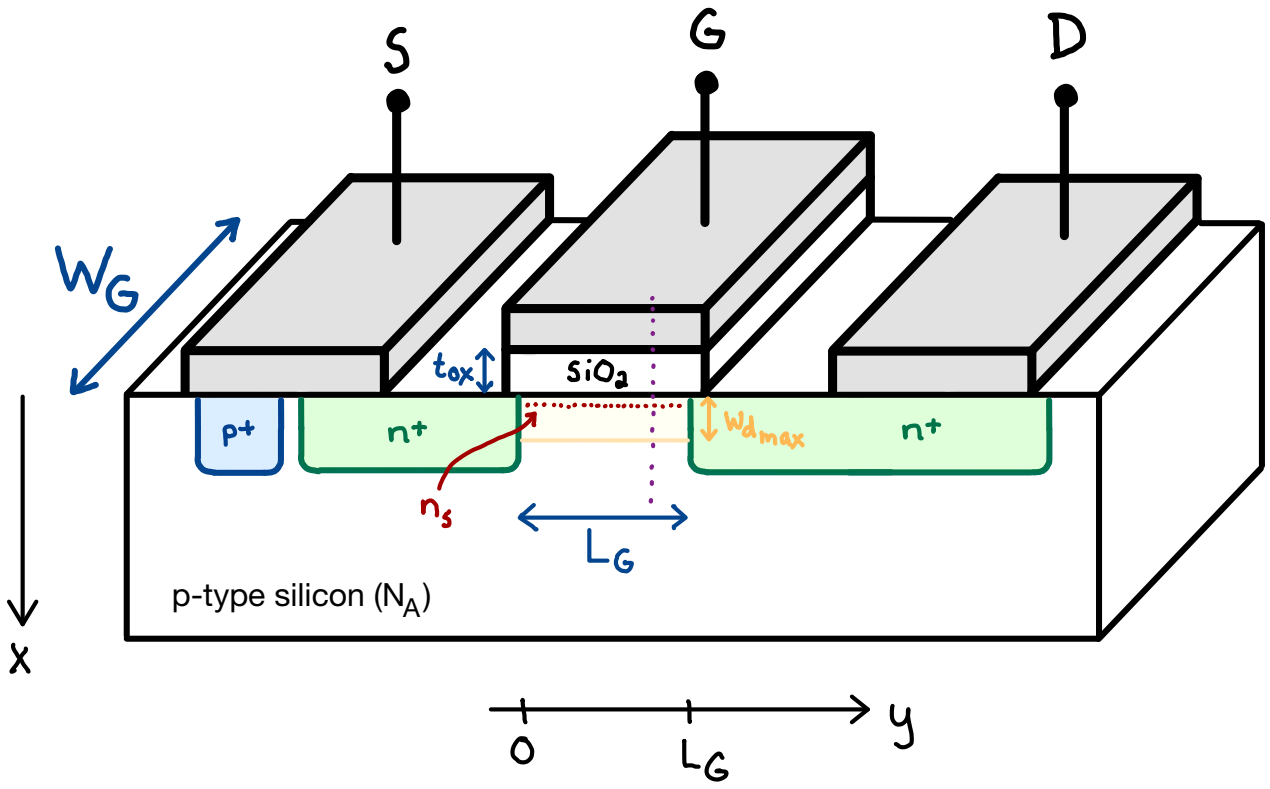
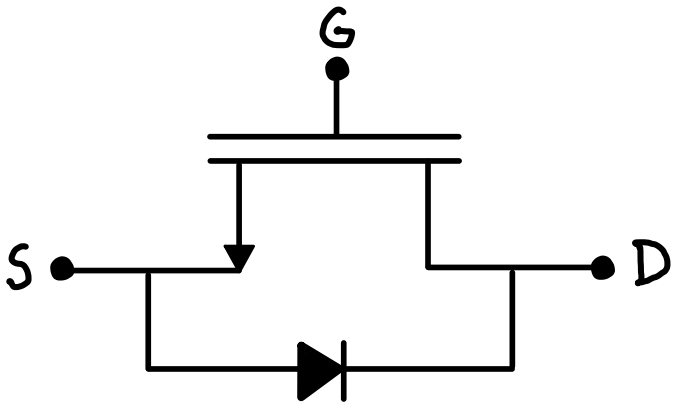
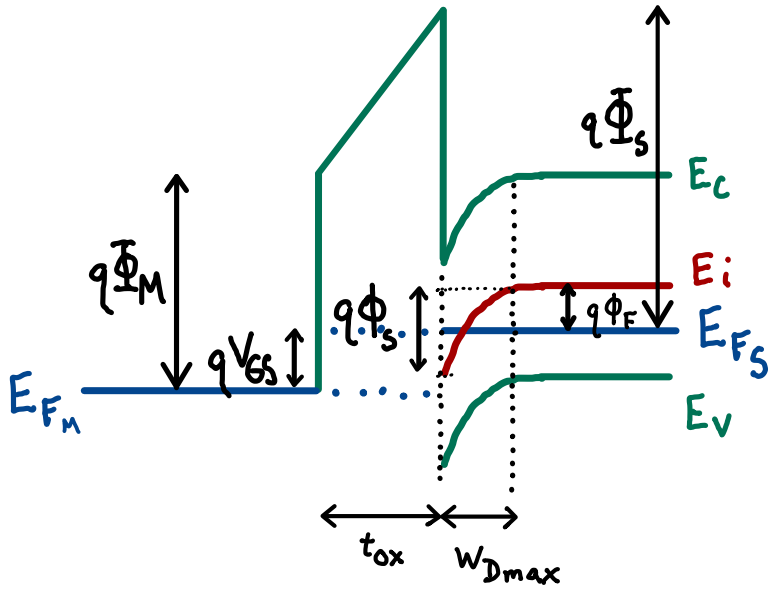
MOSFETs





Band diagram along purple dotted line ($V_{GS} \geq V_{Th}$):



$$\Phi_{MS} = \Phi_M - \Phi_S$$

$$\phi_F = \frac{kT}{q} \ln\left(\frac{N_A}{n_i}\right)$$

$$\phi_s = 2\phi_F \quad \text{(condition for strong inversion)}$$

$$W_{Dmax} = 2\sqrt{\frac{\epsilon_s \phi_F}{qN_A}}$$

$$V_{FB} = \Phi_{MS} - \frac{Q_i}{C_{ox}}$$

$Q_i \equiv$ interface charge

$C_{ox} = \frac{\epsilon_i}{t_{ox}}$

$$V_{Th} = \Phi_{MS} - \frac{Q_i}{C_{ox}} - \frac{Q_d}{C_{ox}} + 2\phi_F \qquad Q_d = -qN_A W_{Dmax}$$

<0 <0 >0 >0

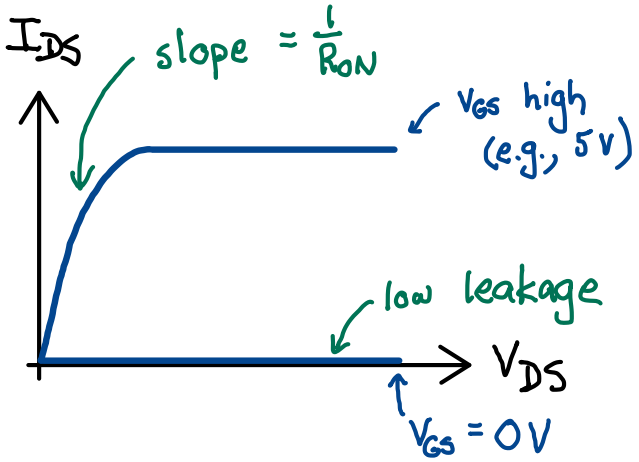
Materials for source/drain and gate contacts:

	Al	n+-poly	Tungsten (W)	p+-poly
$q\Phi_M$ (eV)	4.1	4.05	4.61	5.17
	S/D		Gate	

- p+-poly gate can be deposited by CVD at same time as gate oxide

Desirable characteristics for MOSFETs:

- V_{Th} ~ 1.5V-2V
- Fast switching speeds
- Low switching loss (small R_{ON})
- Low conductive power loss (low leakage)
- Large density of devices

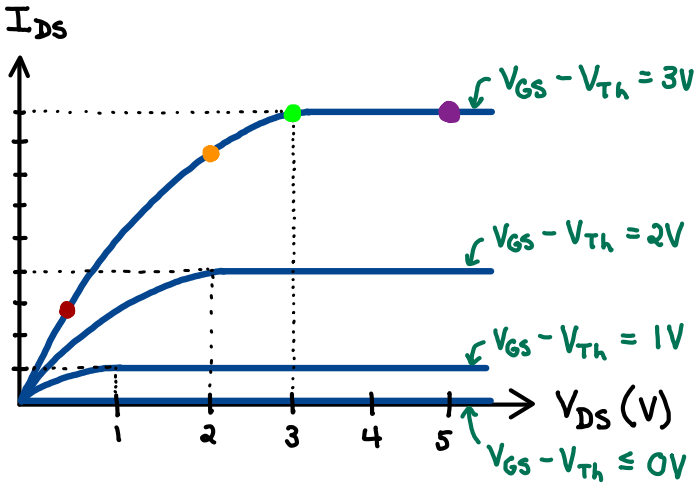


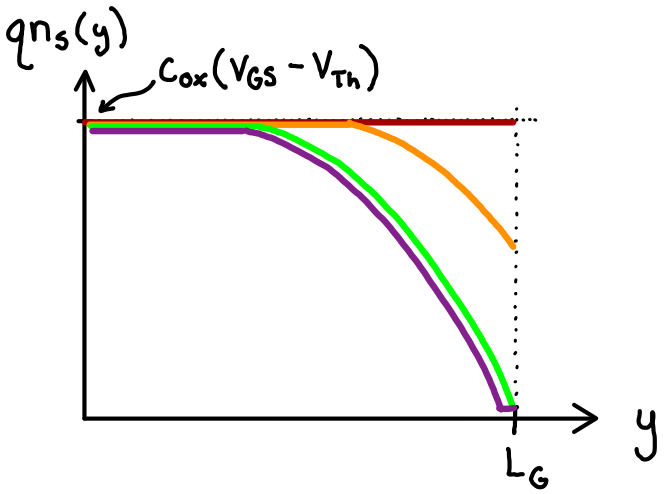
- L_G small (Moore's Law)
- Constant field scaling (scale C_{ox} with L_G)

MOSFET I-V Characteristics

- Long channel device $(L_G \gtrsim 2\ \mu m)$
- Short channel device $(L_G \lesssim 0.2\ \mu m)$

Long Channel MOSFET:





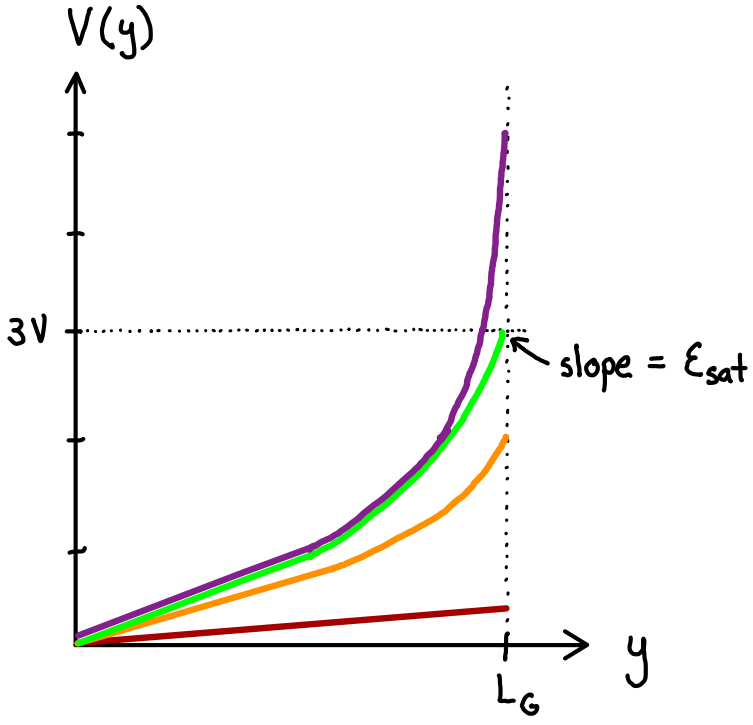
$$V_{knee} = V_{Dsat} = V_{GS} - V_{Th}$$

$$I_{Dsat} = \frac{\mu_n C_{ox} W_G}{2L_G}(V_{GS} - V_{Th})^2$$

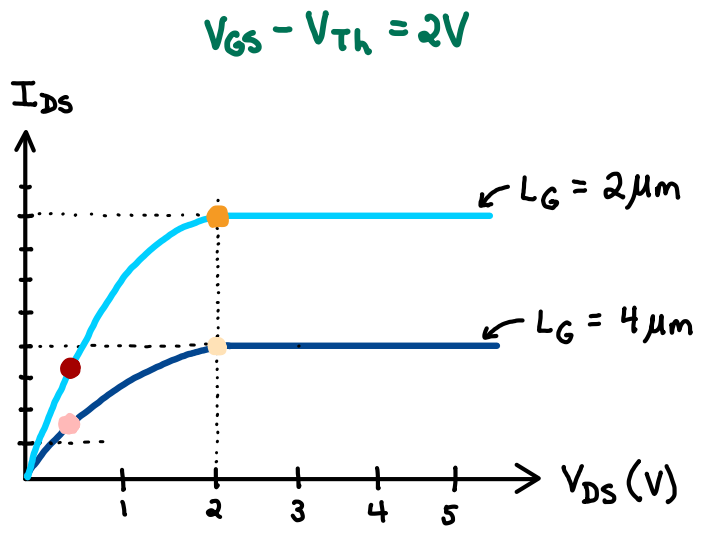
$$\mathcal{E}_y(y) = \frac{dV(y)}{dy}$$

$$v_{el}(y) = \mu_n \mathcal{E}_y(y)$$

$$I_{DS} \propto n_s(y) \cdot v_{el}(y)$$



Scaling of Long Channel MOSFETs



(Note: only the gate length is varied)