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論　文　内　容　要　旨

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学位論文題目	Research on Responsivity Improvement of Single Crystal Diamond UV Photodetector (単結晶ダイヤモンド紫外光検出器の感度向上に関する研究)		

内容要旨

Ultraviolet detection technology is a high-tech technology, which has great application prospects in environmental monitoring, information technology, medical treatment, astronomical observation and satellite communication. As a wide band gap semiconductor, diamond has excellent properties such as high carrier mobility, high saturated carrier drift rate, high thermal conductivity, low dielectric constant, high chemical stability and radiation resistance. It is an ideal material for fabricating ultraviolet detectors. In this dissertation, a series of studies have been carried out to improve the responsivity of single crystal diamond ultraviolet detectors.

Ultraviolet detectors with photocurrent gain were fabricated by the single crystal diamond intrinsic epitaxial layer with NV color center defect. The origin for the photoelectric gain is the electron injection, whose opening voltage decreases with the increase of the number of photo-generated electrons. When the bias voltage is greater than the open voltage, the photocurrent increases rapidly, and the responsivity of the detector increases rapidly from 4.29 mA/W at 3 V to 51 mA/W at 12 V. In the deep ultraviolet band, avalanche effect was observed as the voltage increased further. The photocurrent increased 10 times rapidly, and the responsivity at 50 V was as high as 1.18 A/W.

The diamond groove three-dimensional structure detector was fabricated by bottom-up method. Firstly, the selective epitaxial process is optimized. The metal mask needs high melting point and stability, and the annealing and cooling processes are needed to maintain the integrity of the electrode. On this basis, the diamond groove three-dimensional structure photoconductive detectors and photovoltaic detectors were investigated. Photoconductive

detectors have high responsivity, but the dark current is high and the response speed is slow. Photovoltaic detectors have low responsivity, but their dark current is five orders lower than that of photoconductive detectors, and the response speed is fast.

Diamond strip arrays were etched on the surface by optimized ICP etching process, and quasi-one-dimensional diamond ultraviolet detectors were obtained with the interdigitated electrodes set perpendicular to the direction of the diamond strip. Because of the etching defects, the as-fabricated detectors have better performance than planar detectors only when the electrode spacing is large, and the photocurrent of the detectors is increased by 14.6%. After a second growth process, the surface defects were recovered, then the performance of quasi-one-dimensional structure detectors is better than that of planar structure detectors at any electrode space. The photocurrent and responsivity of quasi-one-dimensional structure detectors are increased by 106%, and the UV/visible light rejection ratio and transient response performance are improved.

The spectrum response range of diamond detector is extended by using TiO_2. TiO_2 thin film was deposited directly on diamond epitaxial layer by magnetron sputtering technology, and interdigitated structure detector was fabricated. The spectral response curves of the detector show response peaks at 290 and 225 nm, which are derived from the ultraviolet response of TiO_2 and diamond respectively. By combining the two materials, the responsivity of the detector in the whole ultraviolet band is improved.

In the investigation of diamond p-i-n photodiode, the n-type doping process of diamond was studied firstly. The results show that the phosphorus doping concentration increases with the increase of growth temperature and the decrease of methane concentration. The growth rate of phosphorus-doped diamond films is over 20 μm/h and the doping concentration is 10^{18} cm^{-3} by high temperature and high methane concentration process. Diamond p-i-n photodiodes have been fabricated based on this process, which have obvious photoelectric response. At 5 V, the responsivity at 215 nm is 730 A/W, and the UV/visible light suppression ratio of 215 nm/400 nm is 1.4×10^{3}. However, the acceptor concentration induced is high, which leads to a large dark current and a slow response speed.