Analysis of Wear Behaviors in Hard Disk Drive Manufacturing Processes for Selection Appropriate Coating Films

Kanoktip Tipsuwan[1], Pongpan Kaewtatip[1*] and Anak Khantachawana[1]

1 Department of Mechanical Engineering, King Mongkut's University Technology Thonburi, Bangkok, Thailand 10900
* Corresponding Author: Tel: 02 470 9117, Fax: 02 470 9111,
E-mail: pongpan.kae@kmutt.ac.th

Abstract

One of the main problems in Hard Disk Drive (HDD) manufacturing is the contamination during fabrication. This problem is caused by wear particles of fixtures and other moving parts. Among those, stainless steel particles are found to be the main causes of scratches occurring on the part surface and hence should be eliminated. Surface coating is one solution that can reduce tool wear. This research is aimed to improve the surface properties of tooling used in Hard Disk Drive manufacturing process by Physical Vapor Deposition (PVD) coating technique. The abilities of the film to reduce wear are studied. The commercially coated thin film properties are evaluated by various tests. Ball-on-Disk tests were carried out in order to obtain the specific wear rate of each surface. The SUS304 balls were prepared by coating with TiCN, AlCrN, TiAlN (Nanolayer), TiAlN films. The disks were made of SUS304. Hardness of each coating films is measured by nano-indentation test. The surface resistivities of the coating films are measured by surface resistivity test. The result reveals that all of coating surfaces can reduce the specific wear rate within the allowable contact pressure of 600 MPa comparing to non-coated surface. Especially TiAlN (Nanolayer) and AlCrN films show outstanding ability to reduce specific wear rate. Further, it is seen that the similar level of surface resistivity was obtained independent of type of coating film.

***Keywords**:* Hard disk drive, Contamination, Surface coating, Wear Particle, Stainless steel

1. Introduction

One of the main problems in HDD manufacturing is the contamination during manufacture. This problem is caused by the strange particles from workers in manufacturing line and also by the wear of fixtures and other parts used during the process. Stainless steel particles from the worn parts are usually found and often produces scratch on the HDD surface. They should be, therefore, eliminated. One solution at present is to replace some steel fixtures and parts with plastic in which their worn particles are softer and hence can minimise the damage on the HDD. This, however, increases the cost since plastic parts wear rapidly and require frequent change.

Surface coating and modification is another solution to reduce the wear. However, in order to select the suitable types of thin film or surface modification method, it is important to realize the wear behavior and contact condition of each real process, for example contact materials and relative moving speed etc. Such information is necessary to select the optimum coating technique, type of film and surface modification method because each film and method has a feature for different applications. In 2002 R.J. Rodrguez has studies [1] the most usual coatings deposited by reactive arc-evaporation techniques, in order to find the tribological performance, microstructure and characteristics of the different coatings. The best results were obtained by using TiCN films. In 2007, J.L MO [2] has studied the tribological behaviours of the two commercially available high-aluminum-content TiAlN and AlCrN monolayer coatings. They were comparatively investigated with focusing on their friction behaviors and wear mechanisms. The AlCrN coating showed better performance of anti-oxidation and anti-spalling as compared with the TiAlN coating.

In this work, the authors aim to investigate suitable film that can effectively prevent wear of stainless steel parts used in HDD manufacturing processes. First, the manufacturing lines are explored to indicate the procedure that produces large amount of wear particles. The obtained data will be analyzed and simulated in a ball on disk type tribology testing machine. The information accumulated from the manufacturing line will be used to select the films having high potential to reduce wear. The ball-on-disk tests are performed to determine the specific wear rate between contact surface of coating balls and stainless steel disk. The film coatings used in this work are TiCN TiAlN and AlCrN. All of them are deposited by physical vapour deposition.

2. Methodology

2.1 Ball-on-disk test

The tribology characteristics between coated AISI 304 Stainless steel ball and AISI 304 Stainless steel disk have been investigated using ball-on-disk test. Balls were prepared using conditions shown in Table 1. The equipment use is a commercially tribometer (CSM) and is shown in Fig.1(a) while the elastic contact between the ball and disk is shown in Fig.1(b).

Table 1 Coating films used in the experiments

Film coating	Film thickness*	Process	Color
TiCN	1.68	PVD	Dark violet
TiAlN	1.95	PVD	Violet-gray
TiAlN (nano layer)	0.52	PVD	Violet-gray
AlCrN	1.68	PVD	Blue grey

*The thickness of the film is measured by using SEM.

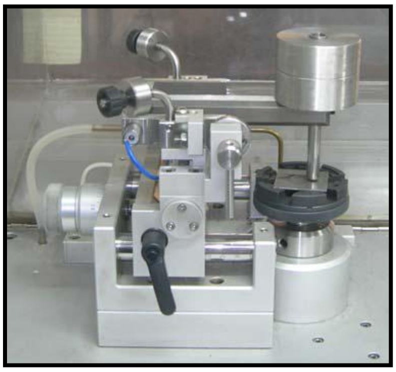
2.2 Nanoindentation test

Nano-indentation was performed using pyramidal (Berkovish) indenter to characterize the hardness and elastic modulus of coating films. The pyramidal indenter was penetrated into the coating surface. The maximum load is 20 N. Loading and unloading rate are the same level at 10 μN/s.

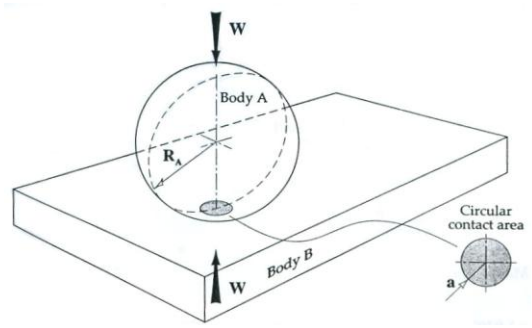
2.3 Scratch test

The Rockwell diamond stylus was scratched on the coating surface. During the test, the friction force and Acoustic Emission

(AE) signal are recorded. A linearly increased (0 to 100 N) normal load, a sliding speed of 10 mm/min and sliding distance of 8.6 mm were used in all experiments.



(a) Commercially tribometer (CSM)



(b) Contact between ball and disk in ball-on-disk test.

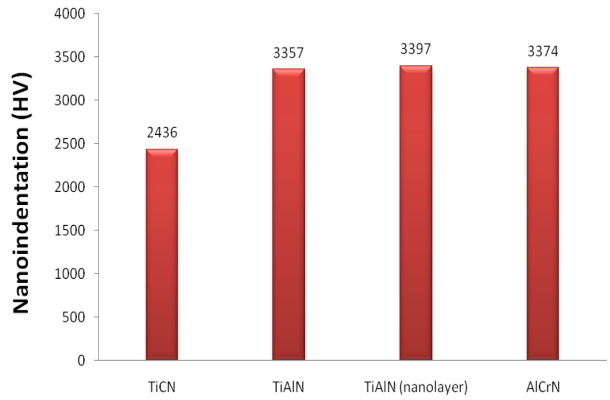
Fig.1 Ball on disk test

3. Exploration results of HDD manufacturing process

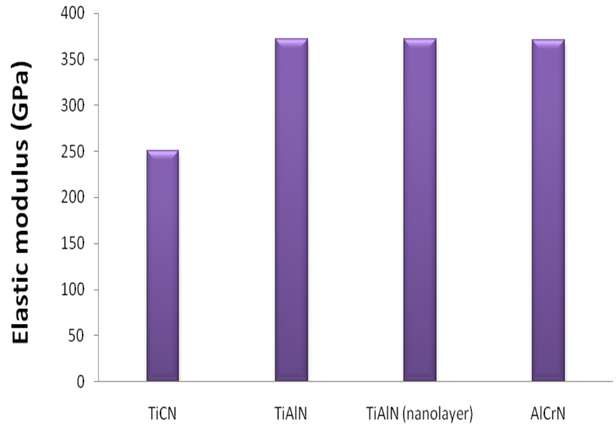
HDD Manufacturing process can be divided into three main parts; (1) Head Gimbals Assembly (HGA), (2) Head Stack Assembly (HSA) and (3) Hard Disk Enclosure (HDE). In this work, we emphasized on the HSA process as our first step. The contamination found in the process can lead to severe problems and need strong attention by the manufactures. Contamination particles found can be divided into two main categories; from worker body and from worn particles of the fixtures and the moving parts. In this work, the authors focused on the contamination from worn particles. They are collected by so called tape test and analyzed by SEM technique. As a result, most of the particles are found to be stainless steel (SUS304). Moreover, the SEM images of the worn area are observed. The images, not presented here, reveal that the majority of wear mechanisms is abrasive type. Since abrasive wear can be prevented by increasing the hardness of contact surfaces, the hard-thin film seems to be effectively used to reduce wear of the moving parts. However, most of parts used in the processes are stainless steel; hence the coating technique is limited to PVD rather than CVD because of the limitation of deposition temperature. By studying previous works and exploring the films that are available domestically, four type of films; i.e., TiCN, AlCrN, TiAlN (Nanolayer) and TiAlN are selected to be used in this work. [5, 6]

4. Result and discussion.

The result of nanoindentation test is shown in Fig. 2. From Fig. 2(a), it is found that all coating films have much higher hardness than SUS304 as expected. Among those, TiAlN (nanolayer), TiAlN and AlCrN have almost the same level of hardness at about 3,350 - 3,400 HV, while the hardness of TiCN is lowest; only about 2,436 HV. The elastic moduli of the films are shown Fig. 2(b). They have the same tendency as the film hardness.



(a) Nano-hardness of the films



(b) Elastic moduli of the films

Fig. 2 Results of Nanoindentation test

Fig. 3 and Fig. 4 shows the relation between wear volume of the balls and sliding distance for the cases of contact pressure 600 and 755 MPa, respectively. Wear volume of the ball is calculated from the worn area of the ball. The worn area is observed by optical microscope for every 200 m of relative sliding distance. From those figures, it is found that wear volume increases with an increasing of the sliding distance. However, as shown in Fig. 4, wear volume of the ball coated with TiCN films is extremely high and its value cannot be illustrated in the same figure. The reason of this is strongly related with bonding strength between the film and the substrate and will be discussed later.

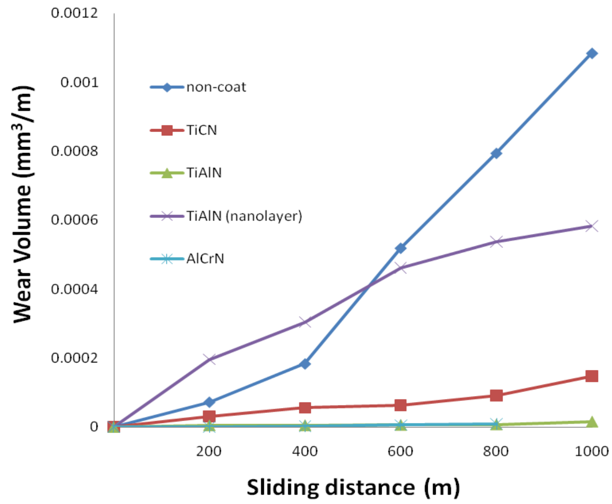


Fig. 3 Wear volume of ball at contact pressure 600 MPa

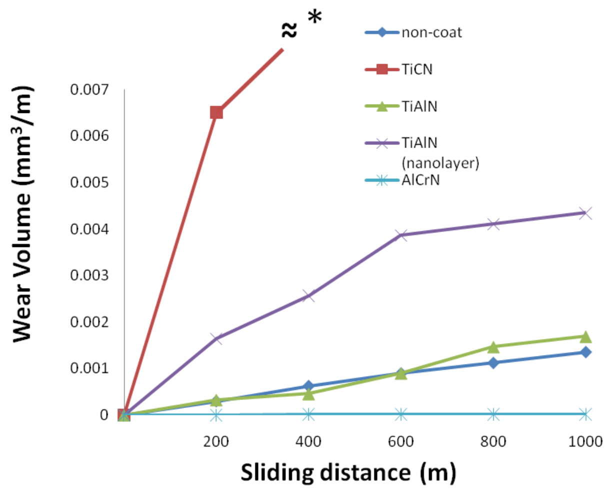


Fig. 4 Wear volume of ball at contact pressure 755 MPa (*For TiCN, the wear volume is too high to represent in the same figure)

The rate of wear volume from the two figures are determined and represented as specific wear rate as shown in Fig. 5 and Fig. 6 for the case of contact pressure 600 and 755 MPa, respectively. From Fig. 5, all coating films used can reduce specific wear rate compared to that of the non-coated ball. Especially, TiCN, TiAlN and AlCrN show outstanding results that can reduce specific wear rate for more than 90%. This can be explained by the superior hardness of the coated films above non-coated stainless steel ball. Since in ball-on-disk test, abrasive wear is also the main type of wear occurred. The higher is the hardness, the higher ability to reduce wear is obtained.

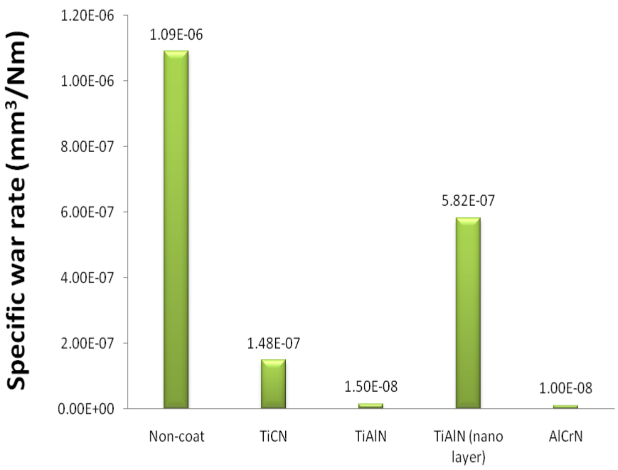


Fig. 5 Specific wear rate for various types of balls at contact pressure 600 MPa

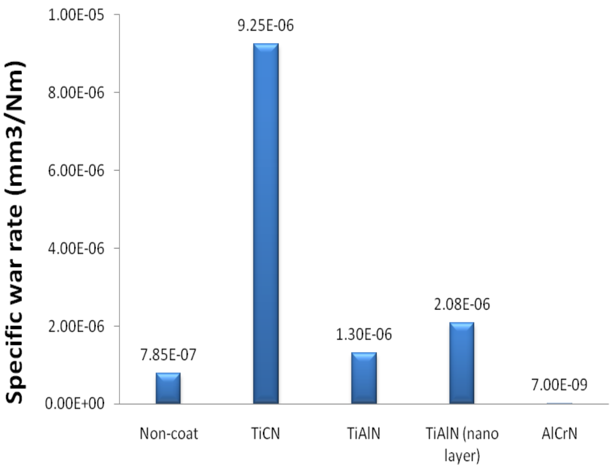


Fig. 6 Specific wear rate for various types of balls at contact pressure 755 MPa

From Fig. 6, it is found that specific wear rates for the case of contact pressure 755 MPa is exceedingly higher than those of 600 MPa. Only the ball coated with AlCrN has specific wear rate lower than that of non-coated ball. The reason of this can be explained by the bonding strength between the films and substrates measured by scratch test as shown in Fig. 7. From the figure, the Lc1 value represents the normal force at which the initial crack occurs, while Lc2 value represents the force at which the film completely fails or peels off. Both Lc values are generally used to characterize bonding strength between a film and a substrate because they are strongly related. Since AlCrN has highest bonding strength, it becomes only one film that can endure high peeling stress occurred during ball-on-disk test under high contact pressure. On the other hand, for the other films, especially TiCN film whose bonding strength is lowest, when the films crack or peel off, the hard worn particles of the films rapidly scratch the ball, resulted in higher wear compared to that of non-coated one.

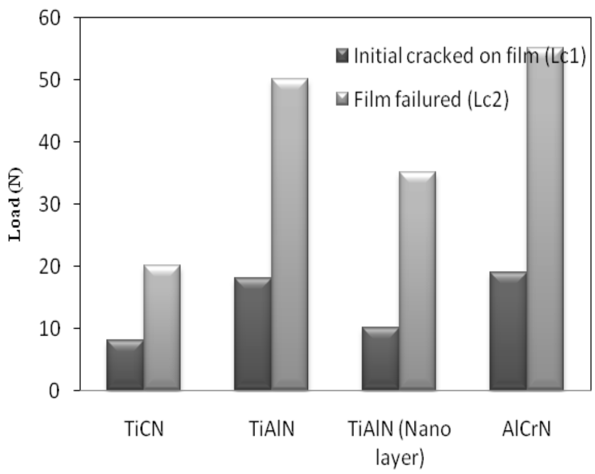


Fig.7. Scratched test results for each surface treatment

5. Conclusion

5.1 By exploring HDD manufacturing process, it is found that SUS304 worn particles are frequently found, and the majority wear mechanism is abrasive type.

5.2 All coating films used can effectively reduce wear rate under contact pressure lower than 600 MPa.

5.3 Among the films used in this study, only AlCrN is found to be effective for the case of high contact pressure up to 755 MPa.

6. Acknowledgement

This research was financially supported by Industry/University Cooperative Research Center in HDD Advanced Manufacturing. Besides, we receive cooperate from Hitachi Global Storage Technologies (Thailand) Co., Ltd. and Western Digital (Thailand) Co, Ltd. All supports are gratefully acknowledges by the authors.

7. References

[1] R.J. Rodrıgueza, J.A. Garciaa, A. Medranoa, M. Ricoa, R. Sancheza, R. Mart!ıneza, C. Labrugereb, M. Lahayeb and A.Guettebr, “Tribological behaviour of hard coatings deposited by arc-evaporation PVD”, Pergamon, Vol. 67, pp. 559-566.

[2] J.L. Mo, M.H. Zhua,, B. Leia,, Y.X. Lenga and N. Huanga, “Comparison of tribological behaviours of AlCrN and TiAlN coatings Deposited by physical vapor deposition”

[3] Shigley, J. Mechanical Engineering Design. New York: McGraw-Hill.1983

[4] Sen, U., 2005, “Friction and wear properties of thermo-reactive diffusion coatings against titanium nitride coated steels”, Journal of Materials & Design, Vol. 26, Issues 2, pp.167-174.

[5] S. PalDey, S.C. Deevi, 2002, “Single layer and multilayer wear resistant coatings of (Ti,Al)N” Journal of Materials Science Engineering, pp.58-79.

[6] T. Polcara, T. Kubartb, R. Novakb, L. Kopeckyc, P. S iroky “Comparison of tribological behaviour of TiN, TiCN and CrN at elevated temperatures”