore, micro scratch tests with a spherical indenter were performed for the quantitative evaluation of the adhesion. Thereby the maximum tension is more often than not inside the coating or at the interface because of the small spherical indenter radius (7 µm). The indentation force was linearly increased to up to both 100 and 1300 mN. The distance of the micro scratch was 50 µm.

3. Results

Base material, coating	$HV_{0.001}$	Modulus [GPa]	Scratch force [mN] at fraction	friction at 100 mN	wear, wet [m^3/Nm]	wear, dry [m^3/Nm]
HSS, TiN	2478	426	830	0,110	$8,3*10^{-14}$	$3,0*10^{-16}$
VHM, CrN	-	-	-	-	-	$2,3*10^{-16}$
HSS, TiCN	2370	397	-	-	$1,1*10^{-13}$	-
HSS, TiAlN	3067	404	937	0,085	$7,1*10^{-14}$	$1,0*10^{-16}$
HSS, TiAlCN	3123	325	-	-	$5,6*10^{-14}$	-
HSS, ta-C	5297	543	603	0,045	$3,2*10^{-15}$	$1,5*10^{-17}$

Figures 1 and 2 show the measured wear coefficients. By a factor of 700 to 200 the wear coefficients (dry) (Fig. 2) are smaller than the wear coefficients (wet) (Fig. 1). Both wet and dry are qualified to simulate the real wear of the hard coatings on tools in applications.
Figures 3 and 4 show both values for the ta-C film determined by standard indentation (10, 30, 50 mN) and by QSCM. The highest measured values of ta-C films measured at 10 mN normal force are 56 GPa (indentation hardness) and 543 GPa (Young's modulus). Furthermore, both figures show the excellent agreement between indentation hardness measuring and QSCM.
Figure 5 shows determined wear coefficients (wet) of several hard materials as a function of their corresponding indention hardness values. The figure shows a simple relation between wear and hardness.
The ta-C film broke at a force value of 600 mN (Fig. 6). Furthermore, the abrupt and complete fracture (Fig. 7) could be explained by intrinsic stress of ta-C films and its high Young's modulus.

Conclusions

The t-aC films deposited by the pulsed arc discharge have a substantial higher hardness in comparison to hard coatings such as TiN, TiAlN, TiCN and CrN. The very high micro indention values above 5,000 $HV_{0.001}$ are validated by QCSM, too. The measured Young's modulus of ta-C-films reaches the half of value of crystal diamond. The function course of indentation hardness of contact depth for ta-C is similar to hard coatings.
The wear of ta-C-films with abrasive diamond suspension is 21 times lower than compared hard coatings.
A convincing coherence between the wear coefficients (wet) and the indentation hardness over a wide range of materials or coatings was demonstrated (Fig. 5). These wear coefficients were easily and reliably determined by wet calotte grindings with diamond suspension on 5 to 10 grindings. They are a measure of the hardness of the investigated coating.

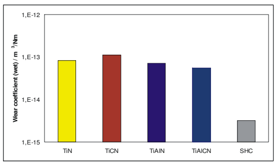

Figure 1: Wear coefficients (wet) of hard coatings measured with a 1 µm diamond suspension and steel balls

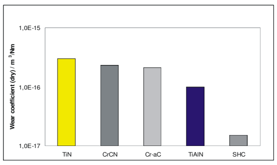

Figure 2: Wear coefficients (dry) of hard coatings measured with WC-balls.

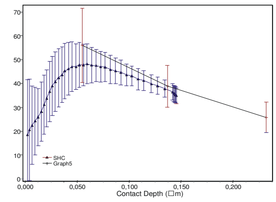

Figure 3: Indentation hardness of ta-C film measured with single measurements and QCSM

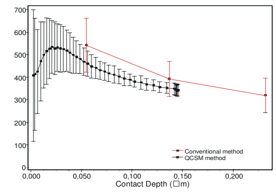

Figure 4: Young's modulus of ta-C film measured with single measurements and QCSM

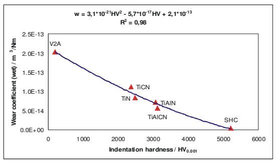

Figure 5: Relation of wear coefficients (wet) to their corresponding indentation hardness for metals and hard coatings.

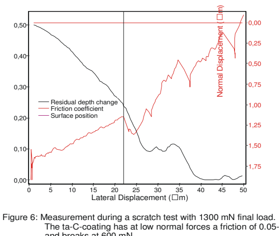

Figure 6: Measurement during a scratch test with 1300 mN final load. The ta-C-coating has at low normal forces a friction of 0.05-0.10 and breaks at 600 mN

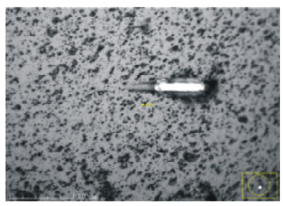

Figure 7: Scratch area on a ta-C sample after a loading from 0 to 1300 mN