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Phase transition transistors based on strongly-correlated materials[1]

MASAKI NAKANO, RIKEN Advanced Science Institute

The field-effect transistor (FET) provides electrical switching functions through linear control of the number of charges at a channel surface by external voltage. Controlling electronic phases of condensed matters in a FET geometry has long been a central issue of physical science. In particular, FET based on a strongly correlated material, namely "Mott transistor," has attracted considerable interest, because it potentially provides gigantic and diverse electronic responses due to a strong interplay between charge, spin, orbital and lattice. We have investigated electric-field effects on such materials aiming at novel physical phenomena and electronic functions originating from strong correlation effects. Here we demonstrate electrical switching of bulk state of matter over the first-order metal-insulator transition [1]. We fabricated FETs based on VO_2 with use of a recently developed electric-double-layer transistor technique, and found that the electrostatically induced carriers at a channel surface drive all preexisting localized carriers of 10^{22} cm^{-3} even inside a bulk to motion, leading to bulk carrier delocalization beyond the electrostatic screening length. This non-local switching of bulk phases is achieved with just around 1 V, and moreover, a novel non-volatile memory like character emerges in a voltage-sweep measurement. These observations are apparently distinct from those of conventional FETs based on band insulators, capturing the essential feature of collective interactions in strongly correlated materials. This work was done in collaboration with K. Shibuya, D. Okuyama, T. Hatano, S. Ono, M. Kawasaki, Y. Iwasa, and Y. Tokura.

[1] M. Nakano et al., Nature 487, 459 (2012).

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