Deep Levels in β-Ga_2O_3 Single Crystals Doped with Mg^{2+} Ions

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The widespread adoption of energy-saving technologies and development of new low-power devices is needed to provide a stable supply of energy. The transition to efficient power electronics can be achieved by replacing the silicon components (transistors, diodes) to the components made from wide-gap semiconductors that provide lower loss at switching.

The large breakdown field (8 MV/cm) and large band gap (4.8 - 4.9 eV) of gallium oxide (β-Ga_2O_3) have excellent perspective for application in power electronics devices. Recently reported the successful production of Schottky diodes [1] and field effect transistors (MOSFETs) [2] based on β-Ga_2O_3. MOSFETs have good characteristics, including the breakdown voltage (over 400 V), extremely low leakage current, and excellent ratio currents in switched on and switched off states (more than 10 orders of magnitude). Transistors have shown good performance at high temperatures (250 °C) without significant impairment of parameters. These results indicate that β-Ga_2O_3 has more potential than Si and other typical wide-gap semiconductors such as SiC and GaN for applications in power electronics.

However, the successful using of β-Ga_2O_3 as a material for devices of power electronics, optoelectronics in UV range and other applications is hampered by small amount of papers devoted to studying the fundamental properties of β-Ga_2O_3, including the role of impurities and host defects in donor and acceptor levels creating as well as of capture and recombination levels, which play a crucial role in the charge transfer.

This paper presents the investigation results of the optical absorption, photoconductivity, thermally stimulated luminescence (TSL) and thermally stimulated conductivity (TSP) of undoped and Mg^{2+} activated β-Ga_2O_3 single crystals with various heat treatments. Additional bands in the UV region 3.6-4.6 eV and near IR region 0.4-1.2 eV were found in the optical absorption and photoconductivity spectra. Peaks with maxima at about 285 K, 314 K and 354 K and the activation energy of 0.65, 0.72 and 0.84 eV, respectively, were detected on the TSL and TSP curves. The intensities of TSL peaks vary depending on heat treatment and the introduction of Mg^{2+} impurities.

The correlation between bands of the optical absorption and photoconductivity with energy levels of intrinsic defects in β-Ga_2O_3, arising in gallium oxide at a divergence of the oxygen stoichiometry and Mg^{2+} impurities entering have been established. Electronic transitions from shallow donor levels and F-centers are concentrated in the IR region 0.4-1.2 eV and define high conductivity and transparency in long wavelength edge of the material. Absorption and photoconductivity bands in the UV region are associated with transitions of electrons from deep acceptor levels created by host defects and impurities.

[1] K. Sasaki, M. Higashiwaki, A. Kuramata, T. Masui and S. Yamakoshi, *IEEE Electron Device Lett.* **34** (2013) 493-495.
[2] M. Higashiwaki, K. Sasaki, A. Kuramata, T. Masui, S. Yamakoshi, *Appl. Phys. Lett.* **100** (2012) 013504.