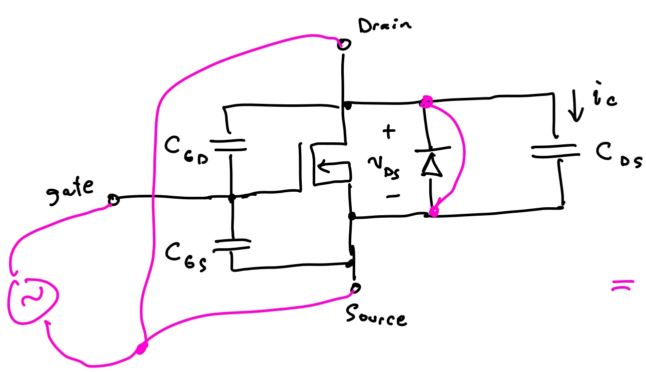
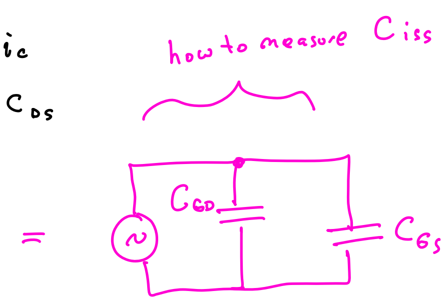
Lecture # 16   11/8/2021

Today :

- Finish Ch 4 (device capacitances)
- Soon start Ch 5 (discontinuous conduction mode)

– Last comments on MOSFET capacitances





Practical guidance on estimating cap values:

On datasheet will find

$C_{iss} = C_{GS} + C_{GD}$ w/ drain-source shorted

$C_{rss} = C_{GD}$

$C_{oss} = C_{DS} + C_{GD}$

on datasheet

– Practical tip on picking transistors

Q: How to compare devices against one another?

A: Need "Figure of Merit" (FOM)

Most popular FOM

$$FOM = R_{on} Q_g$$

R_{on}: $\propto$ to cond. loss

Q_g: $\propto$ to sw. loss

- smaller is better
- generally hard to make both small

Small FOM → better

- FOM gives an idea of what is a "good" sw.
- But, detailed analysis usually need to support decision.

– Wide-bandgap Devices (not in book)

Silicon Carbide & Galium Nitride

Take a look @ physics which dictates R_{on}

all MOSFETs

Majority-carrier device: $\underbrace{\overbrace{AR_{on}}^{\text{specific resistance}}}_{R_{on}^{SP}} = \dfrac{k}{\mu_n \varepsilon_s E_c^{3}} V_B^{2}$

$V_B \uparrow \Rightarrow R_{on} \uparrow\uparrow$

Si MOSFETs limited to 600-900V V_B

A	device area
V_B	device breakdown voltage
E_c	critical electric field for avalanche breakdown
μ_n	electron mobility
ε_s	semiconductor permittivity

V_B: can be adjusted via fabrication

E_c: fundamental material property

- Comparison of material E_c

Material	Bandgap [eV]	Electron mobility μ_n [cm^2/Vs]	Critical field E_c [V/cm]	Thermal conductivity [W/m°K]
Si	1.12	1400	3×10^5	130
SiC	2.36-3.25	300-900	$1.3\text{-}3.2 \times 10^6$	700
GaN	3.44	1500-2000 (AlGaN/GaN 2DEG)	$3.0\text{-}3.5 \times 10^6$	110

can operate @ higher junction temperature

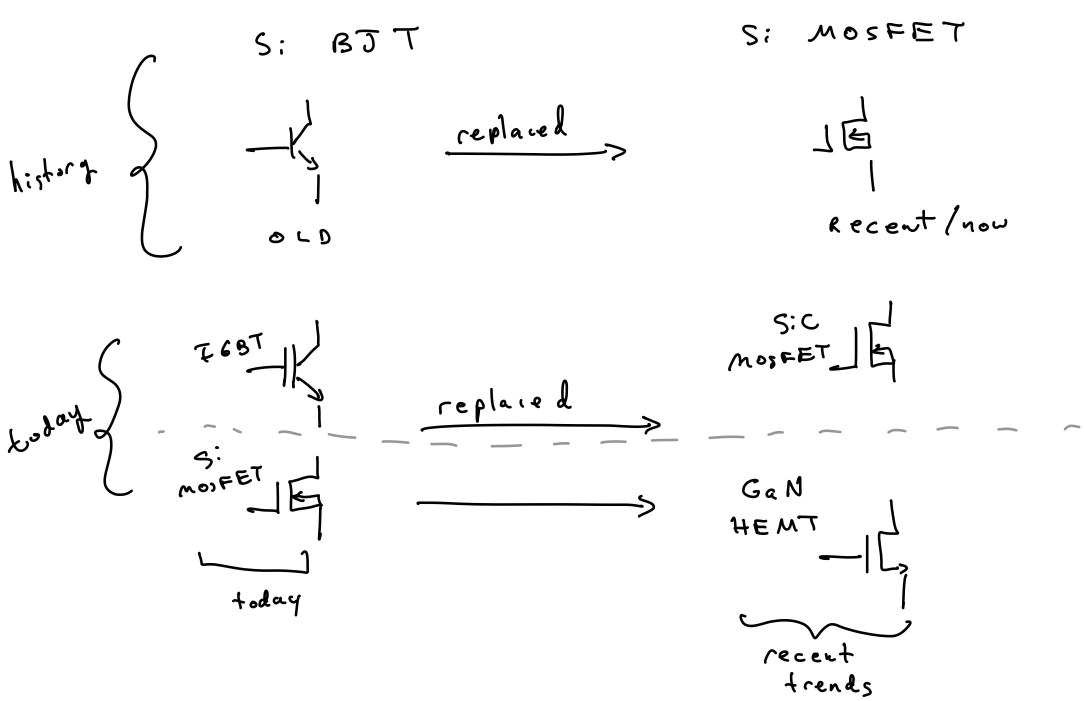
larger E_c, gives $\downarrow R_{on,sp}$

Cons of WBG devices?

→ SiC inferior to Si @ below 600V b/c lower electron mobility

→ GaN devices are lateral b/c of substrate fab. challenges
↳ need GaN on Si

- History / Trends



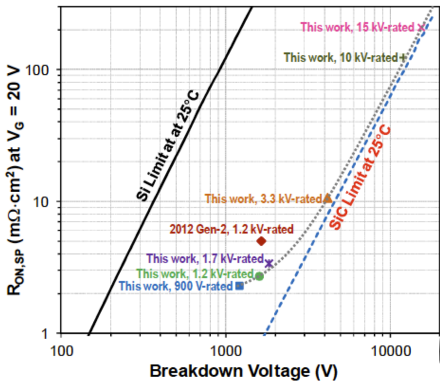


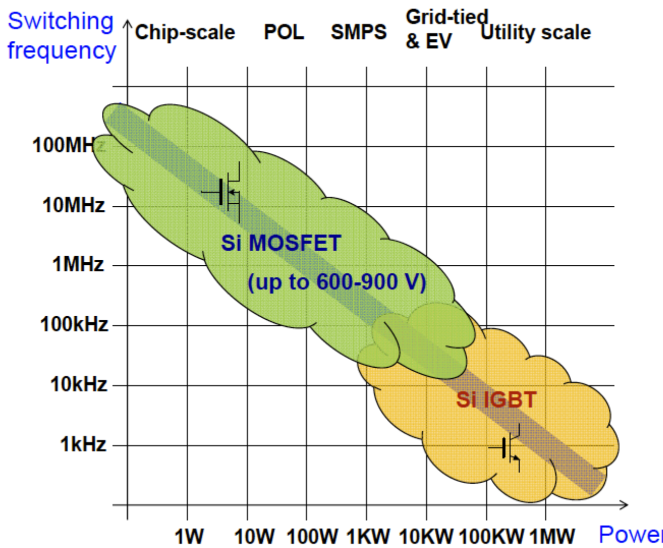
Table 2: Comparison of 10 kV, 15 kV SiC MOSFETs in this work to a commercial 6.5 kV Si IGBTs

energy loss.

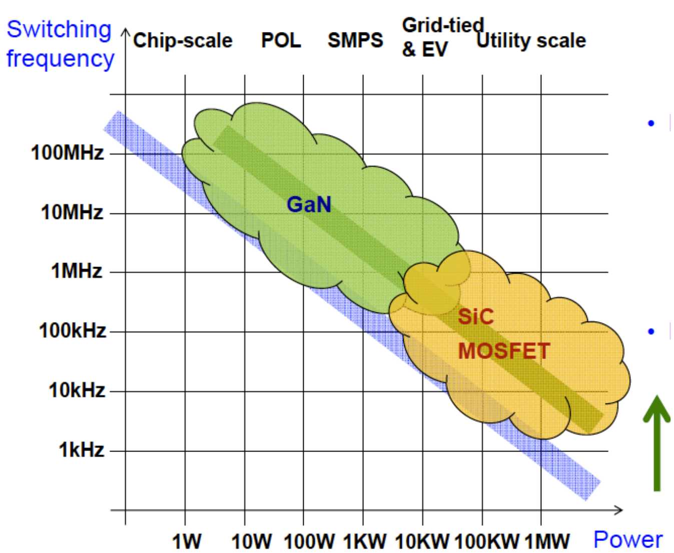
Device	Max Tj (°C)	Rated Current	Die Size (mm²)	$V_{DS\,ON}$ @ Max T_J & Rated Current	E_{ON}	E_{OFF}
Si IGBT [3] 6.5kV	125	25 A	13.6 x 13.6	5.4 V	200 mJ @ 3.6 kV and 25 A	130 mJ @ 3.6 kV and 25A
10 kV/10 A SiC MOSFET	150	10 A	8.1 x 8.1 8×8 mm	10.2 V	5.9 mJ @ 6 kV and 10A	1.3 mJ @ 6 kV and 10A
15 kV/10 A SiC MOSFET	150	10 A	8 x 8	16.3 V	8.9 mJ @ 8 kV and 10A	1.9 mJ @ 8 kV and 10A

faster devices have high $\frac{dV}{dt}$

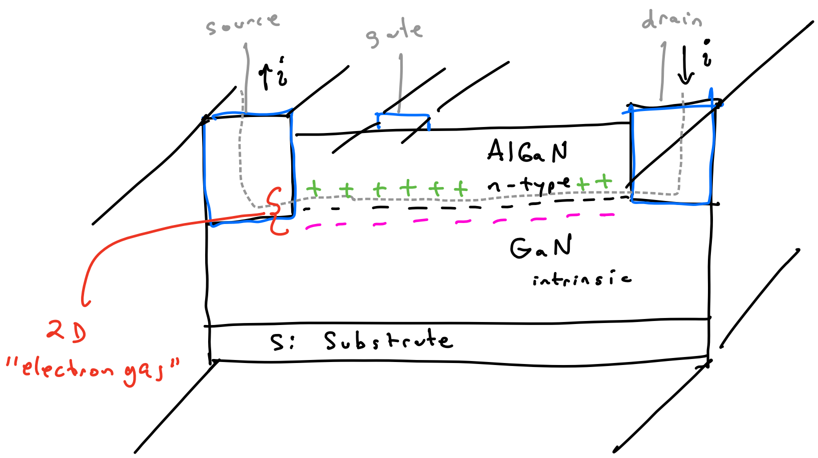
today & recent past



future trend



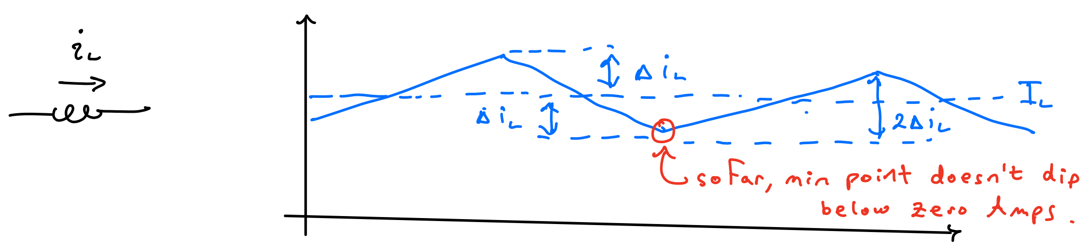
- Power GaN "high electron mobility transistor" (HEMT)



* lateral
* No oxide layers
* Normally ON
  - ↳ Need to drive w V_{gs} ⊖ to turn off
* No body diode
* Avoid too large of v_{gs} ... gate-source diode will turn on & conduct.

- Ch 5 = "Discontinuous Conduction Mode" (DCM)

Main Idea from prior chapters

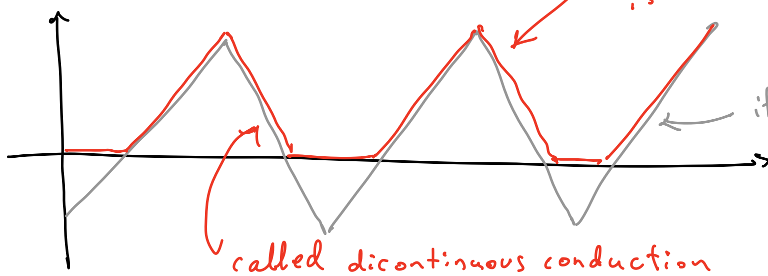


All prior analysis assumed $I_L > \Delta i_L$

↳ called "Continuous Conduction Mode" CCM

– What happens if $I_L < \Delta i_L$

if one device (e.g., diode) is unidirectional



if both sw. are bidirectional current conducting

called dicontinuous conduction mode (DCM)