A Drift-Diffusion Graphene Field Effect Transistor model to study scaling effects on High Frequency performance

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Abstract

Intrinsic properties of graphene make this two dimensional (2D) material ideal for high frequency (HF) applications, both on rigid and on flexible substrates [1, 2]. However, aggressive scaling in Graphene Field Effect Transistors (GFETs) is necessary to improve the HF figures of merit (FoM) such as cutoff and maximum oscillation frequencies (f_T and f_{max}, respectively) [2]. Several GFET models have been proposed on a drift-diffusion basis [3, 4], but they do not consider 2D effects, which become relevant when the device is further scaled down. Thus, we have developed a model that solves self-consistently the 2D Poisson's equation together with the drift-diffusion transport equation to take account of the transistor geometry. It calculates the current-voltage characteristics of the GFETs and the carrier distribution within the channel. The HF performance can be obtained from the GFET small-signal model. This way, we have investigated the influence of the scaling on the HF performance. Figure 1 shows the output characteristics of a GFET with a 40 nm thick SiO_2 insulator, for channel length of 1 µm (a) and 30 nm (b), corresponding to long and short channel behavior, respectively. For long-channel devices, the output characteristics have been benchmarked against the 1D model from ref. 4, which shows a similar behavior. However, short-channel devices, present a decrease in the transconductance at high drain voltages (V_{ds} > 0.4 V), caused by the dominant influence of the drain over the gate in determining the channel potential (see fig. 1b). The intrinsic f_T derived from our model is shown in fig. 2. The dashed line represents the physical limit [5]. For long channel devices, f_T is independent from V_{ds} and it follows a $1 / L^n$ law (with n = 2), in the same way as the 1D model. As the channel gate becomes shorter, f_T continues increasing, but at a lower rate. For low drain voltages, the exponent thus decreases ($1 < n < 2$), but the loss of transconductance makes n reach values even lower than 1 at high V_{ds}. Our model is also able to predict Negative Differential Resistance (NDR), a valuable property of GFETs for many applications [6].

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References

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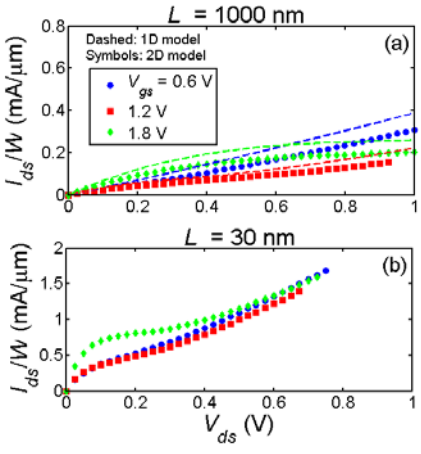

Figure 1. Output characteristics are represented for L = 1 µm (a), and 30 nm (b). L = 1 µm channel device is compared with the 1D model [4].

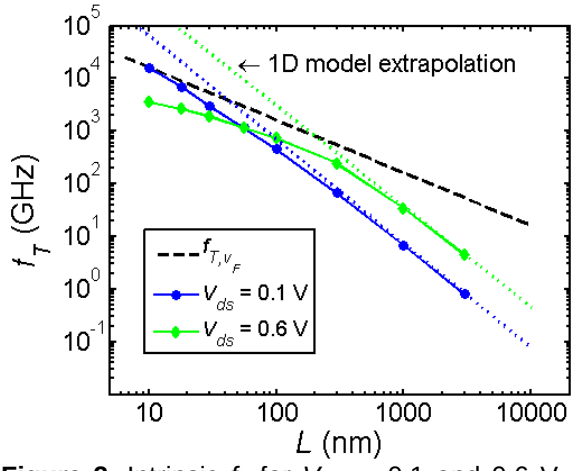

Figure 2. Intrinsic f_T for V_{ds} = 0.1 and 0.6 V. Our model is compared with the 1D model [4], and with the theoretical limit $f_{T,vF} = v_F / L$.