Composants WBG en GaN: Nouvelles Opportunités pour l'Électronique de Puissance

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GaN Development Strategy

September 24, 2018 (*)

ST and **CEA-Leti** have joined forces to develop **a 650 V normally-off GaN HEMT** at 8'' exploiting a full range of IPs owned by both Companies to deliver the state-of-the-art GaN technology for the most demanding **power conversion applications**

September 26, 2018 (**)

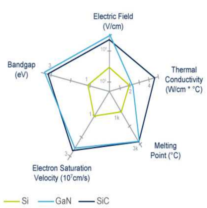
STMicroelectronics va créer une ligne de fabrication de puces en nitrure de gallium à Tours
Bonne nouvelle pour le site industriel de STMicroelectronics à Tours. Le fabricant franco-italien de semi-conducteurs compte y ouvrir en 2020 une ligne de production de circuits de puissance en nitrure de gallium (GaN pour gallium arsenide) sur plaquettes silicium de 200 mm de diamètre. **La technologie y sera transférée depuis l'IRT Nanoelec à Grenoble**, où il collabore à son développement avec le CEA-Leti, le laboratoire d'électronique du CEA qui pilote cet institut de recherche technologique

Sources:
(*) https://www.st.com/content/st_com/en/about/media-center/press-item.html/t4092.html
(**) https://www.usinenouvelle.com/article/stmicroelectronics-va-creer-une-ligne-de-fabrication-de-puces-en-nitrure-de-gallium-a-tours.N746629

Why Gallium Nitride?

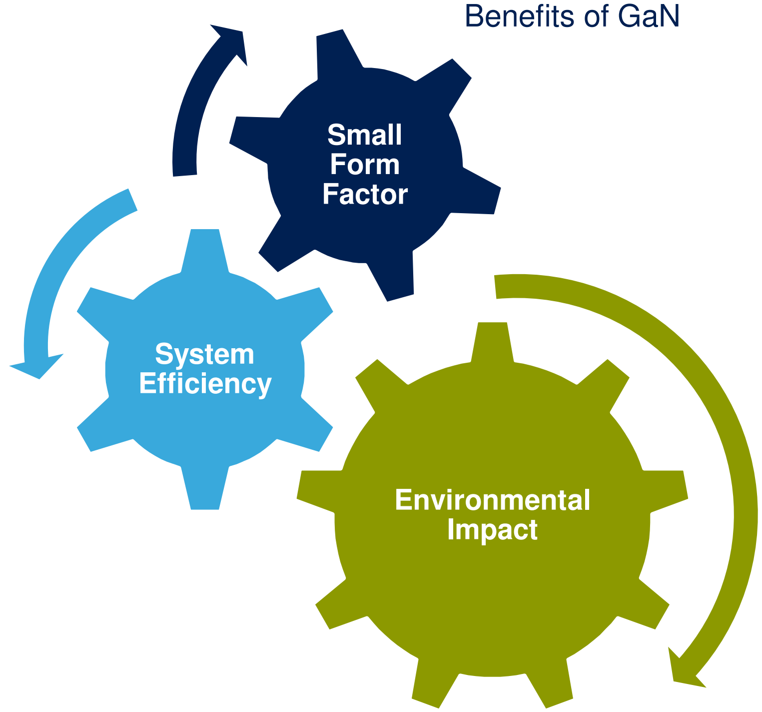
The ever-increasing demand for electricity and pervasive use of Internet services must cope with efforts to de-carbonize our society. This can be achieved by improving the efficiency of all energy conversion systems from generation down to distribution

Silicon has dominated power applications for many years, but its physical limits are being approached. Only minimal improvements inefficiency can be achieved.



Wide Band Gap (WBG) semiconductors, and especially Gallium Nitride (GaN), have unique properties including lower on-resistance and faster switching that allow energy loss reduction and miniaturization. GaN is now a credible alternative to silicon in power conversion processes.

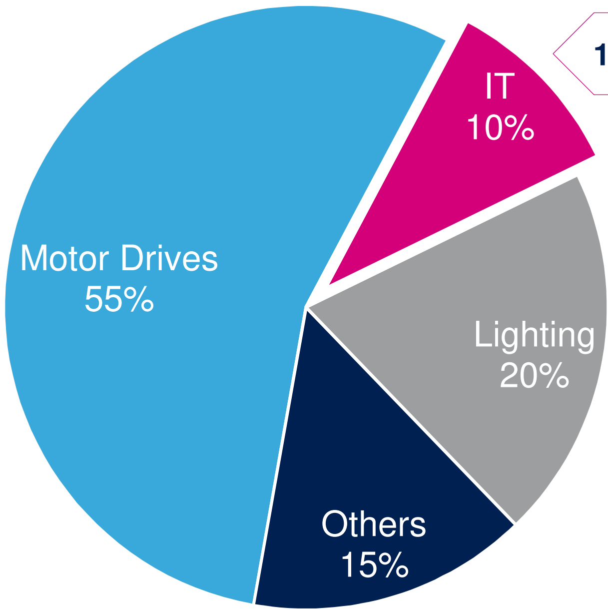
Benefits of GaN



GaN Impact on Energy Consumption

IT (Information Technology) Infrastructure Scenario

17,641 TWh Total WW Electricity Consumption (2014)



Electricity Consumption by Application

1,764.1 TWh

Assuming **1%** efficiency improvement in IT power supplies, we will get a total energy saving of **17.6 TWh**

1,513,327.6 TOE 

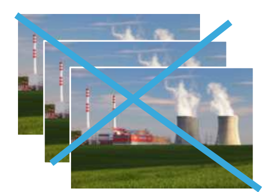
2,161,896.5 TCE 

6,201,869,960 Kg CO_2e 

10.36 MMBOE 

An average nuclear plant has a capacity of 0.7 GW, so output in one full year is almost 6 TWh

Therefore the total energy saving equals that of (17.6 / 6) ~ **3 nuclear plants !**



MMBOE: Million Barrels of Oil Equivalent
TOE: tonnes of oil equivalent
TCE: tonnes of coal equivalent

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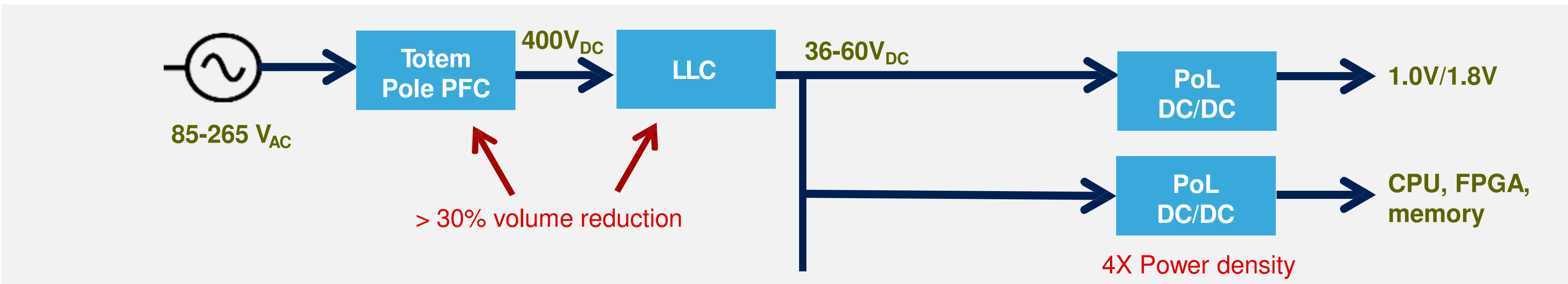
Sources: U.S. Energy Information Administration, STMicroelectronics

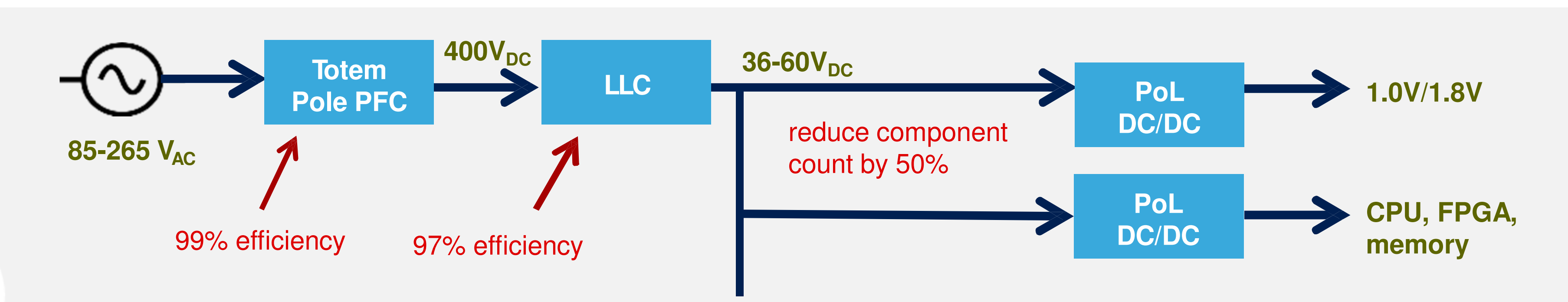
Powering Next-generation Datacenters with GaN

IT (Information Technology) Infrastructure Scenario

Improving form factor and power density



Boosting efficiency and reliability



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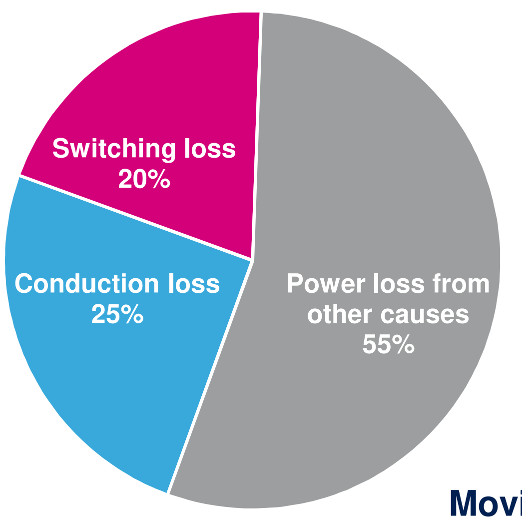
GaN Enables Total System Efficiency Improvement

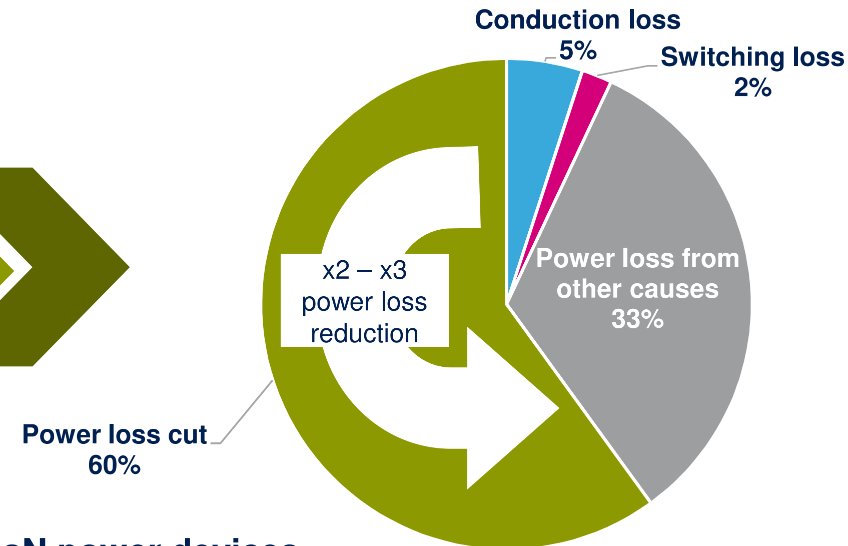
GaN power devices allow for reduced gate charge without sacrificing on-resistance leading to power saving and total system downsizing

Silicon MOSFET



Total efficiency: ≥ 85%

GaN power device



Total efficiency: ≥ 95%

Moving from Si MOSFET to GaN power devices

On-resistance losses: about 1/5

Switching speed: x40 - x100

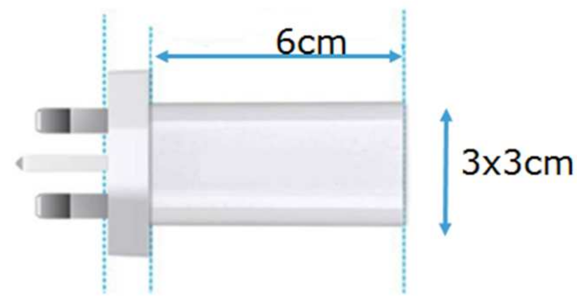
Operation frequency: 3x

Source: STMicroelectronics

60 W Laptop Adapter
with 92% Efficiency and Small Form Factor

Conventional adaptor based on Silicon switch*

Adaptor based on GaN switch



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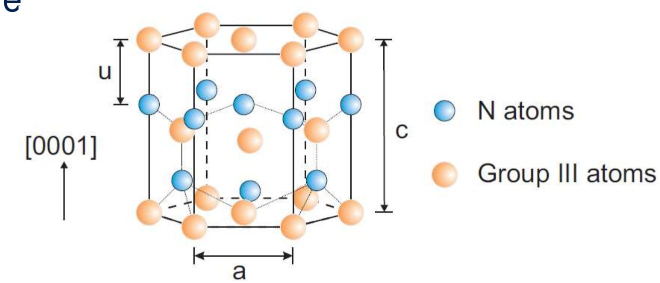
*Super Junction power MOSFET

What is GaN ?

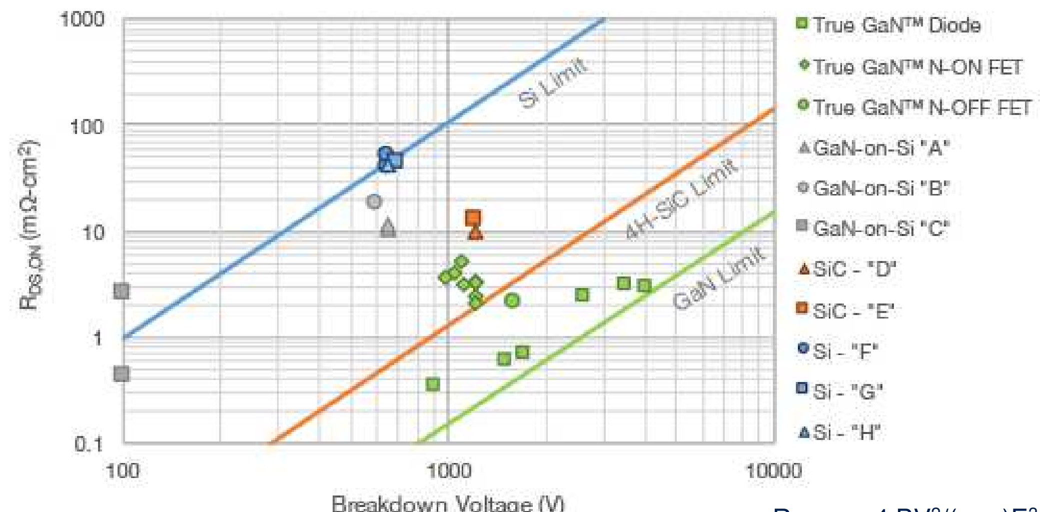
- GaN is a binary compound whose molecule is formed from one atom of Gallium (III-group, Z=31) and one of Nitrogen (V-group, Z=7) with wurztite hexagonal structure

	II	III	IV	V	VI
2	Be	B	C	N	O
3	Mg	Al	Si	P	S
4	Zn	Ga	Ge	As	Se
5	Cd	In	Sn	Sb	Te



Material properties	Si (111)	GaAs	SiC	GaN
E_g (eV)	1.1	1.43	2.86	3.39
E_c (MV/cm)	0.3	0.45	2.0	3.33
ε_r	11.9	13.1	9.8	9
μ ($cm^2/V \cdot s$)	1350	8500	650	1700
v_s (10^7 cm/s)	1	2	2	2.5
Melting point (K)	1415	1238	2827	2791
κ (W/cm·K)	1.3	0.46	4.9	1.3

Specific on-resistance of WBG vs. Si



$R_{on,\ spec}=4\ BV^2/(e_0 e_r)E^3_{cr}$

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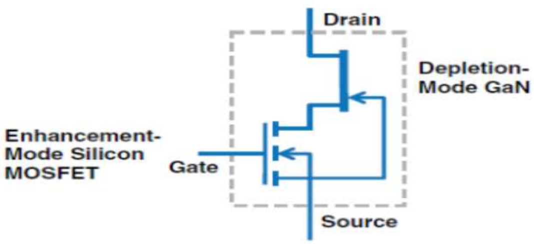
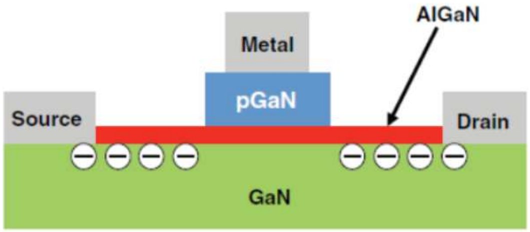
E-Mode GaN HEMT

Different Implementations Overview

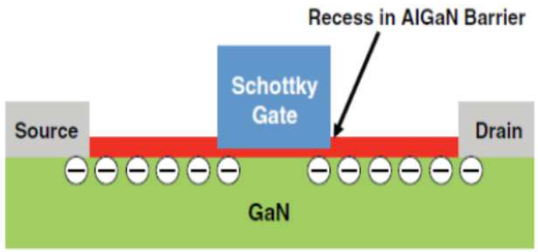
E-Mode by cascode configuration	pGate	Recessed gate



- No intrinsic normally-off
- Needs an Si device
- Best mobility and charge
- Stable gate structure



- High sheet resistance out of the gate
- Cannot tolerate Vg > 6 V
- Normally-off
- No insulator reliability issues

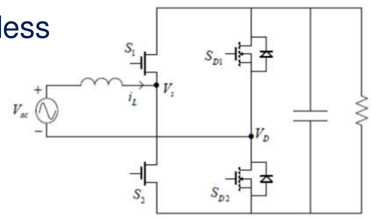


- Poor mobility under gate
- Insulator reliability issues
- Normally-off
- Low resistance in the access region and tolerate high VG value

GaN Enables New Topologies

Totem-pole PFC

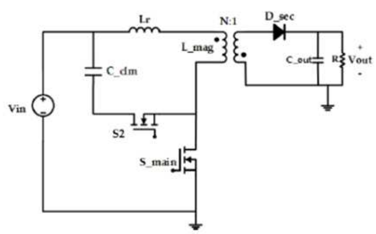
Bridgeless



Efficiency can reach 99%

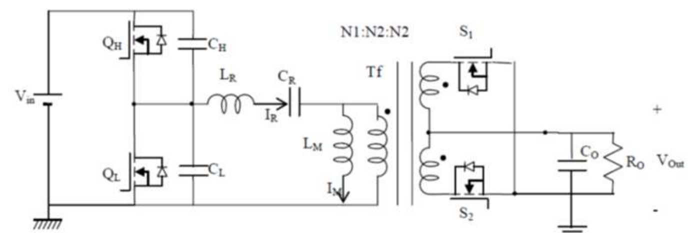
- High power density
- High efficiency
- Distributed heat

Active Clamp Flyback (ACF) converter



Low switching losses and inductive energy utilization can be used at high frequencies in applications such as adaptors resulting in drastic size reduction

Half-bridge LLC converter



LLC converters use ZVS switching. Coss is discharged before the transistor turns on. Discharge time is therefore a limiting factor for higher frequency unless a GaN transistor is used

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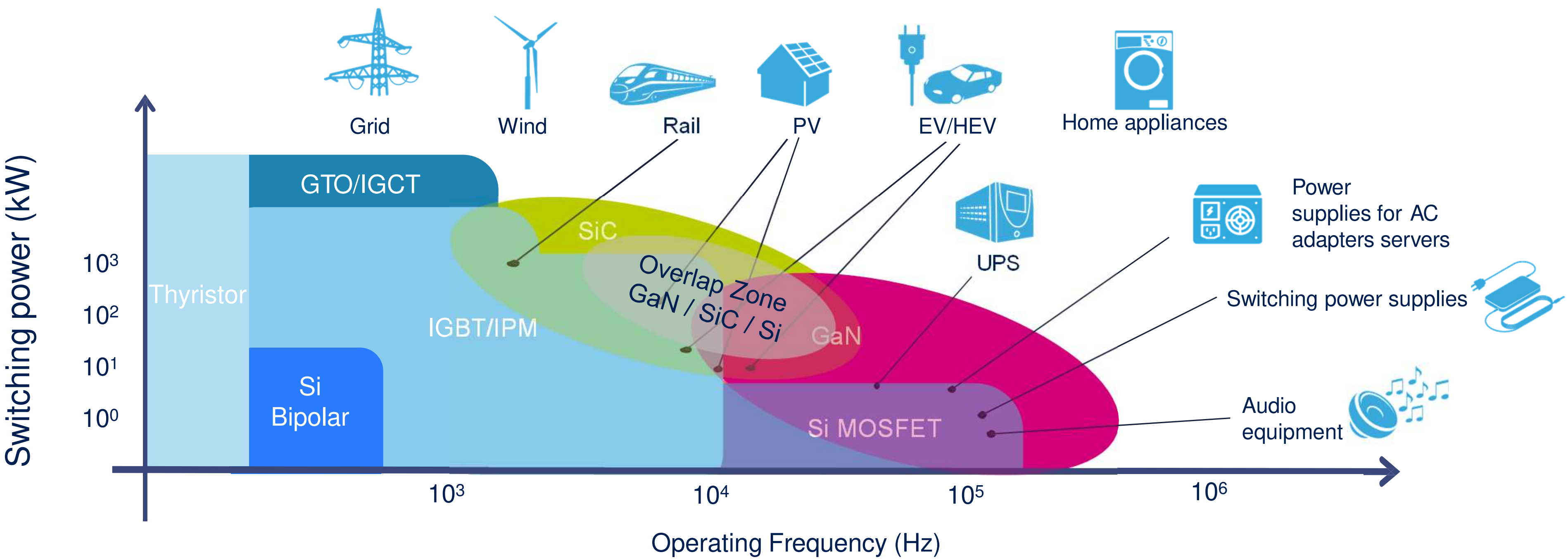
Power vs. Frequency on Electronics

Power Device Technology Positioning (2018)



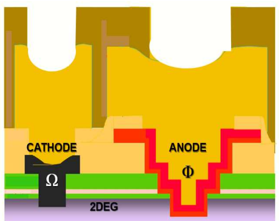
Use of parallel and series connections for power semiconductors, as well as power converters, means that virtually any amount of electric power can be transformed, converted into another energy form or "generated" from another type of energy.

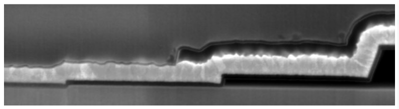
Gate turn-off thyristor (GTO)
Integrated gate-commutated thyristors (IGCT)

Source: Yole Power SiC 2018: Materials, Devices, and Applications

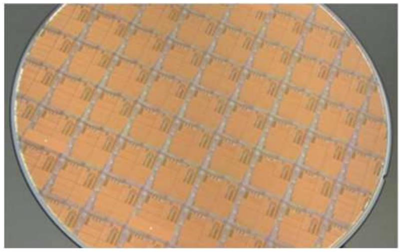
650 V GaN-on-Si diode Development

2DEG lateral technology

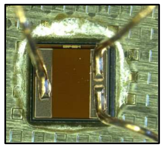


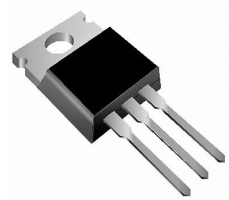


GaN on 8'' Si



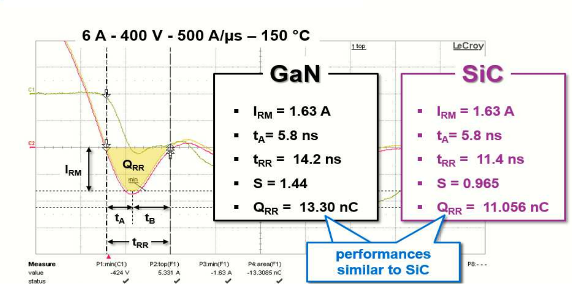
TO220 Package

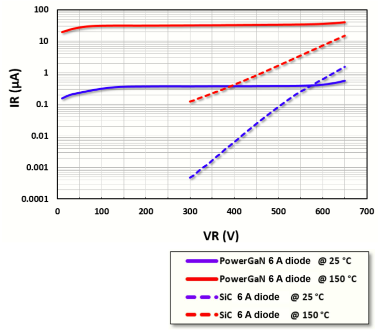




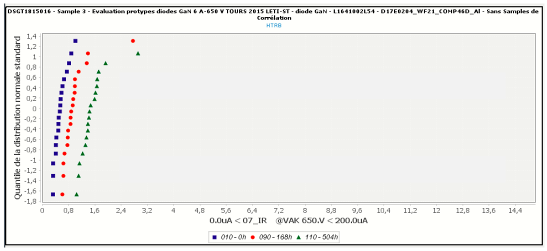
Electrical performances

Switching measurements: GaN vs. SiC





Reliability in blocking mode at 150° C demonstrated up to 650 V



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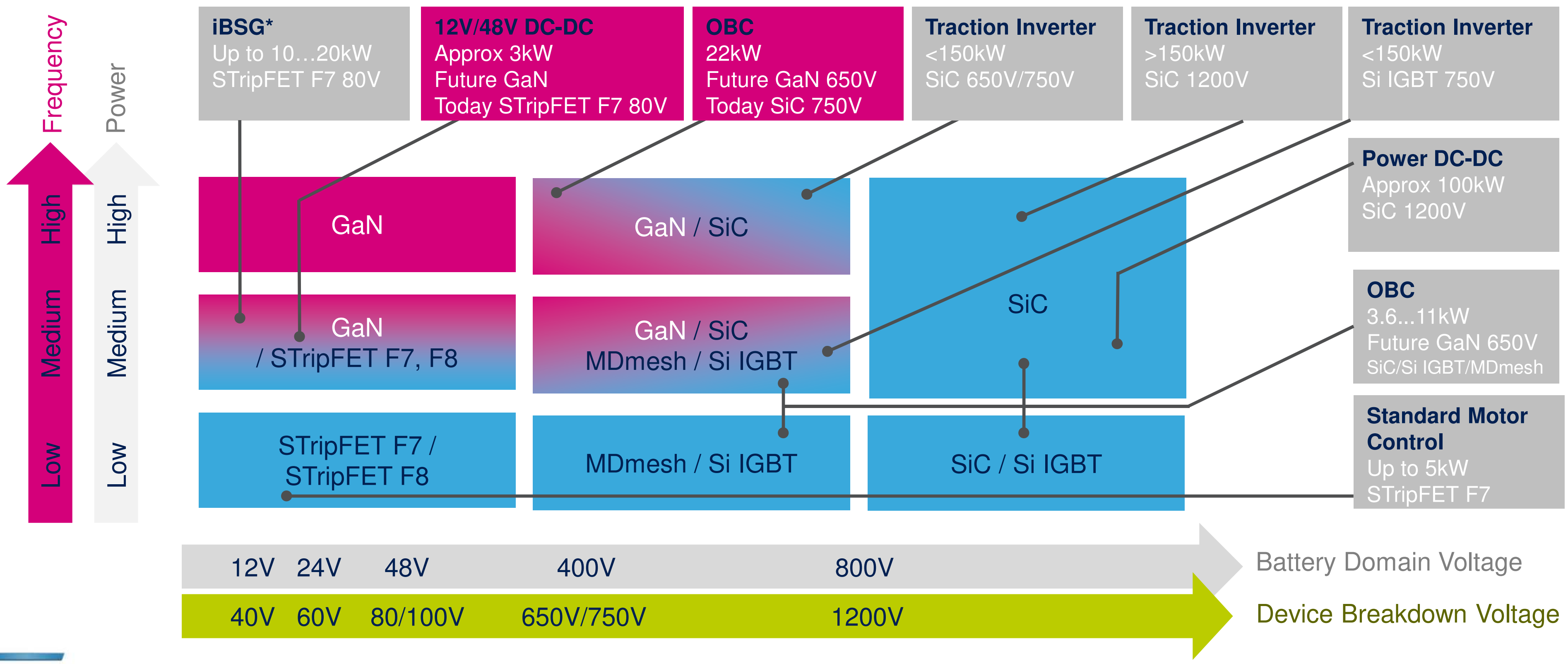
GaN inside ST Power Ecosystem

Car Electrification Power Electronics by applications and technologies



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*Integrated Belt Starter Generator • STripFET™ F7, F8 (low voltage Power MOSFET) • MDmesh™ (high voltage Power MOSFET)

GaN HEMT
Main Target Markets and Applications

- **High Voltage GaN HEMT (650 V)**
  - Adaptors (PC, Portable Gear, Wall USB chargers)
  - Servers (PFC)
  - On Board chargers for EV / Plug-in HEV
  - Space and Avionics

- **Low Voltage GaN HEMT (100 V – 200 V)**
  - Telecom / Datacenter DC/DC converters
  - Wireless Charging
  - Points-of-loads (POL)
  - Class-D audio amplifiers
  - Mild hybrid powertrain








Points-clé à Retenir

- STMicroelectronics a pris la décision stratégique de compléter son portefeuille technologique de composants de puissance Si et SiC avec une technologie GaN-on-Si en 200 mm.

- L'IRT Nanoelec est un outil de collaboration multi partenarial particulièrement bien adapté à la stratégie de développement de STMicroelectronics sur le GaN
  - Innovation en rupture sur toute la chaîne de la valeur
  - Excellence du consortium
  - Flexibilité du programme technique

- La première génération de composants GaN-on-Si 650V développée dans l'IRT Nanoelec sera transférée sur la ligne pilote 200 mm de ST Tours à partir de l'an 2020.

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