Supplementary Information for

Artificial Synapse with Tunable Dynamic Range for Neuromorphic Computing with Ion Intercalated Bilayer Graphene

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Figure S1. AFM phase image corresponding to Figure 1c, showing the surface morphology of the bilayer graphene device.

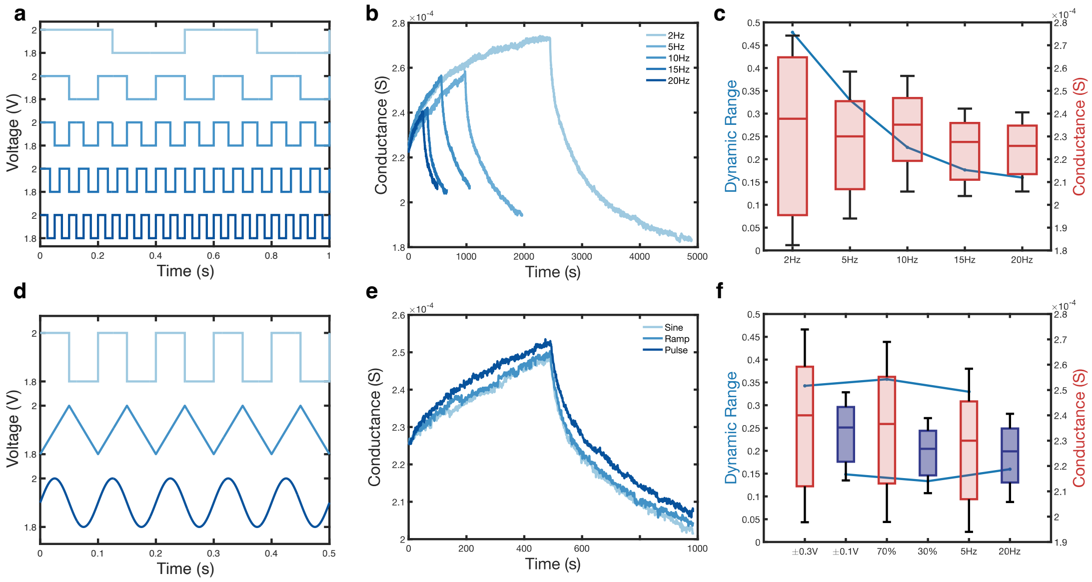

Figure S2. a) pulses of different frequency, ranging from 2 Hz to 20 Hz; d) pulses of different waveform. Bilayer graphene ECRAM's conductance change when input pulses are b) pulses of different frequency; e) pulses of different waveform. Bilayer graphene ECRAM's dynamic range when input pulses are c) pulses of different frequency; f) pulses of different setting.

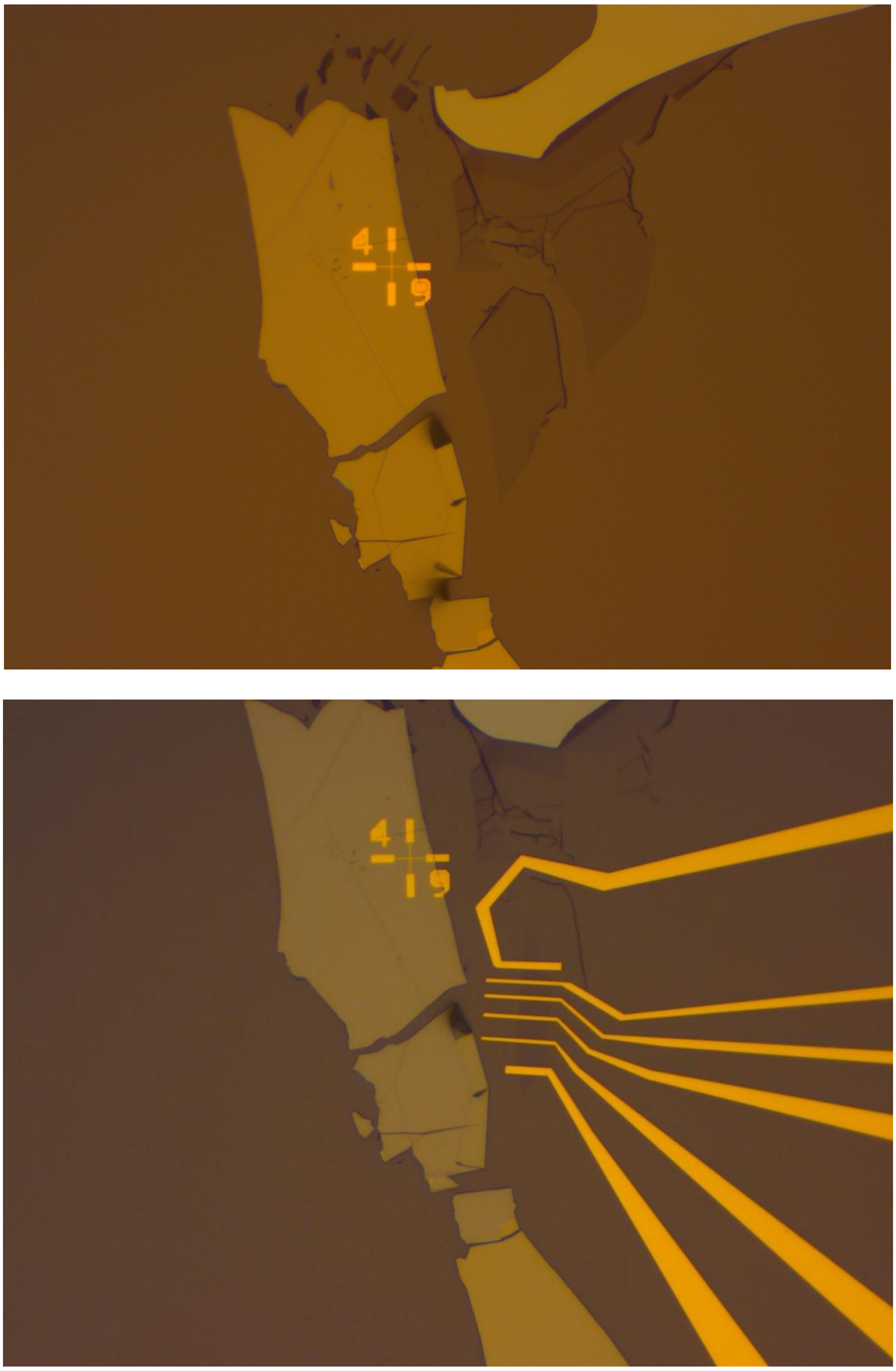

Figure S3. Optical microscope image of the device before graphene etching and after etch for 4-terminal measurements as shown in Figure 4b. The outermost two electrodes are used for applying a small current, while the inner electrodes are used for voltage sweeping and measurement[1].

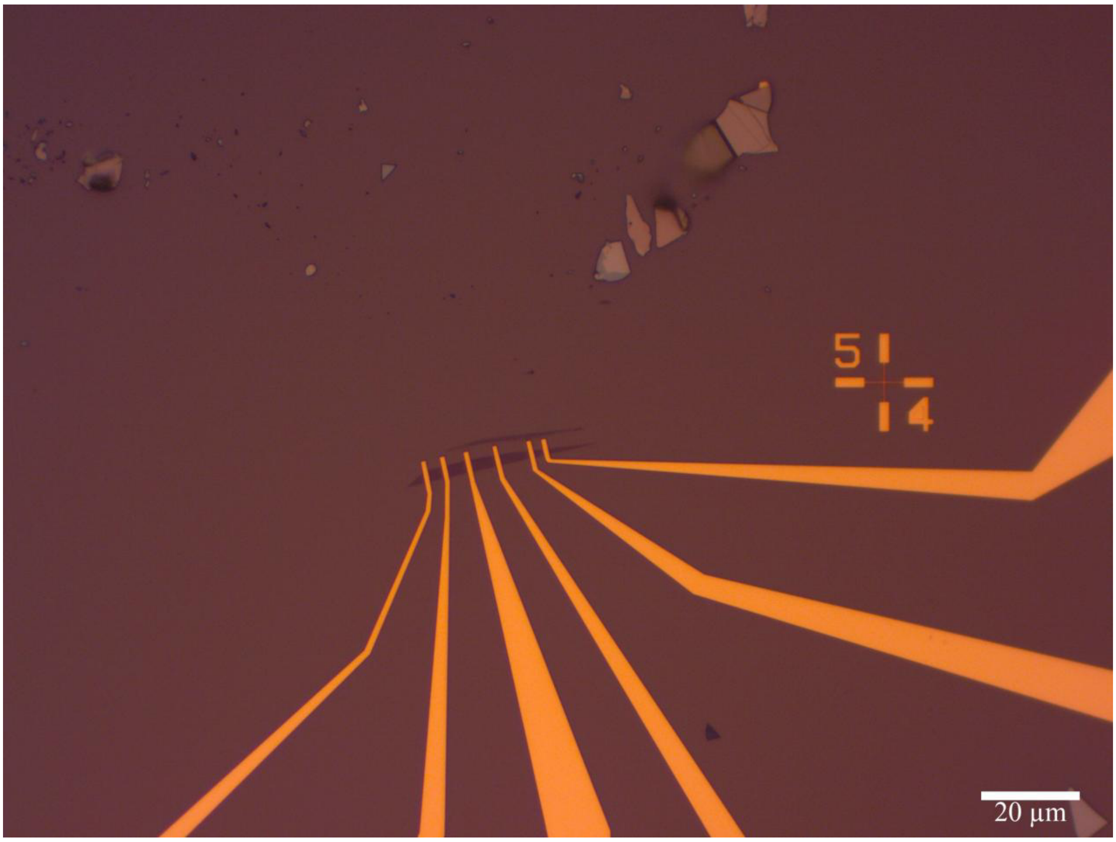

Figure S4. Optical image of the multilayer graphene device.

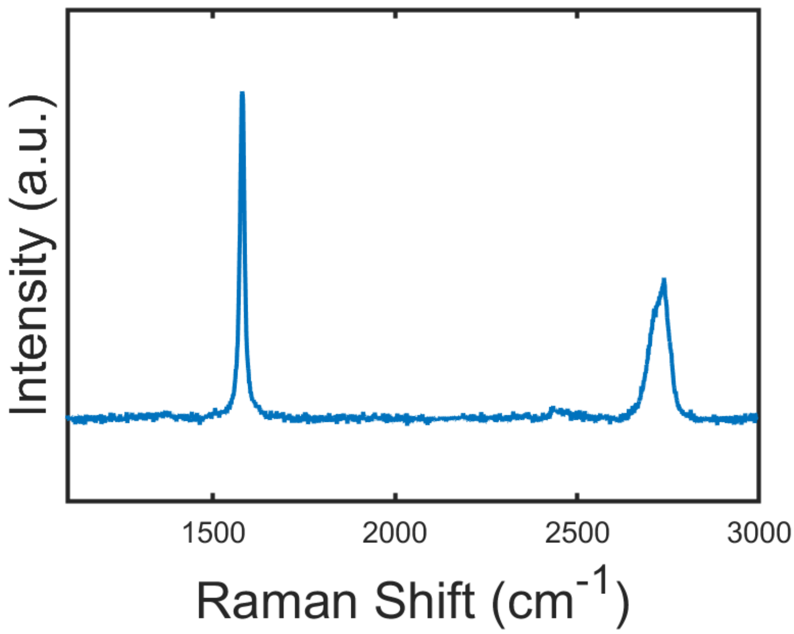

Figure S5. Raman spectrum showing the G peak being more intense than the 2D peak, indicating the presence of multilayer graphene[2,3].6/6/25 10:58:00 AM

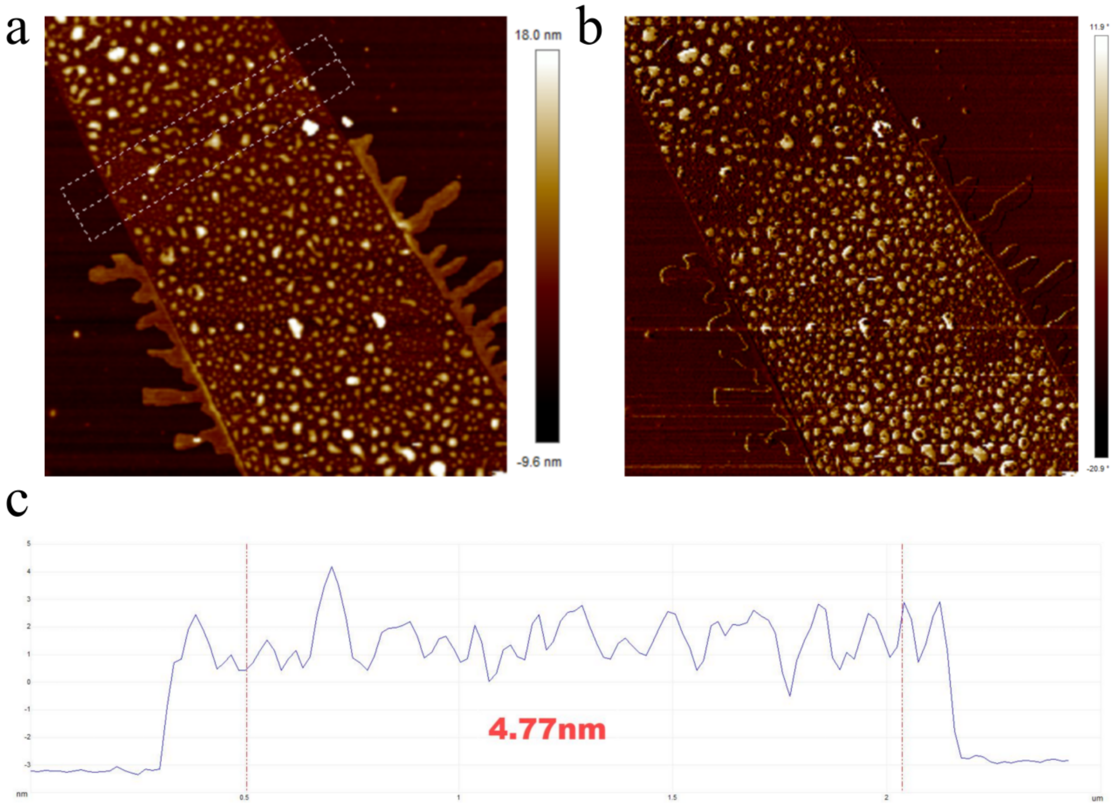

Figure S6. (a) Atomic force microscopy (AFM) height image of the graphene device after the experiment, with the dashed box indicating the measured step range. The LiClO4/PEO layer was removed using acetone. (b) AFM phase image. (c) Thickness profile showing a measured height of 4.77 nm, confirming the multilayer graphene structure.

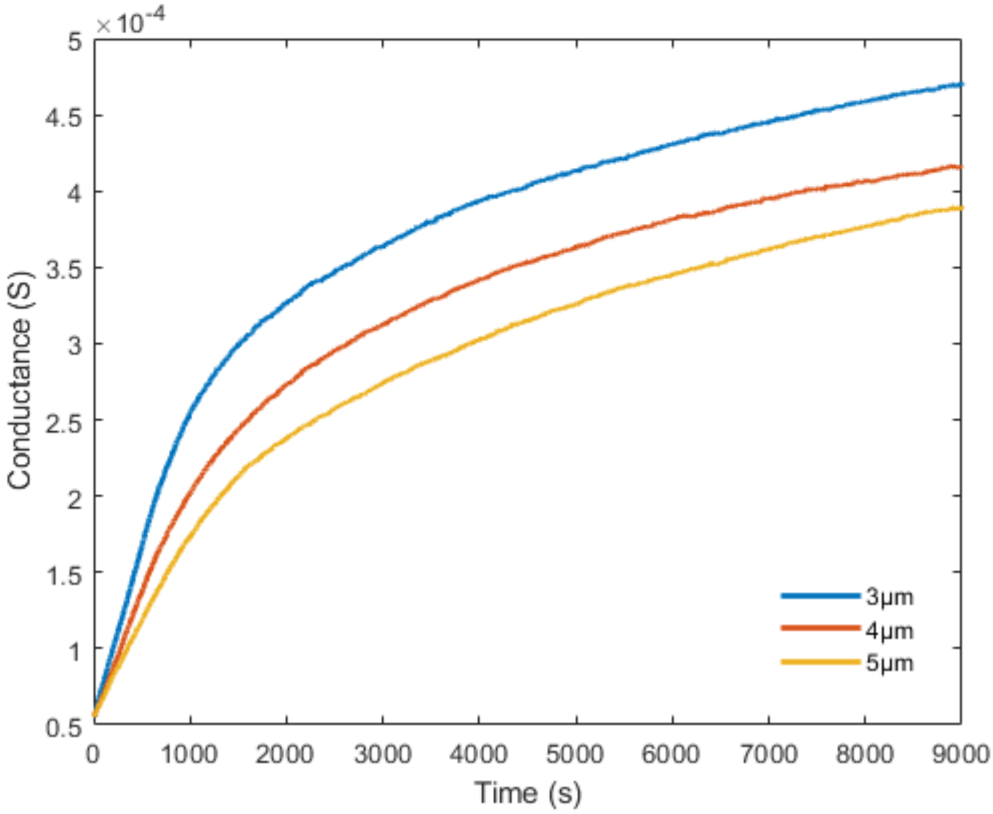

Figure S7. Conductance versus time during the intercalation process of multilayer graphene for different channel lengths (3 μm, 4 μm, and 5 μm) as shown in Figure 4c.

As shown in Figure S7, the bilayer graphene device exhibits a maximum conductance of 480 μS and a minimum conductance of 55 μS, resulting in a dynamic range of 7.7. All conductance states within this range are stable, owing to the reversible and electrochemically robust lithium-ion intercalation into the bilayer structure. This intercalation process induces continuous modulation of carrier concentration without compromising the structural integrity of graphene, thereby ensuring non-volatile and reliable conductance states. The absence of drift or degradation over time highlights the intrinsic material stability and supports its applicability in neuromorphic architectures requiring high precision and endurance[4].

References

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