学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称　博士（総合化学）　氏名　田村　貴大

学　位　論　文　題　名

Development and Exploration of New Materials Related with Carbon and Boron Nitride
（炭素及び窒化ホウ素系新規材料の開発と物性探索）

Materials related with carbon and boron nitride have various structures and have various properties derived from the structures. Among others, diamond and cubic boron nitride (cBN) have specific physical properties such as very high thermal conductivity and wide band gap, and it is possible to add functions such as conductivity and luminescence by doping. Therefore, it is gaining attention as materials for future electronic devices having performance exceeding SiC, GaN, etc., which can be used as power devices and deep ultraviolet LEDs. However, the diamond has problems with the synthesis of n-type semiconductors and the cBN has problems concerning large single crystal growth, which make device application difficult. In this thesis, I have developed a new method for doping to the diamond and have established a new method using cBN microcrystals in order to advance the application of these materials.

Chapter 1 is the introduction of this research including background.

In Chapter 2, I developed a new technique to grow doped diamond thin films. The method involves simply immersing the solid dopant source into the plasma during microwave plasma chemical vapor deposition (MPCVD) to sputter and atomize the dopant elements. I demonstrated the doping of boron from a sintered boron rod and characterized the sample by XRD, Raman microscopy, and glow discharge optical emission spectroscopy (GDOES). I found that 1% B-doping was possible, but the distribution of boron is macroscopically inhomogeneous, with concentration ranging from 1% to 0.02% within a 6-mm sample. This technique is suitable for examining the possibility of doping of various elements including multiple dopants.

In Chapter 3, I investigated the possibility of doping bismuth in diamond by immersing bismuth in the plasma during the MPCVD growth of diamond. The resulting film was polycrystalline diamond showing an abnormal nucleation. The main portion of bismuth in the film was not in the diamond lattice, but it was included in the core of the nanoparticles aggregated at the grain boundaries. The shell of the nanoparticles contains molecule-like species such as diamondoids or Bismuth-carbon clusters. I also detected the unusual carbon allotrope chaoite near the grain boundary.

In Chapter 4, I developed a method for handling microscopic cBN crystals and studied N_2 plasma etching of low and high index surfaces. Characteristic surface morphologies ranging from triangular etch pits to periodic faceting were observed. They can be explained by the stability of (111)B surfaces against the N_2 plasma etching, which originates from the strong three-directional bonding of positively charged topmost B atoms with N atoms.

In Chapter 5, to investigate the mechanical properties of cBN single crystals, I have established a method of nanoindentation using sub-mm sized crystals. I first experimentally clarified the hardness and elastic modulus of the cBN surface with various index including (111) face of cBN single crystal grain. As a result of measuring the samples with 15 random orientations, I found that the hardest face was (100) and the elastic modulus showed the same tendency. From these results, the results of the theoretical prediction that (111) dislocation defects are unlikely to occur in the (100) plane were confirmed.

Chapter 6 is the general conclusions of this thesis.