Research and Development of Tribological Techniques for Automotive Parts

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ABSTRACT

According to the prevention of global warming and the energy saving policy, the diversification of fuels (bio diesel, ethanol, etc.) for vehicles and the growth of market share of electrical and hybrid vehicles have been increasing. In this paper, a unique in-situ analysis technique and a typical achievement in the fuel tribology related to automotive parts were described as a 1st topic. And as a 2nd topic, tribological and electrical behaviors of a metal containing Diamond-Like Carbon nanocomposite coating deposited on an electrical contact material were discussed.

1. Introduction (topic 1)

As an industrial application, Diamond-Like Carbon (DLC) has been used in various components. Especially, in the automotive application, DLC is used in variety of conditions such as dry, E/G oil and fuel. However, the optimum structure of DLC has not been clarified in each environmental condition.

Recently, we have developed an in-situ system to observe the behavior of lubricant during friction by combining the fast-scan Fourier transform infrared attenuated total reflection (FTIR-ATR) spectrometer with the friction equipment as shown in Figure 1 [1]. In this study, we will report the experimental data of structural changes of DLC in various conditions as measured using the in-situ observation system.

2. Experiment (topic 1)

The infrared spectra were obtained by two experiments, annealing test and in-situ friction test. The annealing test was conducted at 500°C for 2hr. Table 1 shows the test condition for in-situ friction test.

3. Results and Discussion (topic 1)

Figure 2 shows the infrared spectra after annealing at 500°C. We have assigned bands of DLC with some papers (e.g. [2]). The spectra after anneal test shows the large change at ca. 1100 cm-1 which represented the aroma structure and ca. 1600 cm-1 corresponding to sp2 conjugated C=C. It is clarified the graphitization and aromatization are caused by the high temperature.

The intensity of the band at 1600 cm-1 and the friction coefficient obtained by using in-situ observation system are shown in Figure 3. In the running-in region, the intensity of sp2 band obviously increases. The intensity of aroma band also increases during friction. However the behavior of sp1 band intensity is difference between anneal test and friction test. The sp1 band intensity decreases as the temperature rises. In contrast, that intensity increases during friction (Table 2).

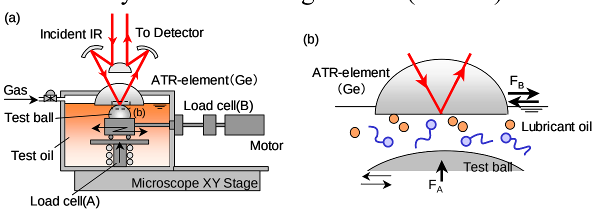

Fig. 1 Schematic diagram of in-situ observation system

Table 1. Experimental conditions

Specimen	a-C:H (on S45C Cylinder)
Speed	0.5mm/s
Load	55N (125MPa)
Time	6hr

Table 2. Structural changes of DLC for each test

	Aroma	sp1C-C	sp2C=C	$sp3CH_3$
Annealing	+	-	+	-
Friction	+	+	+	-

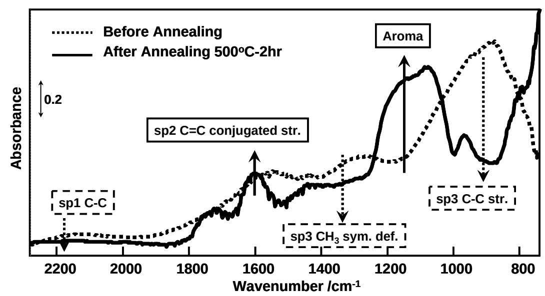

Fig. 2 Infrared spectra after annealing

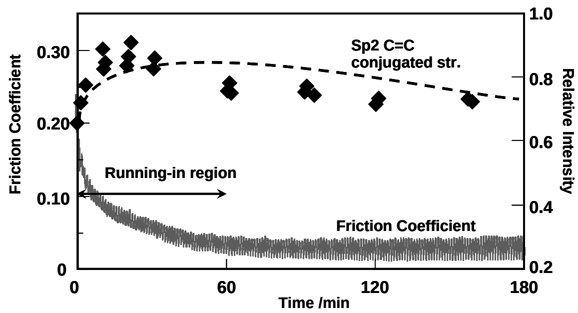

Fig. 3 Time dependence of band intensity and COF

4. Summary (topic 1)

The structural changes of DLC under friction were researched. The experimental results clearly show that friction induces the structural changes of DLC.

ball combination were investigated. A Cu-rich tribofilm was built up on a brass ball by sliding with a Cu-DLC deposited on a brass substrate. This tribofilm provides the good tribo-electrical characteristics.

5. Introduction (topic 2)

Demands for innovative technology on electrical contacts in vehicles have been increasing with the growth of market share of electrical and hybrid vehicles. Reducing the electrical contact resistance (ECR) and the coefficient of friction (μ) are the major technological issues. In this study, tribological and electrical behavior of a copper containing Diamond-Like Carbon (Cu-DLC) nanocomposite coating deposited on a brass (Copper-Zinc alloy) substrate was investigated.

6. Experiment (topic 2)

Experimental materials and conditions are shown in Table 3. A hybrid deposition process, coupling plasma enhanced chemical vapor deposition and DC magnetron sputtering of a copper target, was used for the deposition of the Cu-DLC [3]. A brass ball was used as the counterpart of the Cu-DLC. The tribological and electrical contact behavior was investigated by using a ball-on-plate linear reciprocating tribometer. The four-terminal method was used for the measurement of ECR between the ball and the plate during the tribo-test. A combination of an uncoated brass plate (the substrate of the Cu-DLC coating) and a brass ball was performed for comparison purpose.

Table 3. Experimental materials and conditions

Materials	Ball (φ6.35mm)	Brass	
	Plate (20 x 20 x t0.5mm)	Brass (uncoated)	Cu-DLC (brass substrate)
Conditions	Normal load	1N	3N
	Track length	0.8mm	
	Frequency	0.5Hz	
	Electrical current	0.2Amps	
	Sliding cycles	up to 2000	
	Atmosphere	Ambient air (20-25 °C, 25-35%RH)	

7. Results and Discussion (topic 2)

Figure 4 and Figure 5 show the typical ECR, μ responses of each material combination, respectively.

In the case of the uncoated brass plate, ECR was initially around 50 milliohms but it decreased down to 1.0 to 2.0 milliohms after few cycles. The initial value of μ was approximately 0.3 and it increased rapidly to around 0.8 after few cycles. After, the variations of ECR and μ around these average values were relatively wide.

In the case of the Cu-DLC, while initial value of ECR was hundreds of milliohms, it gradually decreased with cycles and reached 1.5 to 2 milliohms after 600 cycles. μ started below 0.35 and decreased progressively, and stabilized around 0.25, also after 600 cycles. Observation of worn surfaces of the different number of sliding cycles reveals that a tribofilm was built up on the sliding surface of the ball, and it grew as the sliding cycle increased, consisting mainly of copper according to energy dispersive X-ray spectroscopy. The Cu-DLC coating on the plate wore gradually and delamination of the Cu-DLC was observed at 450 cycles. Around this number of cycles, ECR started decreasing, suggesting that such decrease resulted from the delamination of the Cu-DLC coating. After less than 1000 cycles, the Cu-DLC was almost worn out. However, detrimental effects could not be observed either on ECR or on μ. So the tribofilm on the ball should have a key role in achieving and preserving these good electrical and tribological characteristics.

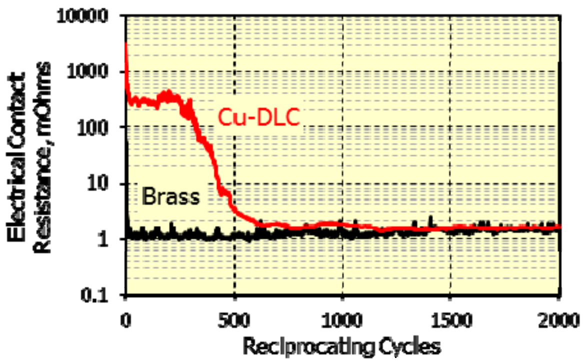

Fig. 4 Electrical contact resistance

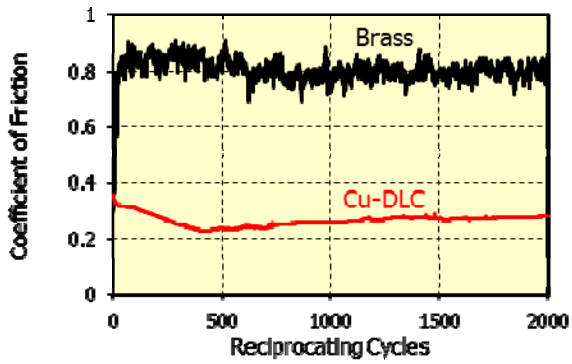

Fig. 5 Coefficient of friction

8. Summary (topic 2)

The electrical contact resistance and the coefficient of friction behavior of a Cu-DLC nanocomposite coating deposited on a flat brass substrate with a brass

References

[1] Keiji Sasaki, Naruhiko Inayoshi, Kohji Tashiro, Rev. Sci. Instrum., 79, 2008, 123702.

[2] Thibaut Heitz, Bernard Drévillon, Christian Godet, Jean-Eric BouréeThibaut, Physical Review B, 58, 1998, 13957.

[3] Takanori Takeno, Toshifumi Sugawara, Hiroyuki Miki, Toshiyuki Takagi, Diamond and related materials, 18, 2009, 1023-1027.