Modern nFET device, $L_g=40$ nm
Equivalent Oxide Thickness (EOT) = 1 nm*

Actually, this has a high dielectric constant gate oxide ($HfO_2$**)
(Intel 45-nm CMOS)

* Note: EOT is 1 nm, but the effective gate capacitor equivalent thickness (CET) is 1.3 nm because quantum effects in the channel push the charge centroid away from the physical interface.

** The relative dielectric constant of hafnium oxide is 25 (vs 3.9 for SiO$_2$).

Simulations courtesy of Professor Dimitri Antoniadis, MIT
Output family, $i_D$-$v_{DS}$ w. $v_{GS}$ incremented

- Notice the more evenly spaced family of curves
- Notice also the more abrupt saturation of $i_D$. In the absence of velocity saturation the onset of the FAR is at $v_{DS} = v_{GS} - V_T$, and the onset would be at 0.75 V when $v_{GS} = 1V$ ($V_T = 0.25 V$). Here it is $\approx 0.4 V$.
- The finite output conductance is due to Drain-Induced Barrier Lowering (DIBL, $\delta$), whereby $V_T$ depends (linearly) on $V_{DS}$, i.e. $V_T = V_{To} - \delta v_{DS}$. 
Transfer Characteristics, $i_D - V_{GS}$ (Log Plot)

Shift of $V_T$: DIBL, $\delta = 0.12 \, \text{V} / 0.095 \, \text{V} = 126 \, \text{mV/V}$
Transfer Characteristic, $i_D - V_{GS}$

(Linear plot)

$V_{DS} = 1 \text{ V}$

$V_{DS} = 0.05 \text{ V}$
Drain induced barrier lowering, $\delta$

Shift of $V_T$ : DIBL, $\delta = 0.12 \text{ V}/0.095 \text{ V} = 126 \text{ mV/V}$
Sub-threshold slope and $n$

Subthreshold slope: $10^5$ in 500 mV = 100 mV/decade

$n = 100/60 = 1.67$
Transconductance, \( g_m = \frac{di_D}{dv_{GS}} \)

Slope = \( \frac{g_m}{W} = \frac{d(i_D/W)}{dv_{GS}} = \frac{1.5}{0.6} = 2.5 \text{ mA/V-µm} \)

Model: \( \frac{g_m}{W} = C_{ox}^* s_{sat} = 2.5 \times 10^{-6} \times 10^7 = 2.5 \text{ mA/V-µm} \)
The finite output conductance, $g_o$, is due to Drain-Induced Barrier Lowering (DIBL), whereby the $V_T$ depends (linearly) on $V_{DS}$: $V_T = V_{To} - \delta \cdot v_{DS}$.

Theoretically, $g_o$ should be $C_{ox}^* \cdot W \cdot s_{sat} \cdot \delta$. This is independent of $v_{GS}$ so all of the curves should parallel in saturation, and this is clearly seen in the figure.

The slope of the orange lines is $\approx 0.3$ mA/V-µm. Using $C_{ox}^* = 2.5 \times 10^{-6}$ Coul/V-cm², $s_{sat} \approx 10^7$ cm/s, and $\delta = 126$ mV/V, we calculate $g_o/W = 0.315$ mA/V-µm.