Substrate temperature impact towards carbon overcoat properties and corrosion performance in magnetic recording media

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Keywords: Substrate temperature; carbon overcoat; corrosion

ABSTRACT – Effect of temperature on the properties of carbon overcoat (COC) films deposited by filament type PECVD technique was studied. Raman spectrometry and Electron Spectroscopy for Chemical Analysis (ESCA) were used to determine the chemical bonding structural change of the COC films. It was found that the increasing substrate temperature from 137 to 204°C transformed gradually DLC films into a graphitic structure. Graphitization of DLC films induced by temperature caused the formation of a large fraction of sp^2 cluster in the COC films, which is a factor influencing galvanic (Cobalt) corrosion. Rich sp^2 cluster acted as a conductor in the films which is also confirmed by conductive atomic force microscope (c-AFM) where higher current flow was observed.

1. INTRODUCTION

Carbon overcoat (COC) or a-C:H contains significant amounts of sp3 (~70%) structure resembling diamond structure which attracts enormous attention mechanical manufacturing as well as media storage owing to their high hardness, hydrophobic behaviors, chemical and electrical resistivity[1-3]. Recently, there are many type of deposition technique used to deposit hydrogenated form of COC, such as ECR-CVD[4], MPCVD[5] and PECVD[6]. Tribological and chemical properties of COC changes significantly with different deposition reactor, precursor gas and process parameters[4-6]. Researchers studied the property of COC by focusing on parameters mentioned instead of the effect of substrate temperature. In this study, the carbon characteristic and corrosion performance for COC films deposited under different substrate temperature using filament type PECVD was investigated.

2. METHODOLOGY

2.1 *Sample Preparation*

COC was deposited on 2.5 inch glass substrate with magnetic under layer at different heater powers ranging from 0.6 to 1.2 kW. Ethylene (C_2H_4) was used as precursor gas during deposition. The heater was placed between magnetic sputtering chamber and COC chamber while IR sensor (temperature reader) was mounted between the heater and COC chamber. Substrate temperature was recorded by the IR sensor before COC deposition.

2.2 *Film Properties*

Raman spectroscope with Ar laser wavelength 532nm was used to confirm the amorphous structural character of COC film from D and G peak position.

sp^2/sp^3 content was determined from the C1s peak by ESCA, (ULVAC-PHI, Quantum2000).

Film conductivity: The AFM used was SII SPA400 under conductive mode. Analysis was done by calculating the percentage of the current area from the scanned AFM image.

2.3 *Media Performance*

Corrosion: 0.5ml 3.0% diluted nitric acid were dropped on top of the sample (disk) and extracted after 1 hour to be analyzed by ICP-MS to check the Cobalt content as corrosion indicator.

3. RESULTS AND DISCUSSION

3.1 *Substrate Temperature*

The substrate temperature before COC deposition was controlled by the heater power as shown in Table 1.

Table 1 Heater power and substrate temperature.

Heater power (kW)	Substrate temperature (°C)
0.6	137
0.8	151
1.0	182
1.2	204

3.2 *COC Properties and Media Performance*

As the substrate temperature increased, the intensity ratio I_D/I_G for D and G peak also increased as shown in Figure 1.

From Raman analysis, the formation of undistorted aromatic rings becomes increasingly more likely as substrate temperature increases in which thermal energy favors the clustering of the sp^2 phase into ordered rings as claimed by Ferrari et al., where the sp^3 phases is considerably low to 0 % at 250°C compared to 30°C [7, 8]. Hence, the film was grown with a more graphite-like structure which was also confirmed by the shift of the Gx (Figure1) towards higher frequencies. The graphitization is consistent with ESCA result where sp^2 content increased as the temperature elevated (Figure2). The parallel increase of corrosion level with the increase of substrate temperature (Figure3) was probably due to the graphitization process as observed in other research [9].

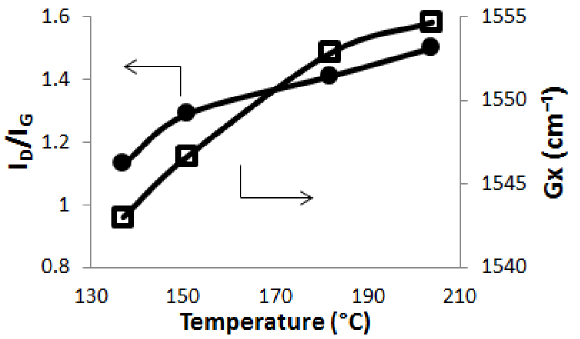

Figure 1 Substrate temperature effect on Raman parameters. (●) Intensity ratio D and G peak, (□) G peak position.

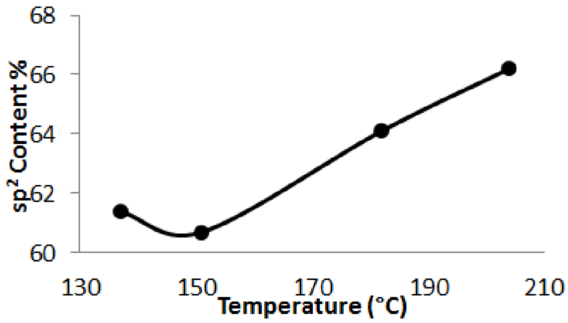

Figure 2 sp^2 content in respect to temperature by ESCA from C1s spectrum.

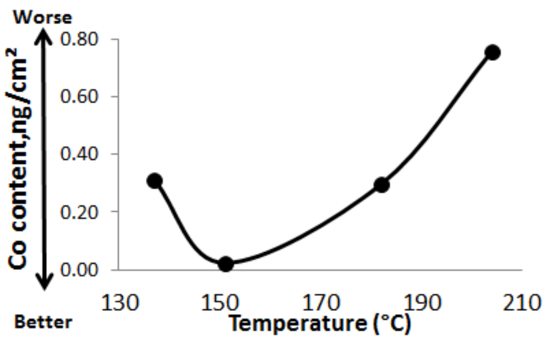

Figure 3 COC film corrosion resistance at increasing substrate temperature.

Raman parameters and sp^2 content results suggest the lower temperature would be preferable for media application but it is insufficient to explain the corrosion resistance optimum at 151°C instead of 137°C. Conductive AFM was done as an additional characterization to support observation mentioned above by checking the electrical resistivity of the film. From Figure4, COC film deposited at 151°C showed the lowest conductivity and the result agrees with Figure3 where the corrosion level is the lowest. Diamond-like structure is resistant towards electrical flow, but graphitic structure observed higher conductivity and less resistance towards electrical flow [10].

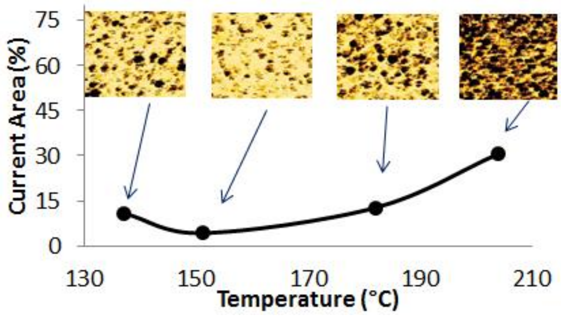

Figure 4 Current flow image for COC at different substrate temperature. Conductivity is higher at the darker area.

4. CONCLUSION

The corrosion performance of COC film at different temperatures were investigated. It was found that low temperature could substantially improve the chemical resistance properties of COC films, which strongly depend on the sp^2 cluster bonding in the films. The results of Raman and ESCA for COC films showed that increasing temperature caused the increase of sp^2 cluster bonds ratio in the films, and consequently a large fraction of sp^2 cluster was formed. These rich sp2 carbon clusters occupied the amorphous network, which becomes one of the factors influencing the degradation of COC film strength towards chemical corrosion.

5. REFERENCES

[1] J.D. Beard, S. Aleksandrov, *et al.* "Magnetically Enhanced Plasma Coating of Nanostructures with Ultrathin Diamond-Like Carbon Films", *RSC Advances*, vol. 4, no. 51, pp. 26635-26644, 2014.

[2] L. Qiang, B. Zhang, *et al.* "Hydrophobic, Mechanical, and Tribological Properties of Fluorine Incorporated Hydrogenated Fullerene-Like Carbon Films", *Friction*, vol. 1, no. 4, pp. 350-358, 2013.

[3] J. Vetter. "60 Years of Dlc Coatings: Historical Highlights and Technical Review of Cathodic Arc Processes to Synthesize Various Dlc Types, and Their Evolution for Industrial Applications", *Surface and Coatings Technology*, vol. 257, no. 0, pp. 213-240, 2014.

[4] Z. Seker, H. Ozdamar, *et al.* "The Effect of Nitrogen Incorporation in Dlc Films Deposited by Ecr Microwave Plasma Cvd", *Applied Surface Science*, vol. 314, no. 0, pp. 46-51, 2014.

[5] Y. Tachimoto, M. Noborisaka, *et al.* "Gas Barrier Properties of Diamond-Like Carbon Films Synthesized by Using Remote Type Microwave Plasma Cvd under Sub-Ambient Atmospheric Pressure", *Journal of Physics: Conference Series*, vol. 417, no. 1, pp. 012043, 2013.

[6] É.C. Oliveira, S.A. Cruz, *et al.* "Effect of Pecvd Deposition Parameters on the Dlc/Plc Composition of a-C:H Thin Films", *Journal of the Brazilian Chemical Society*, vol. 23, pp. 1657-1662, 2012.

[7] A.C. Ferrari, and J. Robertson. "Interpretation of Raman Spectra of Disordered and Amorphous Carbon", *Physical Review B*, vol. 61, no. 20, pp. 14095-14107, 2000.

[8] M. Chhowalla, A.C. Ferrari, *et al.* "Evolution of Sp2 Bonding with Deposition Temperature in Tetrahedral Amorphous Carbon Studied by Raman Spectroscopy", *Applied Physics Letters*, vol. 76, no. 11, pp. 1419-1421, 2000.

[9] A. Dorner-Reisel, C. Schürer, *et al.* "Electrochemical Corrosion Behaviour of Uncoated and Dlc Coated Medical Grade Co28cr6mo", *Surface and Coatings Technology*, vol. 177–178, no. 0, pp. 830-837, 2004.

[10] M. Massi, H.S. Maciel, *et al.* "Electrical and Structural Characterization of Dlc Films Deposited by Magnetron Sputtering", *Journal of Materials Science: Materials in Electronics*, vol. 12, no. 4-6, pp. 343-346, 2001.