MATERIAL PROCESSING OF DIAMOND-BASED RECTIFIERS TOWARD APPLICATION IN RADIATION-HARDENED ELECTRONICS

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Doctoral Thesis: MATERIAL PROCESSING OF DIAMOND-BASED RECTIFIERS TOWARD APPLICATION IN RADIATION-HARDENED ELECTRONICS

Thesis abstract

The growing demand for switching-sensing devices, operable under high temperature and strong radiation (including high energetic particles) circumstances, has increased for nuclear power plant and space technology applications. However, the present electronic technology is on Si-based technology, which proved that Si-based electronics did not match the current demand due to low tolerance and low reliability when such operation conditions are in need. Seeking the next generation of switching-sensing electronics technology has become a hot issue. Among wide bandgap semiconductors, diamond is expected as the most promising candidate for application in next-generation electronics implementing under extreme-environmental conditions with ultrafast-response and low-loss switching energy due to its superior physical properties. Nevertheless, limit of conventional wafer size (2-5 mm) and crystal dislocation in diamond are an obstacle to device realization. Scaled-up diamond devices in parallel of reduction of crystal dislocation in diamond are indispensable to realize diamond-based electronic devices for harsh-environmental implementations.

This doctoral thesis comprehensively provides fundamental physical properties of wide bandgap semiconducting diamond. Firstly, enhanced electrical uniformity of diamond Schottky barrier diodes (SBDs) utilizing metal-assisted termination (MAT) technique was demonstrated. Diamond SBDs were scaled up by using heteroepitaxial substrates, in which could be enlarge a domain size up to 3.5 inches. A key of this enhancement is suppression of dislocation propagation by heavily tungsten incorporated films via metal-assisted termination (MAT) technique. The diamond SBDs were tested under extreme environments such strong x-ray irradiation dose (up to

10MGy), proved that they are tolerance against strong radiation in which conventional Si, SiC or GaN-based SBDs are not capable of. Then, application of N-doped diamond as photoconversion devices were demonstrated. Diamond-based visible light photodetector showed good visible-light responses, even operated under high temperature (250ºC) and strong radiation dose (10 MGy). Further improvement of photo responsivity will substantialize thermally stable radiation-proof diamond-based photoconversion devices for realization in industrial markets. After that, beta and alphavoltaic on 10 mm diamond SBD were tested, and they showed potentials to converse radioactivity of radioactive waste back to electrical energy. Overall, diamond-based electronics were proved that they are the best candidate of any semiconductors for harsh-environmental implementations. Finally, we first demonstrated p-type diamond/n-type β-Ga_2O_3 heterojunctions diodes prepared using low temperature direct-bonding technique. Electrical characteristics of the pn diodes were investigated and confirmed a success of the pn heterojunctions formation. The low-temperature direct bonding technique has great potential to realize heterojunctions where epitaxial growth is difficult and will probably pave the way to realize future electronics, not only diamond and Ga_2O_3 electronics.