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Multiplexing of 2D material quantum devices for faster discovery of novel effects and technologies

We present electrical measurements of up to 16 monolayer graphene devices in multiplexed arrays on a single chip. Each device is measured individually during a single cooldown to cryogenic temperatures. We fabricate two types of arrays; one containing mechanically-exfoliated graphene flakes transferred by dry pick-up techniques [1], and others by transferring large-area monolayer graphene grown by chemical vapour deposition (CVD) [2], etched into individual structures after transfer. The multiplexer overcomes limitations in the number of electrical wires available in cryogenic apparatus by locally increasing the number of contacts on chip. The size of the array increases exponentially as the multiplexer is scaled, and we have developed a structure to address an array of 128 devices requiring only 17 wires.

The multiplexer is compatible with all types of 2D material devices that are grown or mechanically exfoliated. It is also possible to measure multiple-material stacks to test properties of van der Waals heterostructures. The diverse range of properties present in van der Waals heterostructures makes them extremely attractive for developing novel electronics and exploring new physics, and by using the multiplexer the reproducibility of phenomena across many devices can be tested under identical conditions. The impact of design parameters on electronic properties can be quantified by varying geometry (width/length, 2D material thickness, shape, and novel etching patterns), material type, and inter-layer twist angle in devices across the array.

The benefit of measuring arrays of many devices is illustrated in our previous work multiplexing 256 split gate transistors [3], where we measured arrays of both identical devices and varying geometries [4,5]. Using multiplexing we assessed yield and reproducibility of electrical properties, which provides information on the scalability of these nanostructures. Importantly, we identified new trends in physical phenomena through statistical analysis of the results [6]. These benefits apply to analysis of multiplexed 2D material arrays, and we will discuss device resistivity, mobility, conductance fluctuations and localization effects in multiplexed graphene devices as it relates to device size/geometry and array fabrication method. New approaches to data analysis are possible using statistical methods. The multiplexer architecture is highly versatile, for example we have also extended this research to measure arrays of semiconducting nanowires.

Figure 1(a) schematically illustrates the multiplexer structure viewed from above. A branch structure is etched on a GaAs heterostructure containing a 2D electron gas (2DEG). The source contact is connected to individual devices in the array by appropriately biasing surface gates. The array contains $2^{(n-3)/2}$ devices, where n is the total number of contacts required including addressing gates, source and drain, and back gate. Figure 1(b) shows a 16-device multiplexer after fabrication, prior to transferring 2D materials. Figures 1(c) and (d) show individual monolayer graphene structures from two different arrays; an exfoliated flake and etched structure of CVD graphene after transfer, respectively.

We have demonstrated a technique to measure many individual 2D material quantum devices on a single chip which promises to streamline research, by allowing more data to be gathered efficiently and statistical methods of data analysis.

References

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Figures

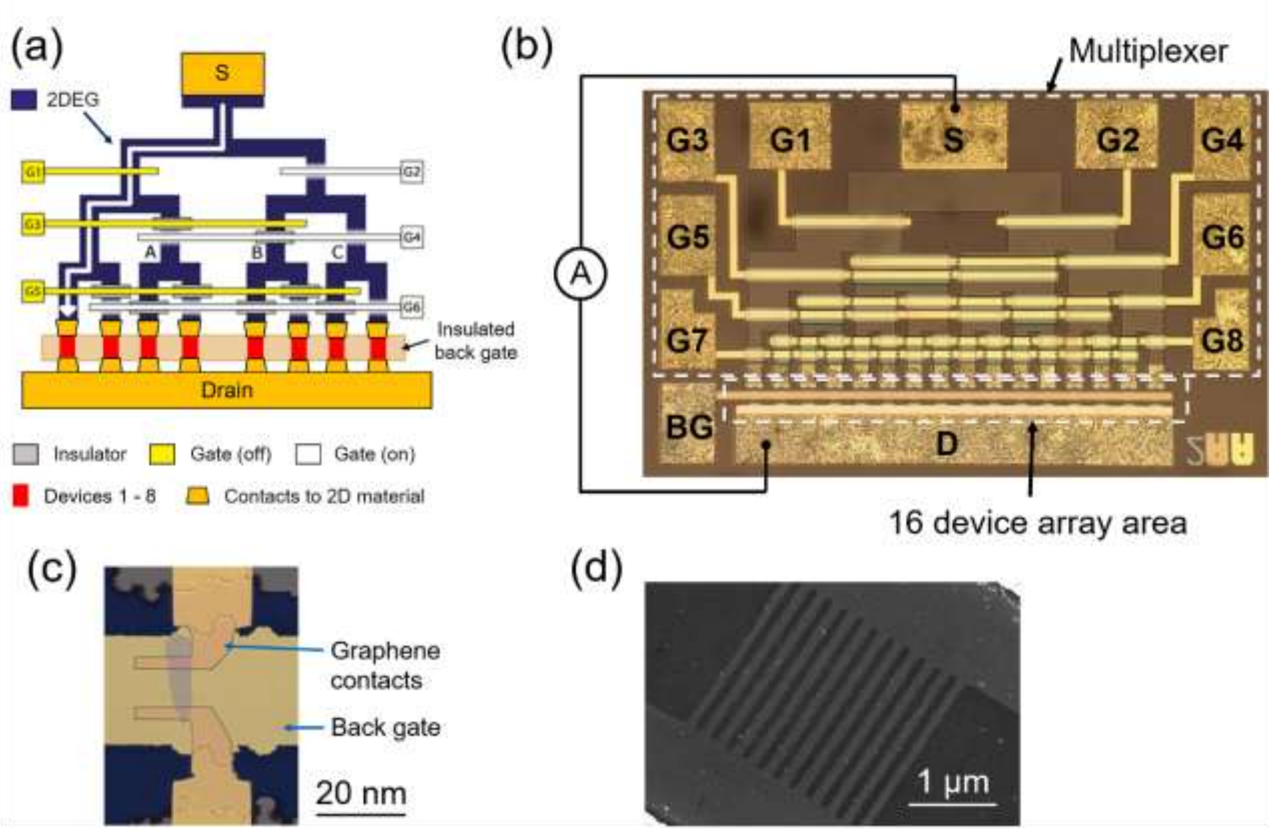

Figure 1: (a) Schematic example of an 8-channel multiplexer. Gates G1-G6 represent multiplexer addressing gates, yellow/white indicates that gates are off/on, respectively. Devices 1-8 are addressed individually by biasing specific combinations of G1-G6. (b) 16-channel multiplexer before 2D material transfer. Labels S, D, BG, and G1-G8 indicate bond pads connecting to the source, drain, back gate, and addressing gates, respectively. The back gate is insulated by 90 nm of Al_2O_3. (c) A monolayer graphene flake, blue (false color), which has been mechanically exfoliated and transferred to the multiplexer. Top contacts are fabricated afterwards for electrical contact to the flake. (d) Individual device in an array of monolayer CVD graphene devices, this device has been etched into parallel nanoribbons following transfer.