RECENT DEVELOPMENT IN TRIBOLOGY FOR SUSTAINABLE SOCIETY

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ABSTRACT
To clarify the both low friction mechanisms of DLC and CNx in dry nitrogen gas and oil, we tried to measure optical properties of surface thin layer of sliding scar of DLC for evaluation of transformed layer of DLC and CNx with reflectance spectrometer. After both experiments, it was shown the very thin transformed layer of DLC and CNx is important to control low friction under the sliding conditions of Nitrogen blowing and oil boundary lubrication for efficient machines in sustainable society.

Keywords: Carbonaceous hard coating, ultra low friction, high seizure load, compact machine.

INTRODUCTION
In these years, ultra energy saving of all of machine will be needed strongly especially for advanced automobiles for sustainable society. For this purpose, the development of materials and mechanical components for internal combustion engine has received increasing demands, to be light-weight, compact, loss-reduction, for improving fuel economy and environmental issue. Lubricant and surface treatment technology will play more important roles, in term of their direct and immediate effects for improving performance. So new technologies were developed especially with hard and lubricious coatings.

The carbonaceous coating such as Diamond-Like Carbon (DLC) coating and amorphous Carbon Nitride (CNx) coating is promising for high hardness, low friction property and affordability. These carbonaceous coatings show low friction less than 0.05 in boundary oil lubrication for automobile engines. Also CNx shows ultra low friction as less than 0.01 in dry nitrogen gas with very thin transformed layer (Umehara, 2000). Though it is reported that transformed layer is important to show low friction, it is still unclear that transformed layer makes an effect on ultra low friction as less than 0.01 in dry nitrogen gas and low friction as less than 0.05 in boundary oil lubrication.

To clarify the both low friction mechanisms of DLC and CNx in dry nitrogen gas and oil, we tried to measure optical properties of surface thin layer of sliding scar of DLC for evaluation of transformed layer of DLC and CNx with reflectance spectrometer. Also we proposed the way to measure thickness, sp²/sp³ ratio and density of dangling bonds of transformed layer in-situ by using reflectance spectrometer while sliding.

EVALUATION OF TRANSFORMED LAYERS
Figure 1 shows the measurement systems of reflectance spectrometry for evaluation of transformed layer on sliding scar of DLC. By the fitting with theoretical curve, we can estimate the thickness of the transformed layer on DLC. Figure 2 shows the relationship
between the thickness of friction coefficient and \( t/\sigma^* \), where \( t \) is thickness of transformed layer and \( \sigma^* \) is deviation of roughness height. \( t/\sigma^* \) means probability of breaking transfer film by surface roughness (Ohara, 2013).

**IN-SITU MEASUREMENTS**

The in-situ observation system of friction area is composed with pin-on-disk friction tester and a reflectance spectrometer that can measure the optical properties of surface coatings as reflectance index and extinction coefficient through sapphire hemisphere as shown in Fig.3. We tried to estimate a thickness, \( \text{sp}^2/\text{sp}^3 \) ratio and density of dangling bonds of the coating in-situ. From the in-situ observation results, we found the relationship between the thickness and properties of transformed layer and friction well, and establish the ultra low friction model (Nishimura, 2015).

On the basis of these research achievements, carbonaceous hard coatings were clarified for quite smart materials to reduce friction for sustainable society.

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**REFERENCES**

