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Electrical Control of Terahertz Plasmonic Crystal Phases

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The grating-gate plasmonic crystal system represents a compelling field for investigating strong light-matter interactions and diverse plasmon resonances. This study reviews the recent discovery of two distinctive terahertz phases of AlGaN/GaN plasmonic crystals that arise from varying the modulation of a two-dimensional electron density beneath the metallic gratings: the delocalized phase at weak modulation and the localized phase at strong modulation [1]. Notably, we delve into the impact of the grating filling factor on the electrically driven transition between these phases [2]. Our findings underscore the critical role of specific metal grating geometry parameters in facilitating this transition. Moreover, we demonstrate two types of controlling at totally depleted gated regions when plasma oscillations were localized only in ungated parts of the grating-gate structures [3]. The frequency of these modes is still gate voltage-dependent in the limited range due to the depletion of the ungated parts located close to the gate edges.

Two types of large-area grating-gate structures were experimentally studied. The first is the typical grating-gate transistor structure that was used to investigate the critical role of filling factors, and the second one includes an additional conducting layer to study additional methods of controlling the uncovered metal part of the transistor channel.

Our investigation notably showcased the feasibility of observing a gate voltage-controlled transition between delocalized and localized phases within the plasmonic crystal phase. We demonstrated that at a high filling factor of 80% the phase transition is not noticeable due to the low contribution of localized plasmon resonance in the studied frequency range. The study of the second type of device with an additional conducting layer (as a gate) has shown, that the frequency of ungated 2D plasmons can be effectively changed in the grating-gate structures of plasmonic crystals. Both top and bottom gates allow the frequency tuning in the THz frequency range in the AlGaN/GaN structures with characteristic dimensions of the grating in the micrometer range. The mechanisms of frequency gate voltage dependences are, however, different for the top and bottom gates. While the top gates affect the plasmon cavities' dimensions, the bottom gate changes the electron concentration in the 2D layer. With the increase in the gate voltage absolute value, the frequency increases in the case of the top gate and decreases in the case of the bottom gate. The combined effect of two gates allowed us the efficient tuning of terahertz frequencies of unscreened modes in the grating-gate AlGaN/GaN plasmonic crystal.

REFERENCES

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