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Investigations of DLC Films for Protection of Organic Photoconductors in Electrophotography

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The diamondlike carbon (DLC) films were deposited by RF plasma CVD system which had cathode consisting of mesh sheet, for the purpose of a protection from wear of OPC surface of the electrophotographic photosensitive body. Material charateristics and tribological properties of the films were also investigated and finally copying performance was evaluated with DLC deposited OPC samples. The surface resistance of the DLC film unaffected by the surface potential of the OPC was about 10^{11} Ω and its hardness was about 1200 kg/mm^2. In this case the film showed typical material strcture of dimondlike hydrocarbon The friction coefficient of the film was lowered to 0.2~0.3 at the optimum condition in this investigation and their wear resistant was improved by DLC-deposition on the OPC surface. DLC-deposited OPC samples with a good copying performance without image flow and draft could be obtained at some depositing conditions.

Key words : Diamondlike Carbon (DLC) Films, RF plasma CVD, Organic Photo Conductor (OPC), Thin Film

I. Introduction

The application of diamondlike carbon (DLC) films has been increasing in many fields of the industry. The followings are a few random examples[1,2]: sensor and infrared optical lens, etc.. Especially, the application in electronics such as the cylinder and capstan of video cassette recorder and recording tape has been watched with interest.[3,4]

On the other hand, recently, the organic photoconductor (OPC) became to use most commonly as photoconductive material in electrophotography, since it has a high quality and can be produced cheaply.[5] However, its service life time is shorter than other photoconductive materials such as a-Si and a-Se.

In this study, DLC film was deposited on the OPC layer for the protection from the wear of OPC layer of the electrophotographic photosensitive body, and then the material charateristics and tribological properties of the film deposited by RF plasma CVD system were investigated.

II. Experimental Details

1. Deposition process

DLC film was deposited by the RF plasma CVD system schematically shown in Fig. 1. This system contained the mesh cathode which was specially designed in order to reduce the attack of high energetic ions against the substrate. RF power of 13.56 MHz was used for the deposition. The DC self-bias voltage on the cathode was controlled by RF power and was measured by a voltmeter connected to the matching net work.

The sheet-type organic photosensitive body (50×50 mm^2) which is schematically shown in Fig. 2 was used as the substrate. This OPC substrate was placed on the water cooled holder in the CVD chamber as shown in Fig. 1

A 99.6% methance gas was used as the source gas for the DLC film. The DLC film deposition was carried out after surface cleaning by sputtering using argon gas for 5 minutes at a bias voltage of -500 V. The DLC films were deposited as a function of chamber pressure (50, 85 m Torr) and DC self-bias voltage (-100~500 V).

2. Evaluation of DLC films

Thickness, hardness and surface resistance of the deposited films were measured by surface profilometer, dynamic ultra microhardness tester (Min. Load; 1 mg) and megohmmeter, respectively.

Figure 3 shows the schematic diagram of surface resistance measuring sample. The slide glass was selected as a substrate material because it has high insulation resistance, and the sample was deposited in the selected area using a mask to minimize the measuring error.

Raman and FTIR analyses were also conducted to investigate the material. On the other hand, friction and wear experiments were carried out, using a ball-on-disk type tribometer. Table 1 shows the experimental conditions for the friction test. Finally, copying performance

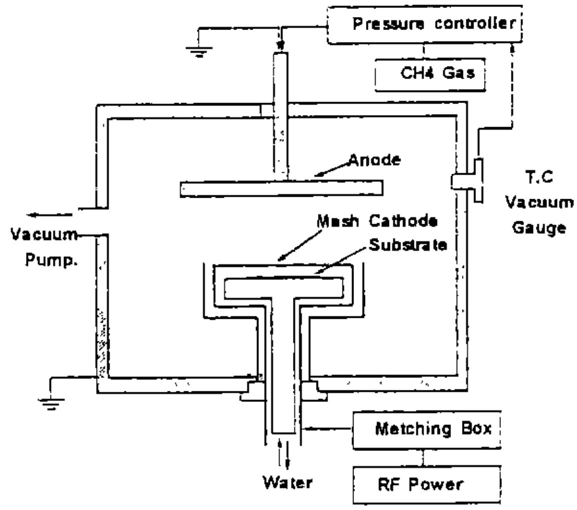

Fig. 1. Schematic diagram of MC-PECVD system.

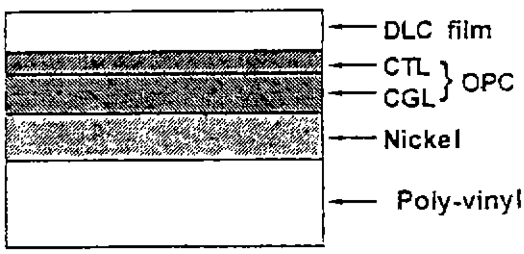

Fig. 2. The cross-section of DLC coated OPC.

Table 1. Experimental Conditions for Tribological Test

Load	101.9 mN
Speed	300 rpm
Time	20 min
Pin material	SiC
Temp.	23.3°C
Hum.	64.5%

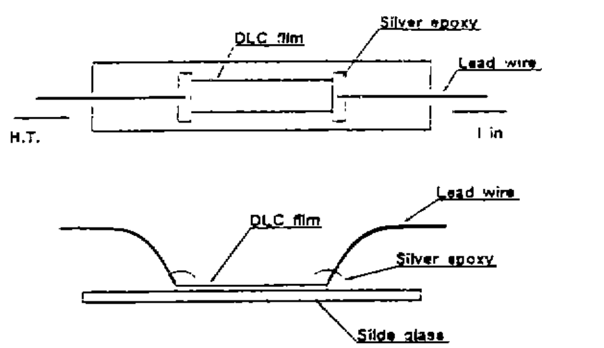

Fig. 3. Schematic diagram of the sample for the measurement of surface resistivity.

of the DLC-coated OPC samples was evaluated by using a commercial copying machine.

III. Results and Discussion

1. DLC Film characteristics

Figure 4 shows the effect of negative bias voltage imposed on the mesh-cathode on the film thickness at constant pressure, 50 and 80 m Torr. The deposition rate increased with DC self-bias voltage because the impingements of ions and radicals on the substrate increased due to increase in the densities of ions and radicals in the plasma with RF power.

Figure 5 shows relation between the bias voltage and the hardness of film. The films deposited at -300 and -500 V had higher hardness than silicon wafer and the hardness of film increased with bias voltage. The maximum hardness obtained was about 2800 Hv (1 g) at -500 V and 500 mTorr in this investigation. This trend may be because of the change in material properties of deposited film from polymer-like to diamond-like due to increase in the number of impact and peening of energetic ions as the DC self-bias voltage increases.

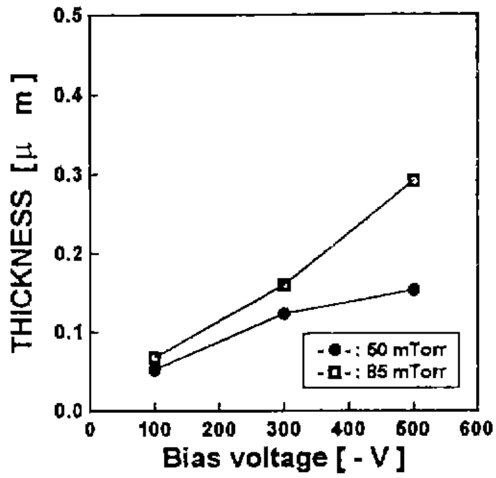

Fig. 4. The effect of DC self-bias on the film thickness.

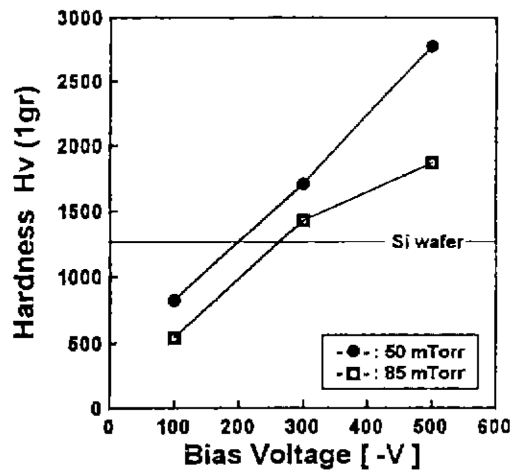

Fig. 5. The effect of DC self-bias and gas pressure on the hardness of film.

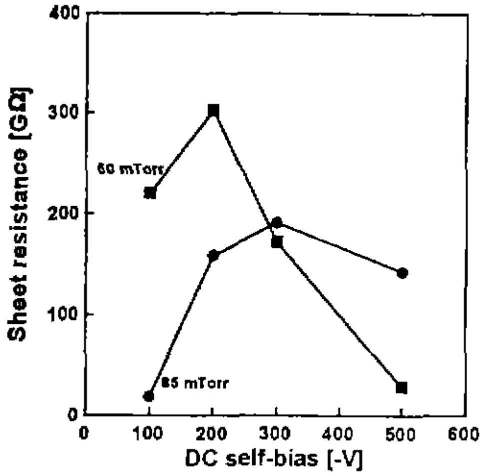

Fig. 6. The effect of DC self-bias on the surface resistance of film.

The current carried by the film was measured by the megohmmeter and its resistivity was calculated. The results are shown in Fig. 6 as a function of DC self-bias voltage.

As the DC bias increased the film resustivity increased and then decreased with further increasing DC bias for both 50 and 85 mTorr reaction gas pressures. However, each case shows the different conversion point in resistivity because the ion impact energy was changed according to gas pressure even though RF power was the same.

The resistances of most samples were above 10^{11} Ω, whic were coincided with the result reported by Nakaue.[5] Those results demonstrate that DLC film deposited does not influence on the surface potential of the OPC. Furthermore, the deposited surface showed the microhardness of 1200 kg/mm^2, which represents that DLC protected film is able to improve the durability of the OPC without image draft and flow.

2. Material structure of DLC fims

Raman and FTIR analyses for the films deposited under each condition, were conducted to characterize the material structure and C-H bonding structure. These results are shown in Fig. 7 and 8, respectively.

It can be seen from the results of Raman analysis (Fig. 7) that the heights of the disorder (D) peak at ~1350^{-1}cm and the graphite "G" peak at ~1550 cm^{-1} increased and "G" peak was shifted to 1500^{-1} cm wavenumber which are typical peaks of diamond-like hydrocarbon films as DC-bias increases. In case of -100 DC bias, "D" and "G" peaks were not observed. This results agree with the results reported by Yoshikawa [6] The films are considered to be polymerlike.

The results of FTIR analysis (Fig. 8) show the broad band with small peaks at 2800~3100 cm^{-1} and the intensity of the peak decreases with decrease of carbon fund gas pressure and increase of DC self bias voltage.

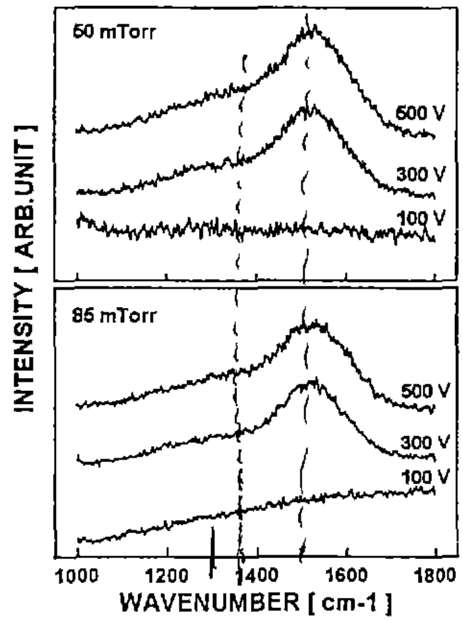

Fig. 7. Raman spectra of deposited film.

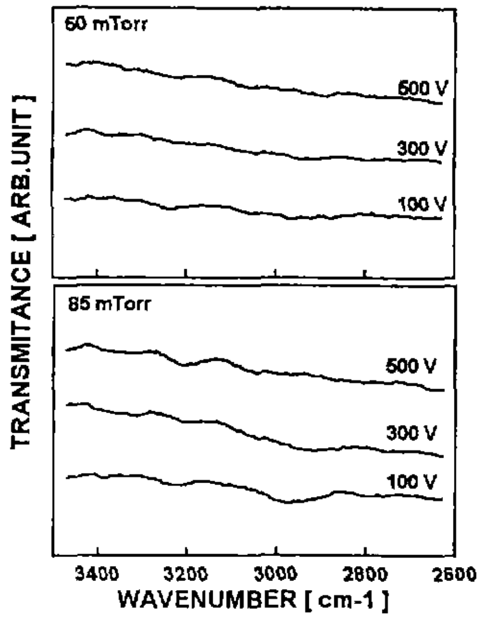

Fig. 8. FTIR spectra of deposited film.

These results suggest that the film had a C-H stretch mode structure and the decrease of gas pressure caused the reduction of hydrogen content in the film.

The above results from Raman and FTIR analyses demonstrate that the films had typical bonding structure of dimondlike hydrocarbon. On the oter hand, the increased ion impact energy due to the increase in the DC-bias broke the C-H bonding-link and caused the increase in cross-linking of carbon atoms. In conclusion, the properties of film varied from polymerlike to dimondlike as DC-bias increased.

3. Tribological properties of DLC films

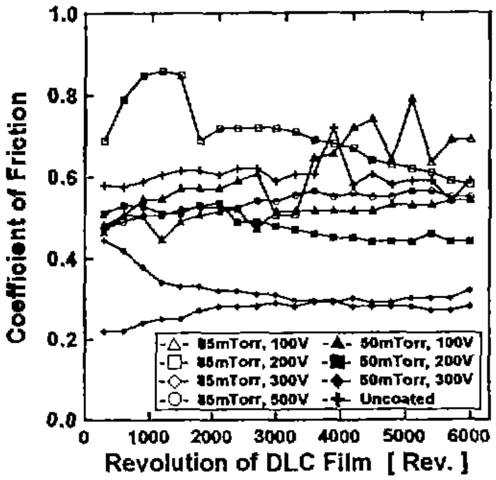

Fig. 9. Friction coefficient of DLC coated OPC and uncoated OPC.

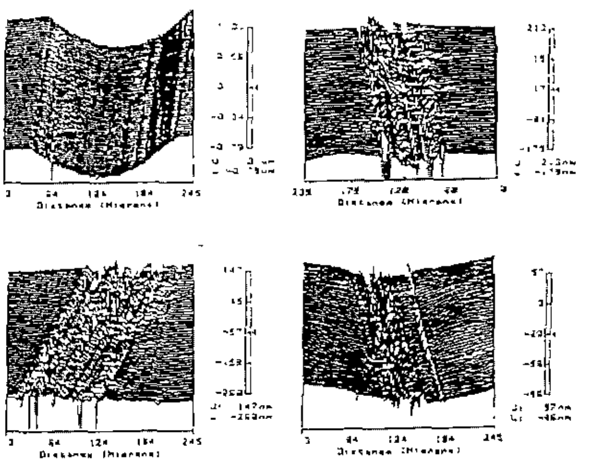

Fig. 10. Wear scar by friction on the uncoated OPC and various DLC coated OPC. (a) uncoated OPC, (b) 50 mTorr, 100 V, (c) 85 mTorr, 100 V, (d) 85 mTorr, 300 V.

Friction and wear experiments were conducted by the ball (SiC)-on-disk tribometer under the condition of light load. The changes of friction coefficients in the DLC deposited samples are shown in Fig. 9 as a function of reaction gas pressure, DC-bias and number of revolution.

The friction coefficients of most sample lower than those of undeposited sample (OPC). Especially, the friction coefficients were as low as 0.2~0.3 in the case of the case of the sample deposited at -300 bias, 50 mTorr. The depth of wear scar on uncoated sample was about 900 nm and the width was about 160 μm (Fig. 10(a)). On the other hand, the depth was 70~170 nm and the width was 25~100 μm in the case of DLC-deposited samples (Fig. 10 (b, c, d). The depth and width of wear scar decreased maximum 12 and 6 times by DLC-deposition on the OPC surface, respectively.

Finally, copying performance of the DLC-coated OPC samples was evaluated by using a commercial copying machine. Good copying performance could be obtained without image flow and draft with the samples deposited under the conditions of 85 mTorr, 200 and 300 V and at 50 mTorr, 100 and 200 V.

IV. Conclusions

DLC films were deposited on OPC by RF plasma CVD system for the purpose of the protection from the wear of OPC surface of the electrophotographic photosensitive body and then, material charateristics and tribological properties of the films were investigated. Finally, copying performance was evaluated with DLC coated samples. The following results were obtained;

1. Using a cathode consisting of mesh sheet in RF plasma CVD system made possible to prevent from damage on the soft and fragile OPC surface by DLC deposition.
2. The surface resistance of the DLC film unaffected by the surface potential of the OPC was about 10^{11} Ω and its hardness was about 1200 kg/mm^2. In this case the film showed typical material structure of diamondlike hydrocarbon
3. The friction coefficients were as low as 0.2~0.3 at optimum conditions and the depth and width of wear scar decreased maximum 12 and 6 times, respectively.
4. DLC deposited OPC samples with a good copying performance without image flow and draft could be obtained at some depositing conditions.

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