Beyond silicon electronics-FETs with nanostructured graphene channels with high on-off ratio and high-mobility

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Equipments for: CVD for growing graphene; ALD; dielectric growth, MBE, metal deposition + Raman and FTIR spectroscopy in a 240 m² clean room with class 1000, and some areas with class 100. 5 millions Euro investments (UE)
My life with graphene

Graphene ink - Nanointegris

Graphene flakes

4 inch graphene wafer on HR Si – Graphenea, Spain

Towards 6 inch wafer

2007

2007 from Manchester Univ. Prof. A. Geim and dr. Peter Blake

2012

First CVD graphene grown in IMT Bucharest, January 2016

2014-2016
GRAPHENE ELECTRONICS CONUNDRUM: HIGH MOBILITY AND HIGH ON-OFF RATIO

• Graphene electronics was almost abandoned because the key electronic device – the graphene field-effect transistor (GFET), cannot be switched on and off due to the absence of a bandgap.

• How to solve the conundrum?

• GFET with a nanopatterned channel is a high-mobility, high on-off ratio FET.
nanohole array with a period of 100 nm and a diameter of 20 nm the corresponding bandgap is about 0.16 eV, but this parameter increases to 0.2 eV if the nanohole diameter becomes 30 nm.

$E_g = 0.16 \text{ eV}$

SEM image of a nanopatterned GFET channel with 2 µm.
90 GFETs on a graphene chip cut from a 4 inch graphene wafer (CVD growth and transfer – Graphenea) - 40% are working very well.
Drain current vs drain voltage characteristics of a nanoperforated GFET at various gate voltages indicated in the inset:

- the drain current tends to saturate at some gate voltages, e.g. at 1 V and -1 V
- a clear negative differential resistance region (NDR) appears at ≈ -3 V and -4 V.
7th edition of the largest European Conference & Exhibition in Graphene and 2D Materials
The on/off ratio between drain currents at 0 V and 2 V as a function of the channel length for several gate voltages indicated in the inset.
Long room temperature localization and phase coherence lengths (8 µm) could be explained by the nonuniform nanohole diameters in the transverse direction, which induces charge carrier focusing/guiding along the middle part of the channel such that the charge carriers avoid the boundaries of the channels and the associated strong recombination centers. These non-uniformities in the hole diameters are induced by the proximity effects due to e-beam lithography. For a nanohole array with a period of 100 nm and a diameter of 20 nm the corresponding bandgap is about 0.16 eV, but this parameter increases to 0.2 eV if the nanohole diameter becomes 30 nm. As a result, the charge carriers are guided through the central part of the channel and recombinations at channel boundaries are strongly reduced.

\[ g_D(L) = g_{d0} \exp(-L/L_{loc}) \]

Strong localization \( L_{loc}=1.9\mu m \)
Thank you!

Romanian Research Centre for Carbon Based Nanomaterials – Electronics at atomic scale.