High speed and large area coating of tetrahedral amorphous carbon with filtered multi cathode vacuum arc plasma system

Young-Jun Jang[1], Yong Jin Kim[1], Gi Taek Kim[1], Yong Jin Kang[1], Jong-kuk Kim[1,*], Seock-Sam Kim[2]

[1)] Surface Technology Division, Korea Institute of Materials Science (KIMS), Changwon, Gyeongnam, 642-831, Korea.
[2)] Faculty of Engineering, University Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia.

[*]Corresponding e-mail: kjongk@kims.re.kr

Keywords: Filtered multi cathode vacuum arc; high speed and large area coating; automobile accessories

ABSTRACT – Filtered cathode vacuum arc (FCVA) method is characterized by plasma beam directionality, plasma energy distribution on substrate, macro particle filtering and coating temperature. Between the two kinds of focus of FCVA method, namely, production cost and high efficiency ta-C coating such as large area deposition with high quality films. In this research, we were filtered muli cathode vacuum arc (FMCVA) system designed and produced to enhance ta-C coating. The system, a specialized configuration of magnetic field with stabilized the d.c. arc plasma discharge during deposition. For acceptable quality for automobile accessories, the magnetic field, T type of filters and multi cathode arc plasma were demonstrated by the deposition of ta-C coating. The measured coating performances were showed that ± 10 % of uniformity, 0.6 um/hr of deposition speed in room temperature and over the 40 GPa of hardness.

1. INTRODUCTION

Diamond-like carbon (DLC) is an excellent coating material for variable application for automobile, mechanical machinery and optical lens etc. In many applications, DLC is playing key parameters for enhanced durability [1].

In case of automobile application, the coated films are subject to anti-delamination at high temperature in these cases, both the thermal stability and high performance of coating such as low friction and adhesion. However, many kinds of hard coating (a-C, a-C:H) were very weak against high temperature. Due to the high mechanical, thermal and chemical stresses applied on coated surface during actual conditions, the surface quality degrades very quickly to an unacceptable level.

ta-C is known as a hydrogen-free carbon coating with 70 ~ 80% of sp^3 phase, smooth surface, good thermal resistance and wear resistance. Moreover, ta-C coating can be synthesized through a relatively convenient method has a much smoother surface, making the tribological performances of ta-C coating better than those of DLC.

Among them, the biggest problems are coating efficiency such as uniformity of large area with high speed of deposition. For these reason, todays coating systems have been developing to achieve high quality of coating film. Hence, the FMCVA system was introduced for the first time for application of automobile accessories.

The FMCVA system is the most powerful technology to enhance coating performance. 5 pieces of multi cathodes has high plasma transmission efficiency, which is desirable and essential for high coating rate. Moreover, multi cathode has strong merit with freedom from size of coating chamber.

In this work, we introduced FCVA with multi cathodes and to investigate the coating performance.

2. FILTERED MULTI CATHODE VACUUM ARC SYSTEM (FMCVA)

Figure 1 (a) shows a schematic illustration for coating system; including T type of filters, multi cathode arc plasma and carbon ion directions. For enhanced deposition speed, multi cathodes were placed in the entrance of magnetic filter on left (3ea) and right (2ea) side. Two streams of carbon arc plasma are transported through the magnetic filter. An optimal filtering of the graphitic macroparticles is obtained with this system. Thus, ta-C coating homogeneous at the um scale are consistently deposited.

Figure 1 (b) shows the distribution to arc plasma flowing form substrate at room temperature, calculated from the numerical analysis (FEMM code).

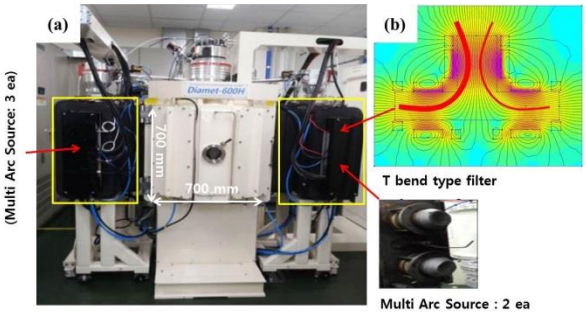

Figure 1 Schematic drawing of the FMCVA (Diamet-600) for ta-C coating system.

Moreover, some studies reported the improved sp^3 content of ta-C coating only when FCVA method was used in deposition; the critical parameters are ion energy and substrate temperature. Among there, temperature is biggest sp^3-to sp^2 conversion of the bond in processing factor. In case of FMCVA, substrate temperature was successfully controlled by bias voltage, arc current.

2.1 Uniformity of ta-C Coating

To apply in industrial field, we tried to get uniformity of ta-C coating on substrate deposited with FMCVA, which has focused on evaluating the coating performance as well as the feasibility of mass production.

Figure 2 to determine the uniformity characteristic, the coating uniformity was aluminum foil marking up to 350 mm diameter by 20 mm intervals on the surface and measuring the thickness. Results showed that average coating uniformity was exhibited ± 10 %, respectively.

Based on the uniformity of ta-C coating, the guideline was defined to within 10 %. Therefore, to obtain a coating film conforming to uniformity of ta-C was acceptable for this work.

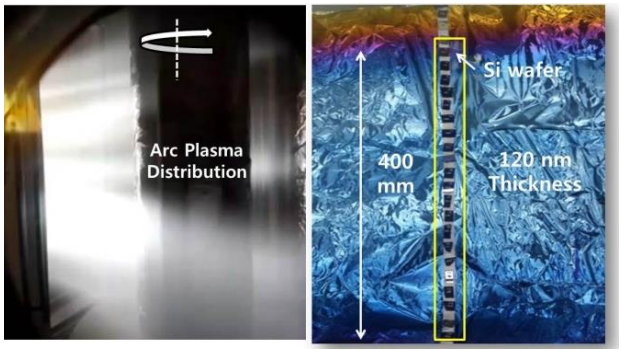

Figure 2 A photograph of the process in coating process and measured uniformity of ta-C coating on aluminum foil with Φ 400 mm width of rotational deposition zone.

2.2 Thickness and Deposition Speed

First, the thickness according to deposition time, when it is the final filtered as described Figure 1(b), was characterized using cross sectional images taken by SEM (Figure 3). A result shows that the thickness of coating was successfully deposited on substrate with 0.6 um/hr of deposition speed.

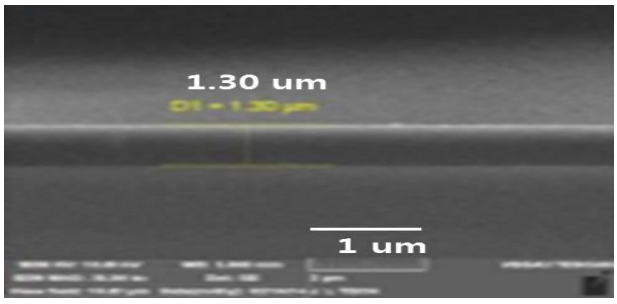

Figure 3 Cross-sectional image of ta-C coating (deposition speed was 0.6 um/hr, respectively).

3. APPLICATION FOR AUTOMOBILE ACCESSORIES

ta-C coatings exhibit high hardness, ultrahigh loading bearing and low friction. These properties protect the coating surface, i.e. including that automobile industry meet the requirements of a wide area of applications.

As early mention before chap. 1, multi cathode has strong merit with freedom from size of coating chamber. To define the coating performance, we applied ta-C coating on 40 mm^2 area with 80A of arc current.

Figure 4 shows the ta-C coating surface on piston ring for GDI (gasoline direct injection) engine using single cathode with FMCVA. The ta-C coating surfaces are uniform, smooth and good colors. The tribological properties are investigation shall be discussing in near future.

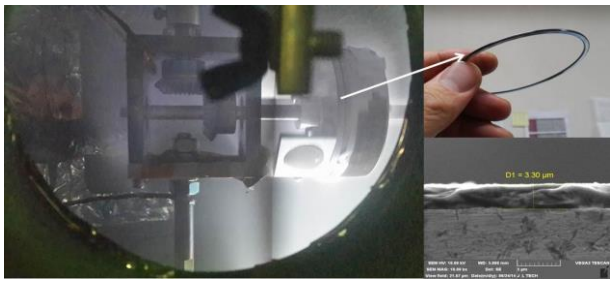

Figure 4 ta-C coated on piston ring with film thickness of 3.3 um. (ta-C/Cr/Al substrate) .

4. SUMMARY

In this research, we have applied to ta-C coating for automobile accessories. ta-C coating was prepared by FMCVA made it possible to investigate of coating properties. The following are the summary that could be drawn from the present work on the applications.

a. We were filtered multi cathode vacuum arc (FMCVA) system designed and produced to enhance ta-C coating on 400 mm with of rotational deposition zone.
b. The uniformity and deposition speed of ta-C coating were ±10% and 0.6 um/hr, respectively.

5. ACKNOWLEDGEMENT

This research is financially supported by the future creation ministry of science in Korea. The authors would like to thank all the engineer of Korea Vacuum limited (KOVA, www.kovac.com) for the technical support.

6. REFERENCES

[1] J. Robertson, “Diamond-like amorphous carbon,” Materials Science and Engineering, R 37, pp. 129–281, 2002.