Comparison of Metallic and Graphene Grating-Gate AlGaN/GaN-based Plasmonic Crystals in THz range

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The grating-gate plasmonic crystal (GGPC), which incorporates a 2D electron gas (2DEG) within the AlGaN/GaN interface and integrates a grating-gate electrode, holds great potential for designing highly efficient and cost-effective devices in the Terahertz (THz) range. We review recent findings on two distinct terahertz phases observed in such plasmonic crystals [1], resulting from variations in the modulation of 2DEG density beneath the metallic gratings: a delocalized phase under weak modulation and a localized phase under strong modulation. Notably, we delve into the impact of the grating filling factor on the electrically driven transition between these phases. Our findings underscore the critical role of specific metal grating geometry parameters in facilitating this transition [2]. Moreover, we explore the potential of utilizing graphene-based gratings as alternatives to metallic gratings. Through the integration of graphene, grown by Chemical Vapor Deposition method on copper foil and then transferred to the high electron mobility AlGaN/GaN heterostructures [3], we achieve an effective modulation of broadband absorption by free charge carriers within the 0.5–6 THz range via electrical biasing of the graphene electrode.

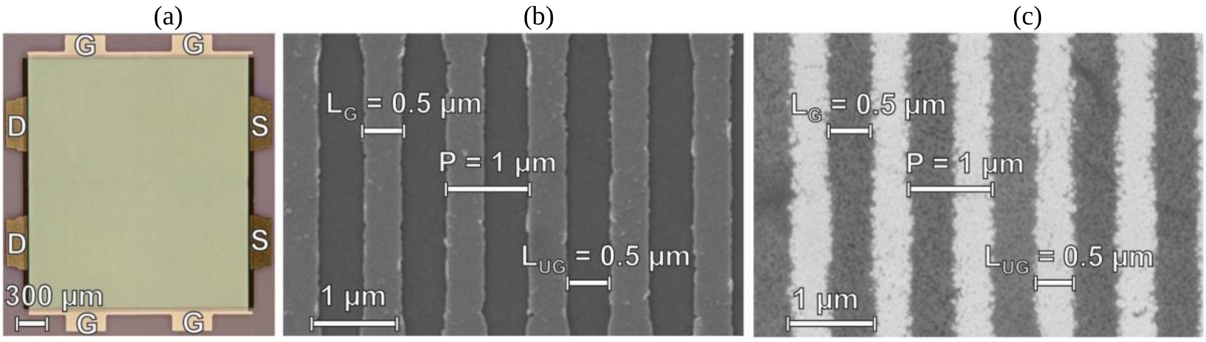

Fig.1. (a) Optical microscope image of the investigated grating-gate. SEM images of metallic grating segment (b), and graphene-based grating segment (c). These samples are characterized by the same length of the gated region L_G = 0.5 μm, the length of the ungated region L_{UG} = 0.5 μm, and grating period P = 1 μm.

Our investigation notably showcased the feasibility of observing a gate voltage-controlled transition between delocalized and localized phases within GGPCs. This transition becomes evident when the frequency of 2D plasmon resonances in both the gated and ungated sections of the plasmonic crystal falls within the same spectral range. Notably, instances of gratings with a high filling factor reaching 0.8 did not exhibit this phase transition, underscoring the nuanced interplay between grating characteristics and phase transitions within GGPCs. We studied regular metallic and novel graphene-based gratings for GGPCs. While metallic gratings presented with tunable plasmon resonances, the adoption of graphene-based gratings enabled for a control over a broadband of the free charge carrier absorption within the 0.5–6 THz range. However, the conspicuous absence of plasmon resonances in graphene-based GGPCs stands as a pertinent avenue for future theoretical and experimental exploration. This discrepancy is attributed to the diminished conductivity of CVD graphene and its reduced polarization efficiency compared to metallic counterparts.

References:

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