ULTRA-FINE PATTERNING OF THE N-DOPED CVD DIAMOND FILMS II. -ELECTRON BEAM LITHOGRAPHY-

H. Gamo[1], N. Fukugami[1], A. Tamura[1], M. N.-Gamo[2], and T. Ando[3]

[1]*Technical Research Institute, Toppan Printing Co. Ltd., Sugito, Saitama 345-8508, Japan.*

[2]*Sensor-photonics Research Center and Department of Applied Chemistry, Toyo University, Kawagoe, Saitama 350-8585, Japan.*

[3]*Advanced Materials Laboratory, National Institute for Materials Science, Tsukuba, Ibaraki 305-0044, Japan.*

A diamond is known to show outstanding properties such as a high hardness, a wide bandgap, a chemical inertness, a high thermal coefficient, and a wide potential window for electrodes. The success of diamond growth from the gas phase opened up a possibility of new applications because it could give a polycrystal diamond as a form of thin film. In order to use the excellent potential of diamond films for wider applications, it is necessary to establish the fabrication technique of the diamond films for desired patterns. For example, an electrochemical sensor head, which is expected to be one of the best applications of diamond films, needs to be as small as possible for achieving the best detection limit. A nano-scale fabrication of diamond is important and should be realized.

In this study, in order to fabricate the diamond films for desired fine patterns, an electron beam lithography technique was examined for a variety of N-doped diamond films having a wider range of the surface roughness, crystallinity, and crystal size.

N-doped diamond films grown with different growth conditions were fabricated by the e-beam lithography to elucidate the relation between the fabricated patterns and the structure of diamond films. A cylindrically coupled microwave plasma reactor was used for the diamond growth. 10% methane (CH_4) diluted with hydrogen (H_2) was used as the reactant gas. For the nitrogen doping, we used N_2 gas as a dopant gas, and the concentration in the gas phase was 0-1 %. The substrate temperature was maintained at 820 ˚C, which was measured by an optical emission pyrometer. The incident microwave power was 2.6 kW. The reaction pressure was 77 Torr, and the total flow rate was 1000 ml•min^{-1}. The growth time was 20 min and the thickness was approximately 1 µm.

As a hard mask for patterning of diamond films, a 500-nm-thick hydrogenated amorphous silicon nitride (a-SiN_x) layer was used. It was deposited by rf plasma-enhanced chemical vapor deposition at a temperature of 350˚C in the presence of 2 % silane (SiH_4) and 5 % ammonia (NH_3) diluted with H_2. The e-beam lithography was carried out by using the e-beam resist (ZEP-520, Nippon Zeon) and the e-beam lithography system (JEOL). A reactive ion etching (RIE) method was utilized for etching both a-SiN_x hard masks and diamond films. The a-SiN_x was etched by using a mixed gases of C_2F_6 and 10% H_2 at a pressure of 30 mTorr. The diamond film were formed by RIE in the presence of O_2 and a few amount of CF_4 at a pressure of 30 mTorr. In order to fabricate nano-scale fine patterns, it is essential to control the amount of added CF_4.

Fig. 1 shows FE-SEM image of the patterned N-doped diamond film. The width of line patterns in the range from 100 nm to 1 µm were achieved. A nanometer-scale patterning of the diamond films has been demonstrated. It will be discussed how the surface morphology, crystallinity, and crystal size of N-doped diamond influence the fabricated patterns.

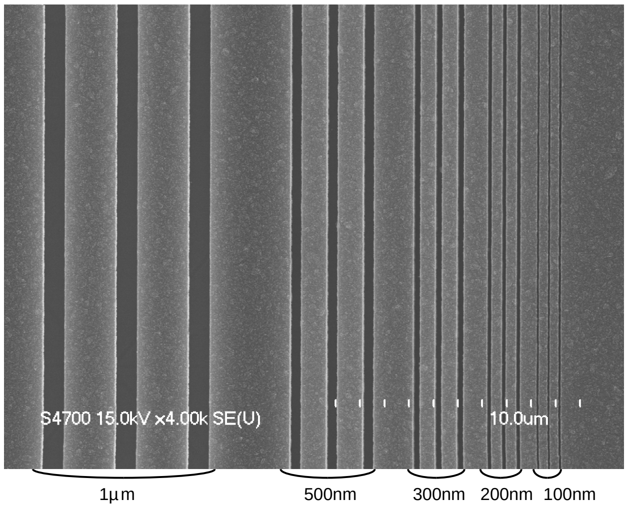

Fig.1 FE-SEM image of fabricated patterns of the N-doped CVD diamond film