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Quantitative study on correlation between wear behavior and frictional energy of soft-metal/DLC nanocomposite coatings by transmission electron microscopy

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Quantitative study on correlation between wear behavior and frictional energy of soft-metal/DLC nanocomposite coatings by transmission electron microscopy (TEM) using the thinned specimens processed by focused ion beam (FIB) has been reported. Surficial damages to the sample surfaces during FIB were evaluated by amorphization of Si (100) substrate by Ga ion bombardment, and were prevented by carbon interlayer by vacuum deposition prior to FIB. TEM analysis showed that the wear amount of the coatings increased with increase of metal content in the coatings, and that the wear property tended to depend on frictional energy as well as the wear mode.

Keywords: soft metal/DLC nanocomposite, TEM, FIB, wear, frictional energy

1. Introduction

Diamond-like carbon (DLC) is well-known tribo-material showing low friction coefficient and high wear resistance, and has been achieved to many kinds of industrial products [1]. Since the characteristics of DLC vary by adding the other elements, adding metals to DLC is effective to improve both electrical and tribological properties. Previously, we have reported that the correlation between friction coefficient and metal content in a soft-metal (SMe)/DLC nano-composite coatings (SMe-DLC) [2]. This result indicated that the friction coefficient of SMe-DLC depends largely on the SMe content which determines interfacial condition between coatings and counterpart. In this study, we investigated the wear property of SMe-DLC by TEM using the thinned specimens processed by FIB, and have discussed as a function of frictional energy during sliding.

2. Methods

SMe-DLCs were deposited on a Si (100) substrate by RF magnetron sputtering (RF-MS) using a concentric composite target (CCT) [2]. The CCT consists of C base target and metal tablet which was located on the center of the base target concentrically. The concentration of metal in SMe-DLC can be controlled widely by changing the area ratio of SMe/C on the CCT. The Cu concentration in the Cu-DLC was measured by Energy Dispersive X-ray Spectroscopy (EDS) by the composition ratio between Cu and C. The thickness of Cu-DLC was controlled by deposition rate, and measured by surface profiler. The nano-structure and wear depth of the coatings was analyzed by TEM. The preparation of the extra-thin cross-section sample of SMe–DLC was prepared using FIB. The surficial damage by ion beam during FIB process was successfully avoided by dual carbon protects layers. A hardness of the film was measured by nanoindentation, and the indentation depth of Berkovich indenter maintained 100 nm for all measurements. The frictional experiments were performed using linear reciprocating tribometer under the sliding speed of 20 mm/s in average. A mirror-polished JIS SUJ2 bearing steel and JIS C2700 brass were used as a counter material.

3. Results and Discussions

The friction coefficient of SMe-DLC changed to three patterns, depending on the SMe concentrations in the coatings. The friction coefficient for both high and low SMe content showed relatively low and steady value approximately 0.2-0.3, and "tribofilm" formed on the counter-face [3]. In the intermedium region, however, no tribofilm was formed on the counterface and the friction coefficient was relatively high. The frictional energy decreased monotonically with increase of SMe content in the coatings. The wear depth of the coatings increased too, with the increase of SMe content. The frictional energy tended to show negative correlation with the wear depth of SMe-DLC.

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