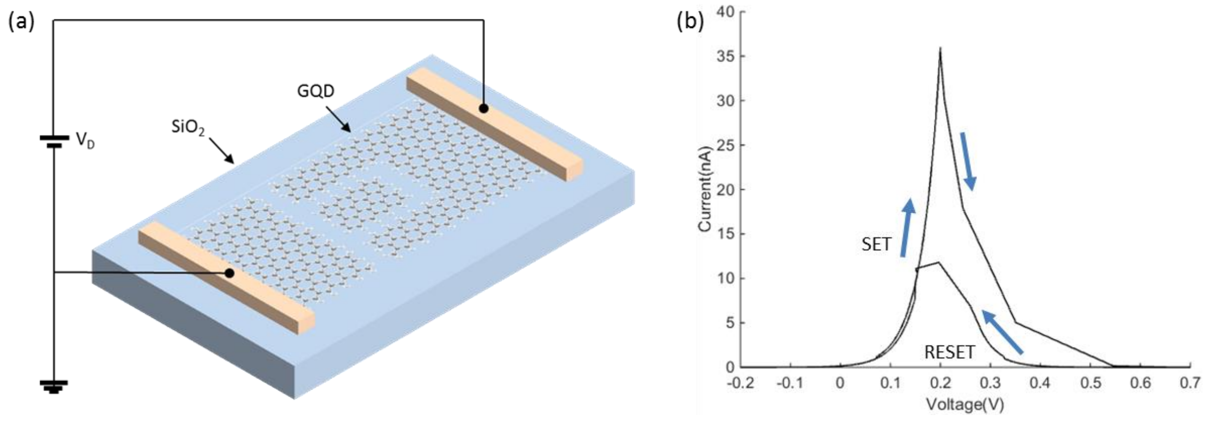
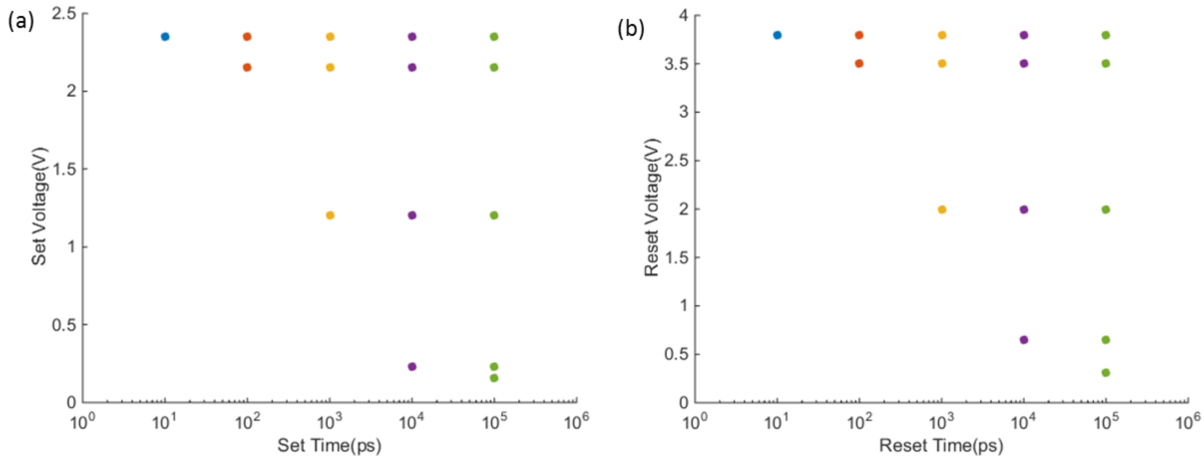
Electronic Supplementary Material (ESI) for Nanoscale.



Supplementary Fig.1 (a) Schematic and circuit diagram of the suspended GQD resistive switching memory device. (b) The simulated I-V characteristics of the structure.

As shown in Fig.S1a is the same device as Fig.1a, but here the h-BN film was removed from the device. The I-V characteristics of this memory device were studied (Fig. S2b). It is observed that when a positive voltage was applied to the suspended GQD, the current increased abruptly and the maximum was achieved at 0.2V, indicating that the device transitioned from the OFF state to ON state. When a reverse voltage was applied, the device reverted back to the OFF state at 0.52V. The suspended GQD showed similar switching characteristics to the h-BN/GQD structure, confirming that the h-BN layer is not a major contributing factor toward the resistive switching performance of the proposed memory device. These results show that the resistive switching characteristic is governed by the GQD structure, and the h-BN layer used has no significant influence on the key switching performance characteristics.



Supplementary Fig.2 Dependence of SET and RESET pulse voltage amplitudes on pulse durations. The voltage amplitude was plotted as a function of time width of pulses able to SET (a) and RESET (b) a GQD memory cell.

Voltage pulses with positive and negative polarity were applied to an electrode (in our case, the left electrode) during SET and RESET respectively. As shown in Fig.S2, both SET and RESET required higher pulse voltage amplitudes for shorter pulse durations, while the SET process has a higher speed when compared to the RESET. Here we extend the definition of SET/RESET to the switch from the highest/lowest resistance state to the lowest/highest resistance state.

The characteristics of the SET and RESET process are attributed to the energy required for the resonant electron tunneling. The energy gained/lost by electrons at the SET/RESET point can be expressed by:[1]

$$E = QV = \frac{V^2}{R}t \qquad (1)$$

where E is the electric energy, Q is the electric charge, V is the pulse voltage, R is the resistance, t is the pulse duration or charging time. During SET/RESET, a certain amount of energy is offered to/taken from electrons by the applied pulse, therefore electrons are able/unable to tunnel through the energy gap, resulting in the switch between the highest and lowest resistance states. The similarity observed in both SET and RESET can be explained by the inversely proportional relationship between the charging voltage and the charging time, as shown in formula (1). The difference is attributed to the larger energy gap on the RESET point (in our case, 0.11eV and 0.35eV at the SET and RESET point respectively), which means under the same pulse voltage amplitude, more charge or longer charging time is need to decrease the energy of electrons to disable the resonant tunneling.

Supplementary Table1. Comparison of different material-based memory concepts

	Graphene/SiO_2 nanogap[2]	**Oxygenated carbon**[3]	**Graphene oxide(GO)**[4]	**Graphene/PMMA nanocomposite**[5]	**Graphene nanoribbon (GN) crossbar**[6]	**GQD (this work)**
Switching mechanism	Redox reaction in the breakdown region of SiO_2	Electrochemical redox reaction of carbon	Charge transfer between GO and thionine	Electron-trapping and electric-screen effect of graphene	Charge transfer in GN multi-layers	Resonant electron tunneling
Switching speed	500ns	≈10ns	<5ns	Not available	<30ps	≈10ps
Type	Nonvolatile	Nonvolatile	Nonvolatile	Volatile	Volatile	Volatile
Validation	Experiment	Experiment	Experiment	Experiment	Simulation	Simulation

Supplementary references:

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