NISTTech

HIGH-PERFORMANCE TOPOLOGICAL INSULATOR Bi2Se3 NANOWIRE FETS

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Abstract

Topological insulator is characterized as a new class of materials which have an insulating band gap in the bulk and gapless surface state which is protected by its intrinsic time-reversal symmetry. These topological insulators have been shown to have unique materials and electronics properties by theoretical and experimental approaches. We designed and fabricated high-performance topological insulator nanowire field effect transistors (TINFETs) based on single-crystalline Bi2Se3 nanowires. The Bi2Se3 nanowires (TINFET's channel materials) were grown in pre-defined location by solid-vapor-solid mechanism. The nanowires were then aligned in those pre-defined location using photolithography. The nanowires were then wrapped with source/drain metal contact, gate dielectric and metal as a gate-surrounding FET. This photolithography assisted by bottom-up growth will enable large-scale intergration for circuit application. The TINFETs exhibited sharp turn-on current, zero off-state current and well-saturated output current-voltage. These excellent characeristics well satisfy the requirement for digital and analog circuit application. The TINFETs based on Bi2Se3 nanowires exhibited dominant metallic (gapless) surface conduction which is isolated from bulk semiconductor conduction. This metallic two-dimensional surface conduction stems from its topological insulator properties. We have shown that the surface metallic conduction can be tuned effectively by the surrounding gate and shows large effective mobility. Therefore the TINFETs compare favorably to conventional MOSFETs. In addition, it is well-known topological insulator material has magneto-electric effect, i.e., the electrons in Bi2Se3 nanowire will experience an extra electric field and potential generated by external magnetic field. As a result, the transistor's threshold voltage will shift with external magnetic field. We proposed a novel three-terminal magnetic field sensor: the sensing of magnetic field bases on threshold voltage shift and the induced large current On/Off ratio. This is a three-terminal MOSFET-like sensor is completely different than conventional two-terminal magnetoresistance sensor.

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Status of Availability

This invention is available for licensing exclusively or non-exclusively in any field of use.

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