NATO Advanced Research Workshop

IMW RPTU

Functional Spintronic Nanomaterials for Radiation Detection and Energy Harvesting

NATO OTAN This workshop is supported by: The NATO Science for Peace and Security Programme

Polar and electrophysical properties of the nanostructure "graphene on $Hf_{0.5}Zr_{0.5}O_2$ thin film"

Morozovska A. N.[1]*, Strikha M. V.[2], Eliseev E. A.[3], & Kalinin S.V.[4]
*lead presenter
[1]anna.n.morozovska@gmail.com, Institute of Physics, National Academy of Sciences of Ukraine, Pr. Nauky 46, 03028 Kyiv, Ukraine,
[2] Taras Shevchenko Kyiv National University, Faculty of Radiophysics, Electronics and Computer Systems, Pr. Akademika Hlushkova 4g, 03022 Kyiv, Ukraine,
[3] Institute for Problems of Materials Science, National Academy of Sciences of Ukraine, Krjijanovskogo 3, 03142 Kyiv, Ukraine
[4] Department of Materials Science and Engineering, University of Tennessee, Knoxville, TN, 37996, USA

Periodic arrays of p–n junctions in graphene, which can be controlled using ferroelectric gates, were realized experimentally and described theoretically. The potential barriers are responsible for the formation of these p–n junctions due to the complex interaction between ferroelectric polarization, chemical interaction, and the structure of defects at the graphene-ferroelectric interface. However, we are not aware of any works in which the graphene-on-multiferroic nanostructure was considered, either experimentally or theoretically. Here we consider a hybrid nanostructure "graphene on $Hf_{0.5}Zr_{0.5}O_2$ thin film", which unusual physical properties is of fundamental interest, and which can be useful for advanced nanoelectronics.

We chose $Hf_{0.5}Zr_{0.5}O_2$ because of its full CMOS compatibility and relatively high ferroelectric polarization (~30 μC/cm^2), which does not degrade, but increases by "waking-up" electric-field cycling. We use the Landau-type phenomenological approach to model the ferroelectric and antiferroelectric properties of $Hf_{0.5}Zr_{0.5}O_2$ thin films, which are strongly affected by surface and size effects. Next, we study the possibility of implementing a stable negative capacitance of the insulator in "graphene on $Hf_{0.5}Zr_{0.5}O_2$ thin film" due to the influence of size effects, which would open the principal possibility to reduce the subthreshold swing to the values below the threshold, 60 mV/decade at room temperature, and supply voltage to the values below the fundamental Boltzmann limit, 0.5 V. It is shown theoretically that it is possible to achieve a transient negative capacitance of a ferroelectric in the situation when the charge at the capacitor plates increases more slowly than the ferroelectric polarization. Due to the stable positive free energy and capacity of the whole system, the effect of the $Hf_{0.5}Zr_{0.5}O_2$ film negative capacitance cannot be manifested outside the hybrid system and so it cannot contribute to further miniaturization of e.g., MOSFETs. However, the nanostructure can be very promising for energy harvesting in the region of size-induced ferroelectric-antiferroelectric transition in the $Hf_{0.5}Zr_{0.5}O_2$ film.

Acknowledgments. A.N.M. work is supported by the Ministry of Science and Education of Ukraine (Grant K-I-70), and NATO SPS Programme Grant G5980 "FRAPCOM".