Study on Production of n-Type Ultrananocrystalline Diamond Films Prepared by Coaxial Arc Plasma Deposition

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(同軸型アークプラズマ堆積法により作製した n 型超ナノ微結晶ダイヤモンド膜の創製に関する研究)

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論 文 内 容 の 要 旨

Currently, ultrananocrystalline diamond (UNCD)/hydrogenated amorphous carbon (a-C:H) composite (UNCD/a-C:H) film, which is a new diamond and related materials, are attractive much attention as a photodetector, field emission source, hard coatings, and micro/nano-electro mechanical systems (MEMS/NEMS) because of its specific film fine structure. UNCD/a-C:H films are comprised of UNCD crystallites with diameter less than 10 nm and an a-C:H matrix. Thanks to this unique film fine structure, the films have interesting physical properties such as occurring p- and n-type conduction by impurity doping, high absorption coefficient, and ultraviolet and visible light detection. Although n-type conduction is extremely hard to be formed for poly- and single-crystalline diamond, a few groups and our laboratory have reported that nitrogen is expected to act as n-type donor. However, in these reports, they utilized chemical vapor deposition (CVD) and pulsed laser deposition (PLD) which are limited methods from industrial and environmental viewpoints.

Therefore, the scope of this study is to propose n-type doping on the UNCD/a-C:H films prepared by coaxial arc plasma deposition (CAPD) which has distinctive features from industrial and environmental aspects for the first time to our knowledge in the research field of diamond. The production of n-type conduction accompanied by an enhancement in the electrical conductivity with increasing n-type dopants content and their relation with the chemical bonding structure of films were studied in details. Firstly, co-doping of lithium and phosphorus, which is well known as ideal shallow donor levels in diamond, was examined for that. After that, nitrogen doping effects of the film is discussed from electrical and structural viewpoints.

The above-mentioned results are discussed in several chapters as follows:

Chapter 1 introduces a position of UNCD/a-C:H films in materials fields by comparing another diamond and related materials. From a results of this review, potential applications of UNCD/a-C:H is considered from basic physical background and growth techniques of that.

Chapter 2 shows the experimental methods including apparatus setup, sample preparation conditions, and evaluation methods. The UNCD/a-C:H films are prepared by CAPD. Electrical and structural characteristics of that are evaluated by Hall effects, current−voltage ($I-V$), capacitance−voltage ($C-V$), and several spectroscopic analysis. Details of those are summarized in this chapter.

Chapter 3 investigates lithium and phosphorus doping effect on the films on the basis of the experimental results obtained from electrical and structural analysis. The enhancement of electrical conductivity is discussed spectroscopic analysis.

Chapter 4 provides nitrogen-doped ultrananocrystalline diamond/hydrogenated amorphous carbon composite films prepared in hydrogen and nitrogen mixed-gas atmospheres by coaxial arc plasma deposition with graphite targets were studied electrically and chemical-bonding-structurally. The electrical conductivity was increased by nitrogen-doping, accompanied by the production of n-type conduction.

Chapter 5 summarizes this work. As mentioned above, this thesis electrically and structurally investigate the n-type semiconducting properties of UNCD/a-C:H films prepared by CAPD, and firstly demonstrate the high potential for electronic applications.