TERAHERTZ TRANSMISSION SPECTROSCOPY OF GRATING-COUPLED TWO-DIMENSIONAL ELECTRON GAS IN THE AlGaN/GaN HETEROSTRUCTURES

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The terahertz (THz) frequency range for many decades has attracted scientists and engineers which demonstrated various new applications of THz technology in security, telecommunication, medicine and materials science [1]. The many THz applications require compact, solid-state devices with electrical tuning of their performance which are capable to emit, detect and modulate THz waves. A promising solution in this area is associated with resonant excitation of the plasma oscillations in low-dimensional systems at the presence of metallic plasmonic elements [2-3]. Exclusive electrical robustness together with relatively high electrons mobility makes III-nitrides hetero-structures an excellent candidate for operation in the THz range. In a number of works, the excitation of a grating-gated two-dimensional (2D) plasmons and their emission at the resonant frequencies has been demonstrated [2-3].

In this work, we studied the grating-gated AlGaN/GaN heterostructures by using THz time-domain spectroscopy (TDS) system. The samples were fabricated of standard AlGaN/GaN high electron mobility (HEMT) structures grown on a 500-μm-thick semi-insulating 6H-SiC substrate by the metalorganic chemical vapour deposition method [4]. The growth began from 1-μm-thick unintentionally doped (UID) GaN and 19-nm-thick AlxGa1-xN (x = 0.25) layers with a 1-nm-thick AlN spacer in between. The metal grating was deposited on the surface of AlGaN/GaN HEMT heterostructures. The area size and filling factor of the grating was 2x2 mm and 50%; respectively. The period of the grating was varied from 600 to 1000 nm for different samples.

The transmission spectra were measured with a commercial TeraVil T-SPEC 1000 spectrometer in the frequency range from 100 GHz to 4 THz. A liquid nitrogen (LN2) cryostat with THz windows was used to study the temperature dependences of the transmission spectra in the range 80–300 K. The steel plate with two apertures with a diameter of 1.5 mm was mounted on the cold finger of the cryostat. The sample was fixed on one of the apertures. The thermocouple was fixed near the sample for accurate readings of the temperature. The radiation transmitted through the empty aperture and through the aperture with the sample was measured within a few minutes interval and used to calculate the transmission spectrum. The cryostat was fixed on a translation stage, which allowed the control of sample position in three coordinates. Sequential measurement of the signal and reference under the same conditions increased the accuracy of the experiment. The THz TDS system was purged with nitrogen to avoid water absorption lines in the transmission spectrum.

All samples demonstrated the resonant behavior which inherent for excitations of the 2DEG plasmons under the grating. The resonant features were observed in the transmission spectrum at temperature 80 K in the frequency range of 0.1-3 THz. More precisely, the sample with the grating period of 1000 nm demonstrated the well-resolved peak at the frequency of 1.4 THz. The spectral position and quality factor of the resonances were depended on the grating period and the temperature. The decrease of the grating period blue-shifted the peak position with little change of its quality factor. However, the quality factor was reduced with the increase of the temperature. And at room temperature, the resonant features were difficult to resolve in the spectrum. The resonant frequency of 2DEG plasmons was found inversely proportional to the grating period in a similar way as it has been demonstrated in [3]. The quality factor dependence on temperature was observed and it was attributed to the decrease of 2DEG mobility with the increase of the temperature which is consistent with the results obtained in [2]. In our report, detail analysis of the transmission spectra will be supported by the theoretical simulation of the Maxwell's equations using rigorous solutions [5].

[1] Yun-Shik Lee. Principles of Terahertz Science and Technology. — Springer, 2009.
[2] A.V. Muravjov et. al., Appl.Phys.Lett. **96**, 042105 (2010).
[3] V. A. Shalygin et. al. J. Appl. Phys. **126**, 183104 (2019).
[4] P. Sai et. Al. Appl. Phys. Lett. 115, 183501 (2019).
[5] Yu. M. Lyaschuk and V. V. Korotyeyev, Ukr. J. Phys. 62(10), 889 (2017).