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Fabrication of diamond-like carbon film on rubber by T-shape filtered-arc-deposition under the influence of various ambient gases

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Abstract

Diamond-like carbon (DLC) films were prepared on rubber substrates using T-shape filtered-arc-deposition (T-FAD), which effectively removes the macrodroplets emitted from the graphite cathode spot from the processing plasma. In the present study, the influence of ambient gas (no gas, Ar, H_2, C_2H_2, C_2H_4, CH_4) was investigated. The DLC films adhered well to the rubber substrate. When the substrate was stretched, the small DLC islands were separated and clefs were opened. The deposition rate on rubber was approximately twice higher than that on a Si substrate. When hydrocarbon gas was introduced as an ambient gas, the deposition rate became higher than that for no gas and H_2 gas. In the cases of C_2H_4 and CH_4 gases, the DLC film was considered to contain a considerable amount of hydrogen. When C_2H_2 gas was used, the highest deposition rate with less surface roughness was achieved.

Keywords: T-shape filtered-arc-deposition; Diamond-like carbon film; Ambient gas; Rubber substrates; Deposition rate; Morphology

1. Introduction

Diamond-like carbon (DLC) film has attractive properties especially for tribology, such as low friction coefficient, high hardness, wear resistance, and corrosion resistance [1–3]. The application of DLC films has increased in utility in a wide number of fields. Recently, coatings of DLC on rubbers and polymers are of interest for industrial applications [4–7]. Rubber has a high friction coefficient and is used as a non-slip component. However, there is a specialized application when the rubber itself absorbs a mechanical shock or stress based on its elastic property but maintains the surface sliding properties. An example of such an application is the O-ring used in the power zoom part of a compact camera. In such an application, the DLC film must flexibly follow the change of the rubber.

There are a variety of methods to prepare DLC film [1–3]. However, DLC film coating on rubber has been investigated only by means of plasma chemical vapor deposition (CVD) [4–6] and vacuum arc deposition (or cathodic arc deposition) [7]. The former employs a capacitive coupling plasma powered by radio frequency (RF) and uses methane gas (CH_4) as a carbon source. In the process, in order to prepare for the adhesion of flexible DLC on rubber, a hydrogen (H_2) plasma treatment of the rubber is introduced as preprocessing before film formation. The latter is ion plating and is one of the physical vapor depositions using solid graphite as a carbon source. In vacuum arc discharge, the cathode is very active and emits electrons to sustain the discharge as well as the highly energized ions of the cathode materials. However, the disadvantages of this method are the emission of the macrodroplets of cathode material from the cathode spot and the subsequent macrodroplet attachment to the preparing film, which results in poor film properties. The cathode spot of graphite cathode extrudes large amounts of macrodroplets and a technique to eliminate macrodroplet attachment to the film is required.

The authors have employed and modified shielded cathodic arc deposition systems with a shield plate between the cathode and the substrate to prevent macrodroplet adhesion, and which have a comparatively simple system set-up [8–10]. However, using the shielded method, it is difficult to prevent adhesion of the solid macrodroplets emitted from the graphite cathode, since the solid macrodroplets bounce the chamber wall toward the substrate. Thus, the authors developed a filtered cathodic arc deposition system with a T-shape duct,

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