2D Quantum Materials: A new approach beyond nanomaterials for terahertz applications

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Recently, new emerging quantum materials [1] enable capabilities that were impossible earlier, which are now revolutionizing scientific development and innovation for advanced quantum technology. Its advent has led to developments comprising advanced quantum photonics, advanced communication, quantum computing, advanced opto-electronic devices and many more [2]. It provides an opportunity to explore many new cutting-edge sciences and possibilities. Among its numerous possible applications, one essential development required at current times is ultrafast advanced wireless communications and the search for its solution from quantum materials is a new perspective and potential field. Today's rapidly developing society requires high data rates, ultra-low latency, better spectral efficiency and devices working in a higher frequency band. To address this issue, the data rates need to be in the order of terabits per second (TBPS), thereby leading to the emerging sixth-generation (6G) network, which can be possible on pushing the operational band to the potential Terahertz (THz) regime [3]. With graphene being the mother of all 2-Dimensional(2D) materials and its discovery achieving the Nobel Prize, many 2D materials have been discovered since then. 2D materials are atomically thin materials which include graphene, transition metal dichalcogenides (TMDCs), e.g., MoS_2[6], WS_2, $MoSe_2$[7], WSe_2[8], hexagonal boron nitride (h-BN), phosphorene, silicene (2D silicone), germanen (2D germanium), borophene (2D boron), and MXenes (2D carbides/nitrides) [9]. Since the 2D materials are atomically thin and their unique electronic and optical properties arise from quantum confinement effects, [9] they are referred to as "**quantum materials**" [1]. Properties like tunable bandgaps, large carrier mobility and enhanced light-matter interactions attribute 2D materials as a promising candidate for terahertz applications as emitters, detectors, modulators and sources. Its unique light-matter interactions arise from the exciton energy dynamics, present only due to quantum confinement in 2D structures, leading to enhanced transmittance owing to its resonance with terahertz frequency. Although graphene has extraordinary properties like nonlinear optical behavior, high optical transparency, high carrier mobility and surface conductivity [5] making it suitable for terahertz applications, it is limited by its airborne contamination nature, zero bandgap and unstable delocalized π- electrons whereas these limitations are not present in other 2D materials like TMDCs. Also, the high modulation efficiency of TMDCs has pushed the new trend of innovation to make their heterostructures with graphene [5]. Such heterostructures incorporate the properties of graphene while overcoming its drawbacks, thus giving further enhanced and better properties [10]. More details about the this will be discussed and described during presentation.

References:

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