PINCH-OFF RESISTANCE AND SCHWINGER EFFECT IN HBN-ENCAPSULATED GFETS

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Electronic transport in hBN-encapsulated graphene field effect transistors (GFETs) has already been characterized in details. [1] With increasing bias, the ohmic regime is first superseded by a velocity saturation regime due to electron scattering with optical phonons of hBN and graphene. Then, further increasing the bias leads to the appearance of an interband current due to Zener-Klein tunneling [2]. These phenomena are well-established in the doped regimes. (Figure 1, negative bias region)

However, near charge neutrality, we cannot ignore that the potential drop along the channel results in non-uniform chemical potential and doping profiles. These inhomogeneities play a critical role and give birth to peculiar transport properties at large bias. [3] As an illustration, in semiconductor MOSFETs, the application of a large bias nucleates an electronic depletion in the channel at the drain electrode. In graphene, a Dirac pinch-off (DPO) occurs as well, but the depletion region is limited due to the absence of gap. (See illustrations on fig. 1, and positive bias region)

We report on the low temperature experimental study of a high mobility hBN-encapsulated GFET with a close graphite backgate. The DPO occurs when the gate and drain voltages are equal, resulting in a zero charge carrier density at the drain side. At DPO, we observe a current plateau with bias which corresponds to a differential resistivity peak. Surprisingly, we observe that the resistance peak increases by two orders of magnitude (resistivity $400\Omega \rightarrow 20M\Omega$) when increasing the gate voltage. This points to the formation of an insulating phase in the DPO region (~ 100nm) with electric fields around 10^7 V/m. At larger bias, an exponentially fast decrease occurs when reaching the bipolar regime.

We interprete the resistance peak as the result of an electronic field focusing effect. Beyond DPO, conductance is restored thanks to electron-hole pair creation at the drain side. This last regime is quantitatively described by the Schwinger theory of particle-antiparticle pair creation and makes the DPO regime an analogue to the breakdown of a relativistic vacuum in QED. Additional measurements of shot noise at DPO support this interpretation

References

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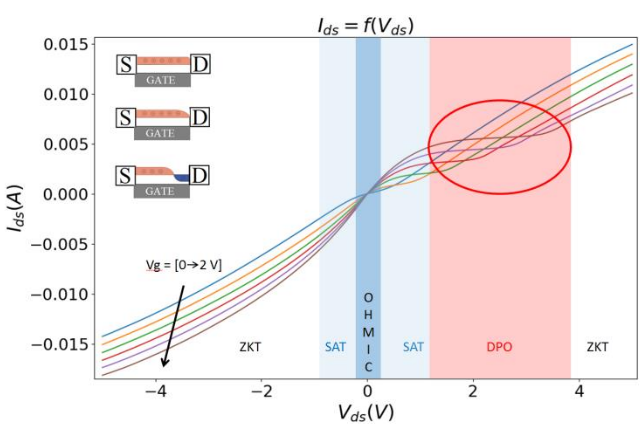

Figure 1: Experimental I-V curves of the GFET at various gate voltages showing the different transport regimes: ohmic behaviour, velocity saturation (SAT), Zener-Klein tunnelling (ZKT), and Dirac Pinch-off (DPO) in the positive bias region. Inset shows the doping profiles along the channel before DPO, at DPO and after DPO with positive doping (resp. negative) in red (resp. blue)

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