An Invited Abstract for the 2012 EIPBN

Graphene for RF Applications: Opportunities and Challenges

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Graphene offers new opportunities for development of high frequency FETs by virtue of its high carrier velocity, excellent scaling properties, configurability for electron or hole channel devices, and limited scattering. The saturation velocity (v_{sat}) of graphene has not been determined clearly yet, but it is estimated to be ~5 times greater than that for Si MOSFETs [1]. With large on-state current density and transconductance per gate capacitance relative to Si, [2] graphene has the potential to offer excellent switching characteristics and short-circuit current gain cut-off frequency. With observed constant device transconductance over a wide gate voltage range [3], graphene FETs could potentially enable low-noise amplifiers (LNAs) with higher dynamic range per given DC power. Graphene FETs biased near the ambipolar point behave close to ideal "square-law" devices, i.e., $I(V_g) \propto V_g^2$. This feature could greatly improve dynamic range in communications [4]. Graphene-on-Si FETs [5] could potentially be further developed and processed in a manner compatible with Si CMOS with desirable integration density for system-on-a-chip applications. Graphene also presents unique problems, such as limitations in voltage and poor pinch-off characteristics. The future success of the RF circuit applications depends on high-quality material growth at large-wafer scales, vertical and lateral scaling of graphene MOSFETs to minimize parasitics and improve gate modulation efficiency in the channel, bandgap engineering of graphene channels in the MOSFETs, and innovative circuit concepts. [6]
In this talk, we will present recent progress in epitaxial graphene RF transistors and suspended membranes, and in circuit concept demonstrations toward mm-wave radiometers and imaging.

[1] A. Akturk and N. Goldsman, J. Appl. Phys. Vol. 103, p. 053702, 2008.
[2] J.S. Moon et al., IEEE EDL., vol 30, p650, 2009.
[3] J. S. Moon et al., IEEE EDL., vol 31, p260, 2010
[4] J. S. Moon et al., IEEE EDL., vol 31, p260, 2010
[5] J. S. Moon et al., IEEE EDL., vol 32, p270, 2011
[6] J. S. Moon et al., IEEE Microwave Theory and Techniques, vol. 59, 2011

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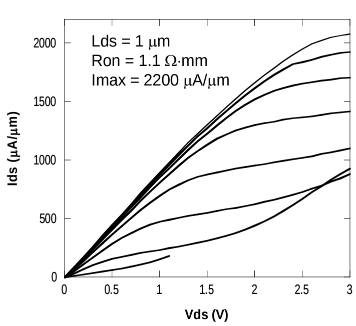

Figure 1. Measured common-source current-voltage characteristics of a graphene FET

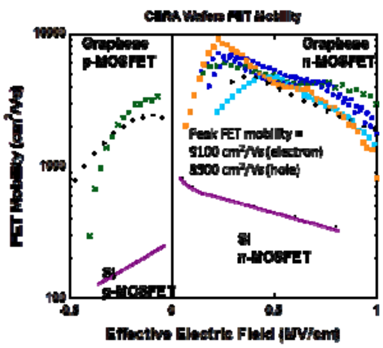

Figure 2. Measured field-effect mobility of graphene n-FETs compared with those of Si n-MOSFETs and p-MOSFETs

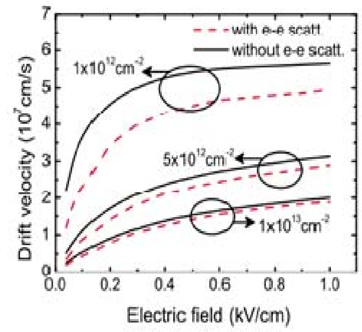

Figure 3. Drift velocity vs. electric field calculated for graphene

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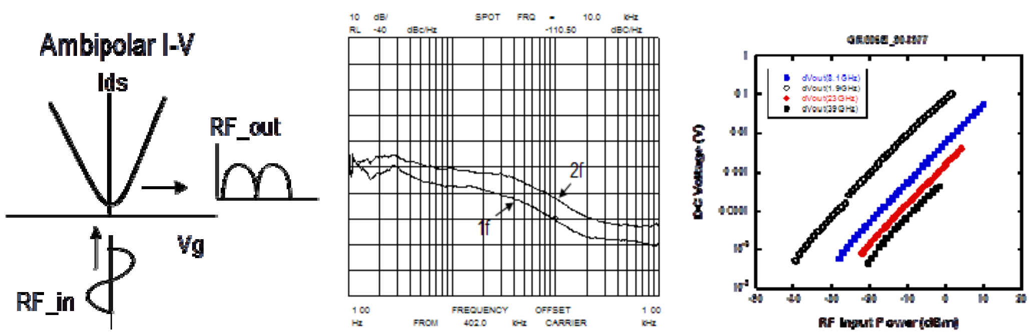

Figure 4. (a) A schematic of frequency multiplication process is shown with RF output spectra consisting of even-order harmonic signals only. (b) Measured phase noise of graphene FET frequency multiplier, (c) Measured performance of graphene FET radiometric detection up to 40 GHz.

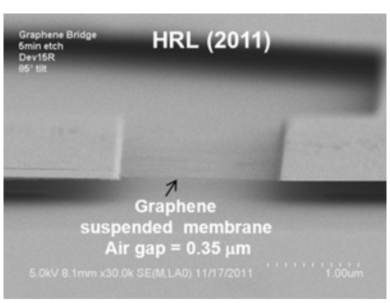

Figure 5. A SEM image of fabricated suspended graphene membrane is shown with an air gap of 0.35 um.

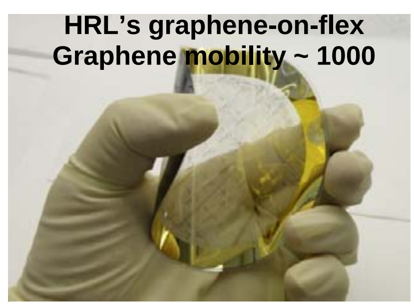

Figure 6. A photograph of a graphene wafer on transparent and flexible Mylar substrate is shown with an electronic mobility of 1050 cm^2/Vs.