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THz bow-tie type diodes and bolometers based on non-uniform electron heating in AlGaN/GaN HEMT channels

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Wide-bandgap semiconductors and in particular AlGaN/GaN HEMT structures with two-dimensional electron gas (2DEG) have been used for development of THz detector such as THz antenna coupled field effect transistors (TeraFETs) [1], Schottky barrier diodes [2], and hot-electron microbolometers [3].

In this work, electron heating in AlGaN/GaN HEMT devices was investigated in order to develop THz bow-tie (BT) type diodes and hot-electron bolometers. Heterostructure layout consisted of 1.5 nm GaN cap, 19 nm $Al_{0.25}Ga_{0.75}N$ barrier, 1 nm AlN spacer, and 1 µm GaN channel layers grown on SiC substrate. A conductive 2DEG channel was observed at 21 nm distance from the surface exhibiting thermally stable density with value of about 10^{13} cm^{-2}. The low-field mobility of 1800 $cm^2V^{-1}s^{-1}$ at the temperature of 300 K increased to 18000 $cm^2V^{-1}s^{-1}$ when cooled down to 80 K. Processed Ohmic contacts of Ti/Al/Ni/Au metal stack demonstrated the specific contact resistance values down to 4×10^{-6} Ωcm^{-2}. Value of the ohmic contact resistance is important to optimize the electron heating effects in contact layers and in 2DEG channel of fabricated HEMT devices [4], [5].

Two types of THz BT antenna integrated detectors were developed employing a non-uniform electron heating in the apex of Ohmic contact layers or of 2DEG channel. The optical responsivity and noise equivalent power (NEP) of the THz detectors were measured in the frequency range of 150-600 GHz at room and at liquid nitrogen temperatures. The BT diodes, based on electron heating in Ohmic contact layers, demonstrated an asymmetric current-voltage (I-V) characteristics and the responsivity values at zero bias to be up to 4 V/W for small apex size values of 2 µm [6]. Second type of THz detectors – BT bolometers – exhibited symmetric I-Vs and two orders of magnitude smaller optical responsivity values at zero-bias. The responsivity was increased to level of about 10^0 V/W by applying an external bias of ± 1 V only. The increase of optical responsivity values with device cooling to 80 K temperature was observed for such type of THz detectors, due to more efficient electron heating in shaped high-mobility 2DEG layer.

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