Tribological and Electrical Contact Behavior of Metal/DLC Nanocomposite Coating on Brass Substrate

R. Hombo[1*], T. Takeno[2], J. Fontaine[3], H. Miki[4], N. Kato[1], T. Nozu[1], N. Inayoshi[1], M. Belin[3] and T. Takagi[5]

[1)] DENSO CORPORATION, 1-1 Showa-cho, Kariya-shi, AICHI 448-8661, Japan.
[2)] Graduate School of Engineering, Tohoku University, Aoba 6-6-1, Aramaki, Aoba-ku, Sendai, MIYAGI 980-8579, Japan.
[3)] Laboratoire de Tribologie et Dynamique des Systèmes, École Centrale de Lyon, 69134 Écully, France.
[4)] Frontier Research Institute for Interdisciplinary Science, Tohoku University, Aramaki aza Aoba 6-3, Aoba-ku, Sendai, MIYAGI 980-8578, Japan.
[5)] Institute of Fluid Science, Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai, MIYAGI 980-8577, Japan.
*Corresponding author: ryoichi_honbo@denso.co.jp

1. Introduction

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 behaviors of metal containing diamond-like carbon (DLC) nanocomposite coating deposited on a brass (Copper-Zinc alloy) substrate were investigated.

2. Experiment

Experimental materials and conditions are shown in Table 1. A hybrid deposition process, coupling plasma enhanced chemical vapor deposition and DC magnetron sputtering of a metal (W, Cu) target, was used for the deposition [1]. The tribological and electrical contact behavior was investigated by using a ball-on-plate reciprocating tribometer. The four-terminal method was used for the measurement of ECR between the ball and the plate during the tribo-test.

3. Results and Discussion

Figure 1 and Figure 2 show the typical ECR and μ responses. In the case of the uncoated brass plate, low ECR and high μ were observed and their variations were relatively wide. In the case of the W-DLC, ECR gradually increased with increasing number of cycles and reached above 100 milliohms at 1000 cycles. In contrast, μ decreased and the value was maintained below 0.25 after 200 cycles. From the sliding surface of the ball, oxygen was detected but W was not detected by energy dispersive X-ray spectroscopy (EDS). Oxides of copper and zinc have high resistivity and low friction characteristics. So, it is supposed that above mentioned phenomena in the W-DLC experiment were caused by an oxidation of the ball surface. 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 after 600 cycles. Figure 3 shows typical sliding surfaces after 1000 cycles. Observation of worn surfaces after different number of sliding cycles reveals that a tribofilm was built up on the sliding surface of the ball, and that it grows as the sliding cycle increased. This tribofilm consists mainly of copper according to EDS. Surprisingly, the Cu-DLC coating on the plate was almost worn out after less than 600 cycles, without detrimental effects neither on ECR nor on μ. The good electrical and tribological characteristics of the contact were thus provided by the tribofilm on the ball.

Table 1 Experimental materials and conditions

Materials	Ball	Brass (φ6.35mm)
	Plate	Brass (uncoated)
		Tungsten containing DLC (W-DLC)
		Copper containing DLC (Cu-DLC)
Conditions	Normal load	3N
	Track length	0.8mm
	Frequency	0.5Hz
	Electrical current	0.2Amps
	Sliding cycles	up to 1000
	Atmosphere	Ambient air (20-25 °C, 25-35%RH)

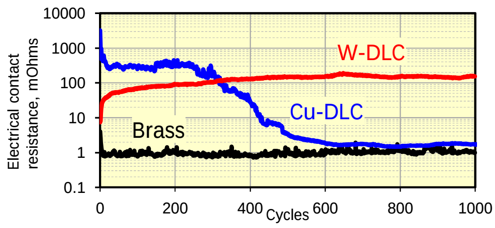


Fig.1 Electrical contact resistance behavior

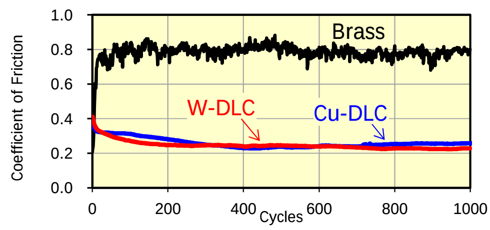
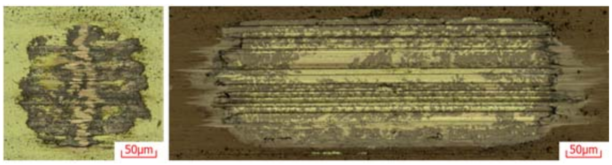


Fig.2 Coefficient of friction behavior



(a) Ball (b) Plate (Cu-DLC)

Fig.3 Sliding surfaces after 1000 cycles

4. Summary

A Cu-rich tribofilm providing good tribo-electrical characteristics was formed on the ball by sliding with the Cu-DLC. In contrast, no W but copper and zinc oxides causing high ECR were observed on the ball after sliding with the W-DLC.

5. Reference

[1] Takeno T et al, Diamond and Related Materials, 18, 2009, 1023-1027.