# Simulation of a Voltage Controlled Resistor Mimicking the Geometry of a MOSFET Device with Graphite Channel

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## Abstract

A Voltage Controlled Resistor (VCR) is simulated by replacing the semiconductor channel of a MOSFET device by graphite and embedding Si nanoparticles near the insulator-channel interface. The change in output drain current is found to depend on the thickness and relative permittivity of the insulator film together with the loading of Si nanoparticles. A material with higher dielectric permittivity as an insulator layer, like graphene oxide, is found to generate a larger change in the output current. Further, increasing concentration of the Si nanoparticles in the channel is found to increase the change in current for constant gate voltage.

Paper-based microelectronic devices [1-3] have attracted attention because of the simplicity in fabrication and cost effectiveness. Previous studies indicate that the fabrication of paper-based FET devices using graphite as the channel [1]. Further, graphene based FET devices have also been reported [4]. Herein we show the response of a paper-based Voltage Controlled Resistor (VCR) in which the semiconductor channel of a MOSFET device is replaced by graphite and Si nanoparticles are embedded near the insulator-channel interface. The study is performed by simulating the system in COMSOL Multiphysics® software using finite element method. The change in output drain current is found to depend on the thickness (dins) and relative permittivity ($\varepsilon_r$) of the insulator film together with the loading of Si nanoparticles. Figure 1 describes (a) schematic diagram of the device, (b) surface electric potential (V) and (c) surface total normalized current density (A/m2) plots in the channel region.

In this study, we used the Semiconductor Module in COMSOL Multiphysics® to study the DC characteristics of the device. The device geometry is similar to a MOSFET as shown in Figure 1(a) where the device is made of graphite channel. Two metal contacts are used as source and drain terminals and the third metal contact as gate placed in between source and drain is separated from the channel by a thin layer of dielectric such as graphene oxide.

Figure 2 shows Surface electric potential (V) plot and Surface total normalized current density (A/m2) plot for Vd value as (a) 5 V (b) 1V (c) 10 mV where $\varepsilon_r$ = 100 and dins = 1 μm. Figure 3 shows drain current versus gate voltage for different (a) dins with $\varepsilon_r$ = 100 (b) $\varepsilon_r$ with dins = 1 μm (c) nanoparticle loading with $\varepsilon_r$ = 100 and dins = 1 μm. In all the cases Vd = 10 mV.

In this study, graphite has been used as the channel material in the geometry of a MOSFET device and the effect of variations in dielectric layer thickness, relative permittivity and nanoparticles loading on I-V characteristics of the device have been presented. It has been observed that a minimum drain current exists without gate voltage but an applied gate voltage changes the conductance of the channel region. In conclusion, the device works as a voltage controlled resistor (VCR) where the conductance or resistance of channel is a function of gate voltage.

## Reference


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4.B. Standley et al., Graphene–Graphite Oxide Field-Effect Transistors,Nano Letters,12,1165( 2012).


## Figures used in the abstract

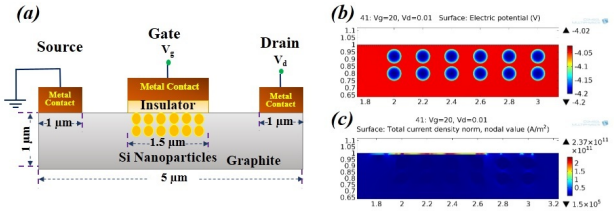


**Figure 1**: (a) Schematic diagram of the device, and the plots of (b) surface electric potential (V) and (c) surface total normalized current density (A/m2) in the channel region.

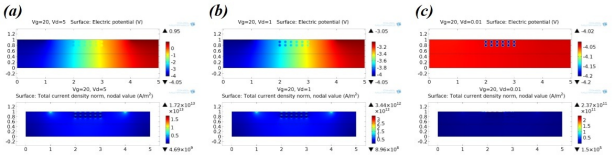


**Figure 2**: Surface electric potential (V) plot and Surface total normalized current density (A/m2) plot for (a) Vd = 5 V, (b) Vd = 1 V, (c) Vd = 10 mV where Ɛr = 100 and dielectric thickness is 1 µm.

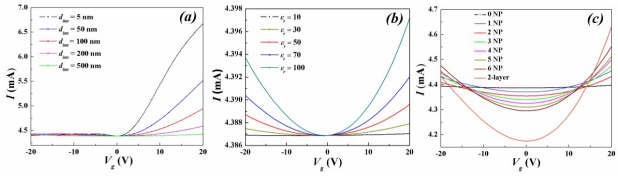


**Figure 3**: Drain current versus gate voltage for different (a) dielectric thickness values with Ɛr = 100 (b) relative permittivity of dielectric material with thickness 1μm (c) nanoparticle loading with Ɛr = 100 and dielectric thickness is 1 μm. In all the cases drain voltage is kept fixed at 10 mV.