Recent advances in the research of terahertz plasmonic devices using graphene-based van der Waals 2Dheterostructures

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1. Introduction and motivation

To realize the next-generation 6G/7G THz wireless communications, the development of room-temperature, intense, and ultrafast laser transistors as well as highly sensitive, fast-response detectors operating in a wide THz range are the mandatory conditions [1]. However, THz electromagnetic waves are still unexplored frequency resources. Graphene Dirac plasmons (GDPs), quanta of collective charge density waves of graphene Dirac fermions (GDFs) are promising physics to bridge over the THz technological gap [2].

2. Physics of the GDPs

Thanks to the extraordinary supreme carrier transport properties of the GDFs, the GDP serves very low damping rate [3], extremely high viscosity [4], and rather strong hydrodynamic nonlinearity [5], which makes the interaction between THz photons and GDFs via GDPs extremely strong and can preserve coherency even at room temperature. Recently generation of higher harmonic resonances has demonstrated even at 300K by the excitation of the GDPs by incident THz radiation [6]. The extremely high viscosity of the GDPs has also been demonstrated to produce the whirlpools and back flows of the GDF under a constant electric field at the localized carrier injection region, resulting in negative resistance and GDP instabilities to generate the THz self-oscillation [4]. However, monotonic spatial distribution of the GDFs never realize the room-temperature operation, but only at rather low temperatures [4].

3. THz device implementations in GDP-based vdW 2D heterostructures

We have theoretically discovered a new type of the GDP instability mediated by ballistic injection of GDFs and strong Coulomb drag effect of the GDPs in a graphene-channel transistor (GFET) structure under a spatially modulated GDF's distribution condition [7], assuring GDP-driven negative THz conductivities even at 300K. Our original asymmetric dual-grating gate (ADGG) GFET structure is suited to promote various types of the GDP instabilities as well as fast, sensitive THz detection [2,8]. This new instability mechanism could outperform our original demonstration of room-temperature THz amplification by excitation of the GDP instability in GFETs [9].

The emergence of the black-phosphorus (b-P), black-Arsenic (b-As), and the compounds of these materials (b-As_xP_{1-x}), in which the energy gap ΔG varies from 0.15 to 1.2 eV depending on the number of the atomic sheets and the carrier transport holds a strong in-plane anisotropy, opens a new paradigm for the creation of the THz sources [10] and detectors (Fig. 1) [11].

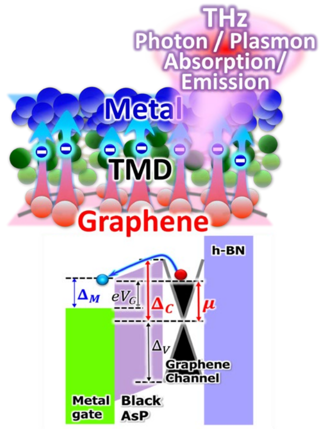

Fig. 1. A metal/b-AsP/graphene gate stack transistor to produce thermionic emission of GDFs by THz radiation incidence, resulting in a new type of fast THz bolometric detection [11].

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5. References

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