

Ion Energy Measurement in Shielded Vacuum Arc with Graphite Cathode

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Ion energy distribution was measured in a shielded and non-shielded cathodic arc deposition apparatus for fabricating a diamond-like carbon (DLC) film, using a selected-mass ion energy analyzer. The graphite cathodic arc was operated with a current of 50 A dc at 0.05 Pa. The ion masses detected were C^+ and C^{++} . The energy of C^+ for non-shielded arc distributed from 10 to 50 eV with a double peak shape due to the thermalized ions and the ions with beam component, whereas that for the shielded arc distributed only from 10 to 35 eV. With regard to C^{++} , the energy for the non-shielded arc distributed widely from 10 to 50 eV with a very low ion count, and the ion was not clearly detected for the shielded arc.

Keywords: cathodic arc, graphite cathode, ion mass spectrum, ion energy, diamond-like carbon film

Diamond-like carbon (DLC) film is one of the most promising materials in use for hard tribological coating on various mechanical and optical industrial parts⁽¹⁾⁽²⁾. The cathodic vacuum arc, which is one of physical vapor deposition (PVD) methods, can fabricate DLC film⁽³⁾. The advantage of this method is that hydrogen-free DLC film can be prepared⁽⁴⁾, since highly energized ion vapor is obtained from the cathode target. The shield type⁽⁵⁾⁽⁶⁾ of cathodic arc deposition allows film to be prepared with fewer macrodroplets emitted from the cathode target⁽³⁾. However, ion energy is considered to be decreased by the shield plate. In the present study, in order to know how much the ion energy is reduced, the distribution of the plasma ion was measured using a selected-mass energy analyzer.

The shielded cathodic arc apparatus with the ion-energy analyzing system is shown in Fig. 1. A graphite (C; carbon) cathode of 64 mm in diameter was placed in the vacuum chamber (320 mm length, 200 mm diameter). The stainless steel-made plate (64 mm diameter) for shielding the macrodroplet was located 100 mm away from the cathode surface. The arc chamber was evacuated using a turbomolecular pump and rotary pump.

The ion-energy analyzer⁽⁷⁾ was commercially called an en-

ergy quadrupole probe (EQP; Hiden Co. Ltd., UK), which is composed of ionizer, energy filter of 45 degree sector type, quadrupole mass filter, and differential evacuation system with an orifice (100 μ m) for extracting particles from the arc chamber. When the ion measurements are carried out, the ionizer is switched off. The EQP analyzer was pumped down less than 5×10^{-4} Pa using a turbomolecular pump and rotary pump.

The arc was ignited by means of a mechanical trigger with a molybdenum (Mo) electrode (3 mm diameter). The experiment was carried out at the arc chamber pressure of 0.05 Pa without additional gas. The arc current was 50 A, supplied by a dc power source in current constant mode. The arc voltage was approximately 24 V. The particle extraction position was set at 185 mm away from the shield plate, namely 285 mm away from the cathode surface.

The deposition film was prepared on silicon (Si) (100) substrate under the same condition, replacing the EQP analyzer with substrate holder, and film was prepared. The film thickness was measured using a stylus surface profilometer (Kosaka Laboratory, HIPOS-ET10) and analyzed using a laser micro Raman spectrometer (Jobin Yvon, RAMANOR T-64000) with illumination spot size of 1 μ m and wavelength of 514.5 nm.

Prior to the ion energy measurement, the film was deposited with and without shield plate. The Raman spectrum of the film prepared by the shielded method is shown in Fig. 2. The broad double peak due to hybridized orbits of sp^2 (1,530 cm^{-1}) and sp^3 (1,350 cm^{-1}) is seen in the spectrum, indicating that the prepared film was DLC⁽⁸⁾. A similar spectrum was obtained for film prepared by the non-shielded method. The deposition rates, obtained from the film thickness dividing by the preparation time, of the shielded method and non-shielded method, were approximately 15 nm/min and 80 nm/min, respectively.

The ion mass spectra were measured at a fixed filtering ion energy of 20 eV. The result is shown in Fig. 3. The detected

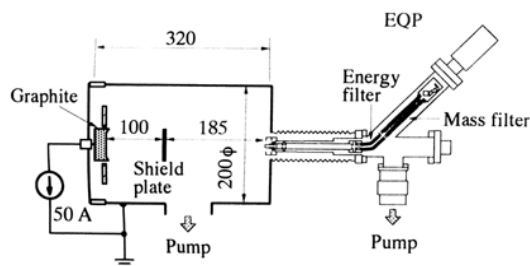


Fig. 1. Cathodic vacuum arc apparatus with graphite cathode with a selected-mass energy analyzer (Hiden, energy quadrupole probe; EQP).