High-Frequency Quantum Devices with Graphene and 2D Materials towards Quantum Information Processing

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Two-dimensional materials represented by graphene have attracted attention as promising platforms for semiconductor quantum technologies, including quantum computing. To realize semiconductor qubit experiments using these emerging materials, it is important to transfer and adapt experimental techniques that have been established in conventional semiconductor systems to new material platforms. A representative example is the high-frequency reflectometry technique, which is widely used for fast qubit readout [1]. However, in conventional two-dimensional material devices, the substrate is typically used as a global back gate, resulting in significant high-frequency leakage to the substrate and making high-frequency measurements difficult. In this work, we propose an improved device architecture employing a local graphite back gate, which suppresses high-frequency leakage and enables highly sensitive high-frequency reflectometry measurements in two-dimensional material devices [2]. Furthermore, we introduce improvements to the high-frequency reflectometry technique to accommodate high-resistance materials, and present experimental demonstrations of this method applied to relatively high-resistance materials such as transition metal dichalcogenides (TMDs) [3]. In addition, we report results on quantum dot formation in various emerging material systems.

References

[1] J. Yoneda *et al.*, Nature Nanotechnol. **13**, 102 (2018).
[2] T. Johmen *et al.*, Phys. Rev. Appl. **20**, 014035 (2023).
[3] M. Shinozaki *et al.*, arXiv:2512.02225.

Figures

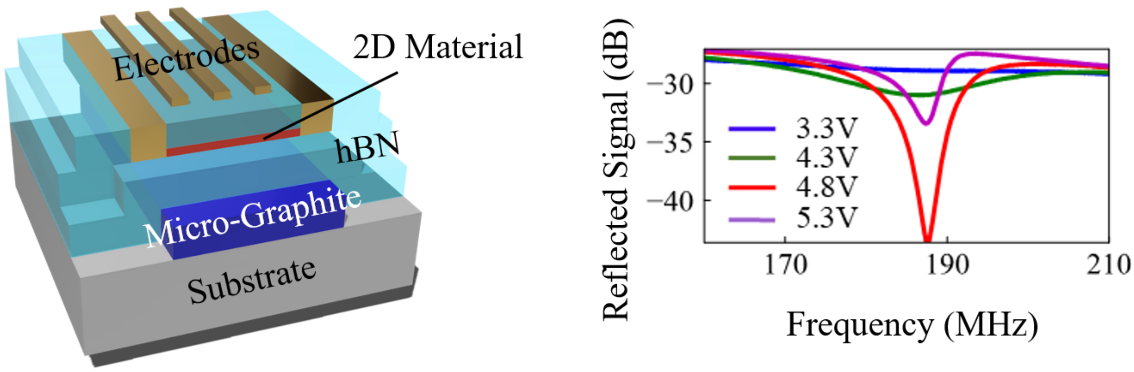

Figure: Device structure of a two-dimensional material for high-frequency measurements and an example of measured RF reflectometry signal [2]