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Numerical simulation of vertical tunneling transistor with bilayer graphene as source and drain regions

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In this paper, the electrical characteristics of vertical tunneling bilayer graphene field effect transistor (VTBGFET) are theoretically investigated. We evaluate the device behavior using nonequilibrium Green's function (NEGF) formalism combined with an atomistic tight binding model. By using this method, we extract the most significant figures of merit such as ON/OFF current ratio, subthreshold swing, and intrinsic gate-delay time. The results indicate that using a bilayer graphene instead of a monolayer graphene as the base material for the source and drain regions leads to a larger ON/OFF current ratio due to the presence of an energy bandgap in biased bilayer graphene. Also, the subthreshold swing of VTBGFET can be much lower than that of vertical tunneling monolayer graphene field-effect transistor (VTMGFET). We find that the increase of the number of hBN layers enhances the ON/OFF current ratio but degrades the intrinsic gate-delay time.

1 Introduction Graphene has attracted significant interest due to its extraordinary properties such as high carrier mobility, high thermal conductivity, and strong break strength [1, 2]. However, native graphene has a zero bandgap and it is not suitable as a transistor channel for digital applications [1, 2]. Several methods have been proposed for opening a bandgap in graphene for increasing the transistor switching ratio such as imposing lateral quantum confinement by using graphene nanoribbon (GNR), applying an electrical field across bilayer graphene, using quantum dots, or chemical derivates [3–6]. These techniques are likely to entail a degradation of graphene mobility. Also, the performance of GNR as transistor channel is limited due to the undesirable line-edge disorder [7]. An alternative approach to increasing the switching ratio of graphene-based devices is to utilize tunneling based device architecture. Recently, vertical tunneling monolayer graphene field effect transistors (VTMGFETs) have been proposed and fabricated by Britnell et al. [8]. Also, several studies about simulation of VTMGFETs have been reported [9–11]. In these transistors, graphene electrodes act as the source and drain regions separated by a 2D tunneling barrier, such as hBN. The performance of VTMGFETs relies on the tunneling barrier height tunability via a shift in the Fermi level of graphene. VTMGFETs exhibit room temperature switching ratio of 30, which is not sufficient for digital applications [10]. One of the possible routes to increase the switching ratio of this device is to induce an energy bandgap in source and drain graphene electrodes. Spatial confinement in GNR leads to the opening of a bandgap [11]. In order to obtain a suitable bandgap, the width of GNRs must be scaled to extremely small values. The presence of the line-edge disorder in narrow GNRs is the critical problem that can degrade the electrical characteristics of the device [7, 11]. The novelty of this paper is to use bilayer graphene with a tunable bandgap as the source and drain regions. Infinite bilayer graphene in A–B (Bernal) stacking provides bandgap without suffering from line-edge disorder [12]. In this paper, we present a numerical simulation based on nonequilibrium Green's function (NEGF) formalism to describe the electrical characteristics of vertical tunneling bilayer graphene field effect transistor (VTBGFET) such as I_{ON}/I_{OFF} ratio, subthreshold swing, and intrinsic gate-delay time. Also, the electrical characteristics of VTBGFET and VTMGFET

Numerical Simulation In Tunneling

K. B. McGrattan

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Materials, Machinery and Applied Technologies M. Han,X.S. Tai,2015-01-08 Selected peer reviewed papers from the 2014 3rd International Conference on Civil Engineering and Material Engineering CEME 2014 December 27 28 2014 Changsha China *Numerical Simulation of the Howard Street Tunnel Fire, Baltimore, Maryland, July 2001* K. B. McGrattan,2003-03-01 A Numerical Simulation of Three-dimensional Flow in an Adaptive Wall Wind Tunnel J. P. Mendoza,1984 *Centrifuge Modeling of the BART Transbay Tube and Numerical Simulation of Tunnels in Liquefying Ground* Jui-Ching Chou,2010 This thesis describes centrifuge model tests and numerical analyses of tunnels in liquefiable soil The prototype of the centrifuge tests was the Bay Area Rapid Transit BART Transbay Tube TBT that connects Oakland to San Francisco CA USA During the tunnel construction much of the gravelly backfill material around this tunnel was placed loosely under water at a relative density less than 50% Because of the low relative density of the backfill material around the tube and low unit weight of the tube there were concerns that tube might suffer large deformation due to buoyancy forces if the backfill material liquefied in an earthquake BART engaged Fugro West Inc Oakland CA to assess the need for ground improvement to mitigate seismically induced deformations of the tunnel in particular the deformations due to uplift of the tunnel in the liquefied backfill Fugro recommended that their numerical analyses and deformation mechanisms should be further verified using centrifuge model tests Centrifuge model tests were performed 1 to assess the stability of the BART Transbay Tube 2 to confirm the uplift mechanisms of the BART Transbay Tube and 3 to verify numerical methods Test results indicated that the anticipated uplift during the design earthquake would be acceptable less than about 0 25 m Three uplift mechanisms were observed in the centrifuge model tests 1 a cyclic ratcheting mechanism of sand moving under the tunnel associated with cyclic lateral deformations of the tunnel 2 seepage of water under the tunnel and 3 heave of soft clay around the trench Flow of the sand as a viscous liquid was not observed Two approaches were used to record subsurface movements in the centrifuge experiments The traditional approach used data from accelerometers and displacement transducers to determine the trajectory of the tunnel A new approach Electric Field Displacement Sensors EFDS involves installation of source and ground electrodes in the specimen through which well defined multi directional electric fields can be set up in the specimen The movement of measurement electrode which can be attached to an object of interest can then be determined simply by measuring its voltage Li 2006 was the first to use this approach but she used an electrode switching system to sequentially excite multidirectional electric fields A new contribution of this thesis was the idea that independent electric fields data from different sources can be excited simultaneously at different frequencies elimination of the need for the switching system has saved a lot of complexity in the equipment and also allowed much improved temporal resolution After comparing the processed data from the EFDS and traditional approaches the EFDS can capture the dynamic response pretty well but the EFDS has its limitations The change of soil resistivity and the heterogeneities of the soil resistivity affect the estimated movements greatly but the change of the soil resistivity can not be captured from the voltage data in the current

implementation With continued work on solving its limitation the EFDS could become a fairly inexpensive tool for tracking movements A parametric study was performed using a finite difference program FLAC 2D In the numerical simulation the UBC Sand model Beatty and Byrne 1998 was used to model the behavior of liquefiable soils A mesh sensitivity study was performed to decide the appropriate number of nodes for the simulations and how to best model sliding at interfaces between the soil and tunnel In the parametric study effects of different geometry characteristics and soil properties on the seismic behavior of the tunnel were explored and the results are summarized in a few dimensionless plots After effects of various factors on the tunnel performance were understood suggestions for the future tunnel design were made 1 densify the liquefiable soils to reduce the cyclic mobility associated with liquefaction 2 minimize the volume of the liquefiable soils and the thickness of the liquefiable soils underneath the tunnel to reduce the volume of pore water expelled and the space through which water and soil may flow under the tunnel 3 make the elevation of the interface between high and low permeability materials shallow enough so that high pore pressures are not trapped near the base of the tunnel 4 make the liquefiable soils as permeable as possible to drain high pore pressures away from the base of the tunnel and 5 make the unit weight of the tunnel as close as to the surrounding soil Proceedings of the 10th International Conference on Civil Engineering Guangliang Feng,2024-07-19 This open access book is a compilation of selected papers from the 10th International Conference on Civil Engineering ICCE2023 The work focuses on novel research findings on seismic technology of civil engineering structures High tech construction materials digitalization of civil engineering urban underground space development The contents make valuable contributions to academic researchers and engineers **Numerical Simulation of Segmental Tunnel Lining** Raja Nurul Afiqah Raja Zulkefli,2015 *Numerical Simulation of Two Opposing High-speed Trains in a Tunnel* S. V. Ramakrishnan,1995 Numerical Simulation of Resonant Tunneling Devices Described by the Wigner-Poisson Equations Anne Stefanie Costolanski,2013 **Physical Model Tests and Numerical Simulation for Assessing the Stability of Tunnels** Han-Mei Chen,2014 Numerical Simulation of the Howard Street Tunnel Fire K. B. McGrattan,2006 **Evaluation of the National Aerospace Initiative** National Research Council,Division on Engineering and Physical Sciences,Air Force Science and Technology Board,Committee on the National Aerospace Initiative,2004-07-16 The National Aerospace Initiative NAI was conceived as a joint effort between the Department of Defense DOD and the National Aeronautics and Space Administration NASA to sustain the aerospace leadership of the United States through the acceleration of selected aerospace technologies hypersonic flight access to space and space technologies The Air Force became concerned about the NAI s possible consequences on Air Force programs and budget if NAI program decisions differed from Air Force priorities To examine this issue it asked the NRC for an independent review of the NAI This report presents the results of that assessment It focuses on three questions asked by the Air Force is NAI technically feasible in the time frame laid out is it financially feasible over that period and is it operationally relevant Proceedings of the 2025 7th

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