Two-Terminal Multibit Optical Memory via van der Waals Heterostructure

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Abstract

2D van der Waals (vdWs) heterostructures exhibit intriguing optoelectronic properties in photodetectors, solar cells, and light-emitting diodes. In addition, these materials have the potential to be further extended to optical memories with promising broadband applications for image sensing, logic gates, and synaptic devices for neuromorphic computing. In particular, high programming voltage, high off-power consumption, and circuital complexity in integration are primary concerns in the development of three-terminal optical memory devices. This study describes a multilevel nonvolatile optical memory device with a two-terminal floating-gate field-effect transistor with a MoS2/hexagonal boron nitride/graphene heterostructure. The device exhibits an extremely low off-current of ≈10−14 A and high optical switching on/off current ratio of over ≈106, allowing 18 distinct current levels corresponding to more than four-bit information storage. Furthermore, it demonstrates an extended endurance of over ≈104 program–erase cycles and a long retention time exceeding 3.6 × 104 s with a low programming voltage of −10 V. This device paves the way for miniaturization and high-density integration of future optical memories with vdWs heterostructures[1].

References

[1] Minh Dao Tran, Hyun Kim, Jun Suk Kim, Manh Ha Doan, Tuan Khanh Chau, Quoc An Vu, Ji-Hee Kim and Young Hee Lee, Advanced Materials, 31 (2019) 1807075

Figures

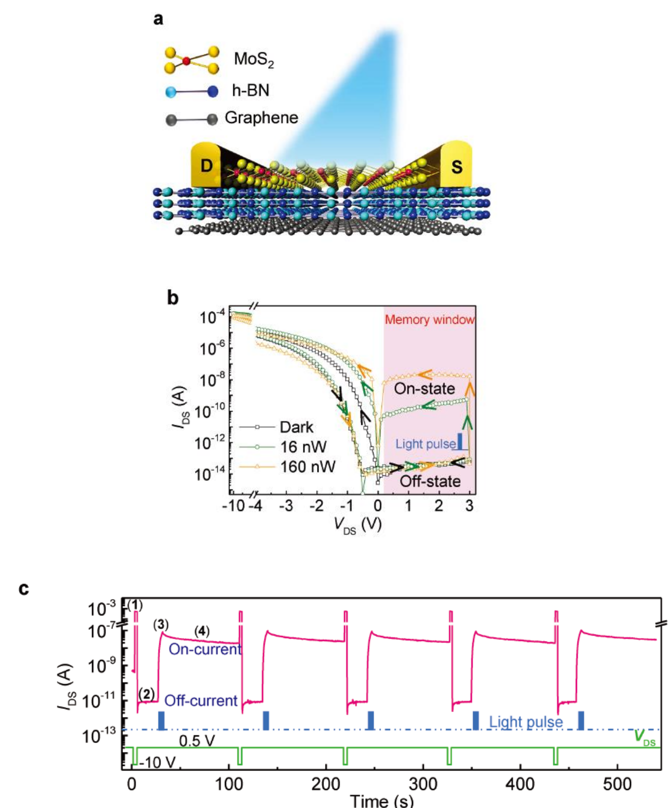

Figure 1: Device structure and operation mechanism of optical memory devices. a) Schematic structure of an optical memory device based on the floating gate FET of the MoS2/h-BN/graphene heterostructure. b) Hysteresis I–V characteristics of a 7 nm thick h-BN device obtained with and without light pulses (power of 16 and 160 nW, duration of 1 s) at VDS = 3 V. c) Operating sequence of the device for five cycles. Each cycle includes: 1) programming by a VDS-pro pulse (−10 V, 1 s), 2) off-current reading for 20 s, 3) erasing by a 458 nm laser pulse (160 nW, 1 s), and 4) on-current reading for 80 s. The source–drain current (IDS) was read at VDS-read = 0.5 V