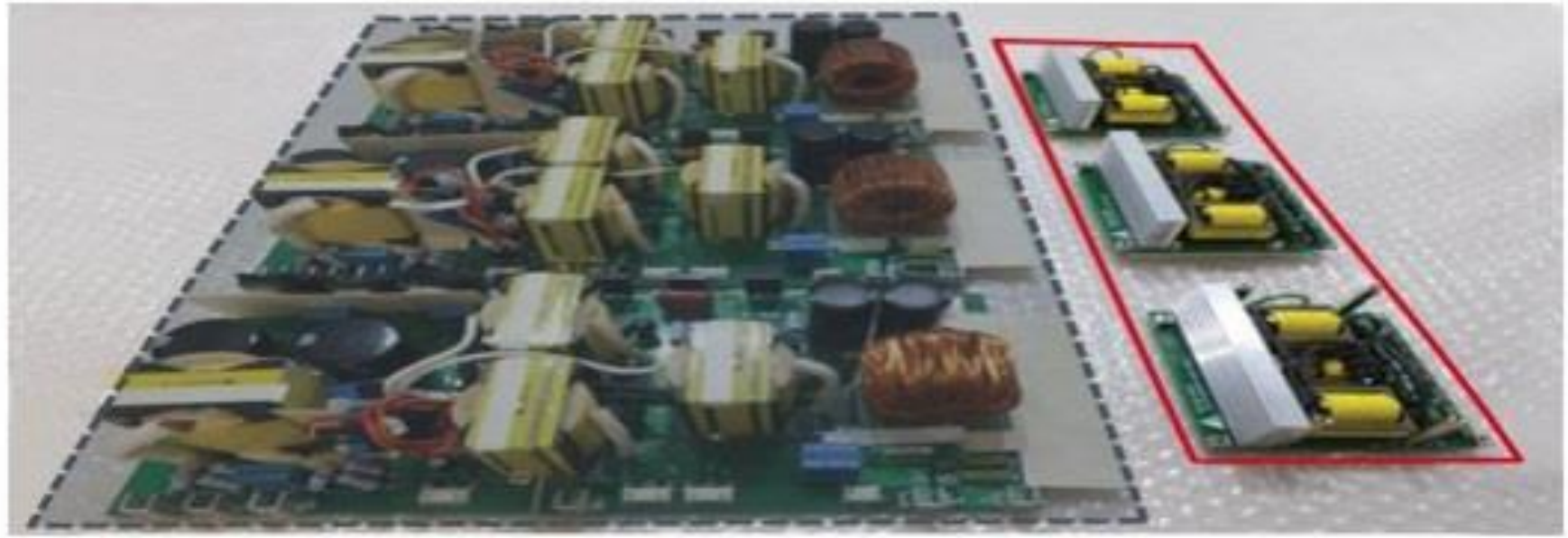
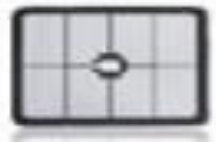
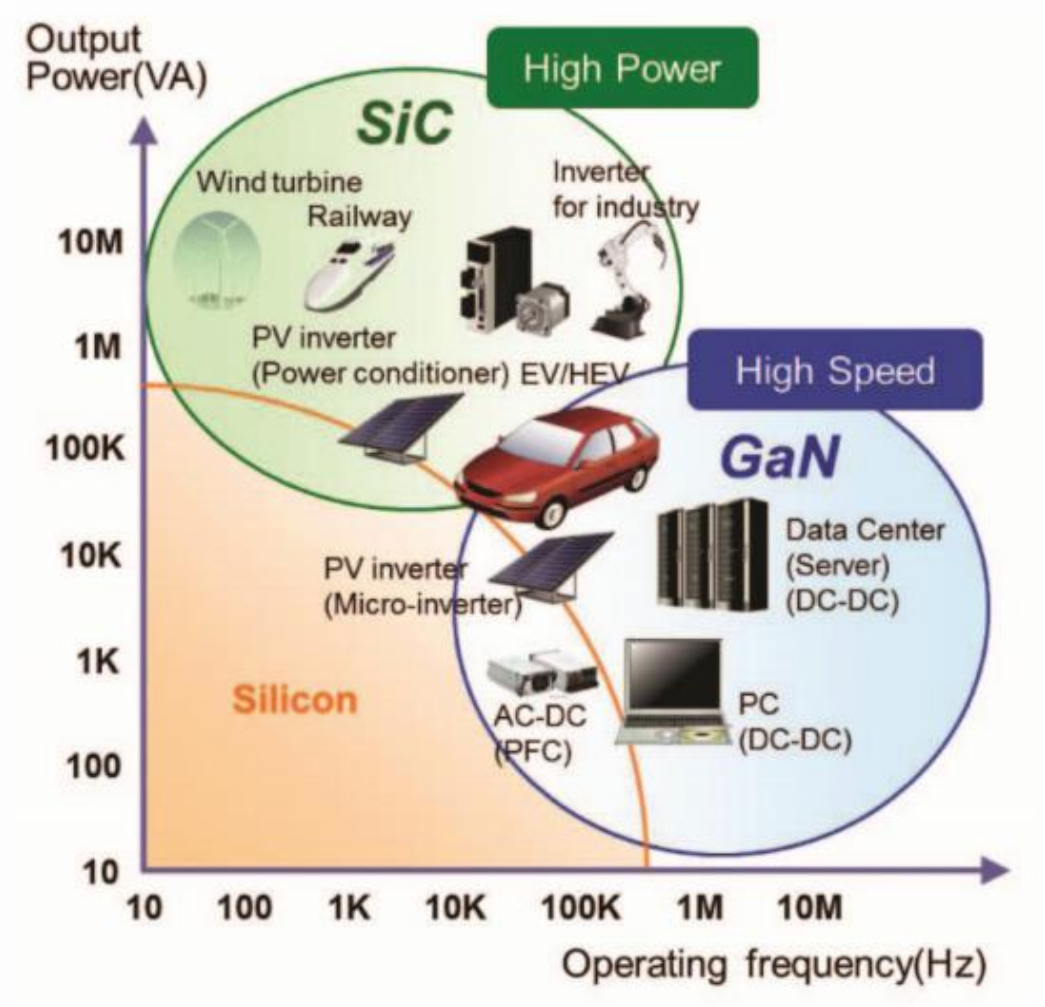


	System with Si IGBT	System with SiC
Weight	7 kg	0.9 kg
Volume	8.775 cc	1.350 cc

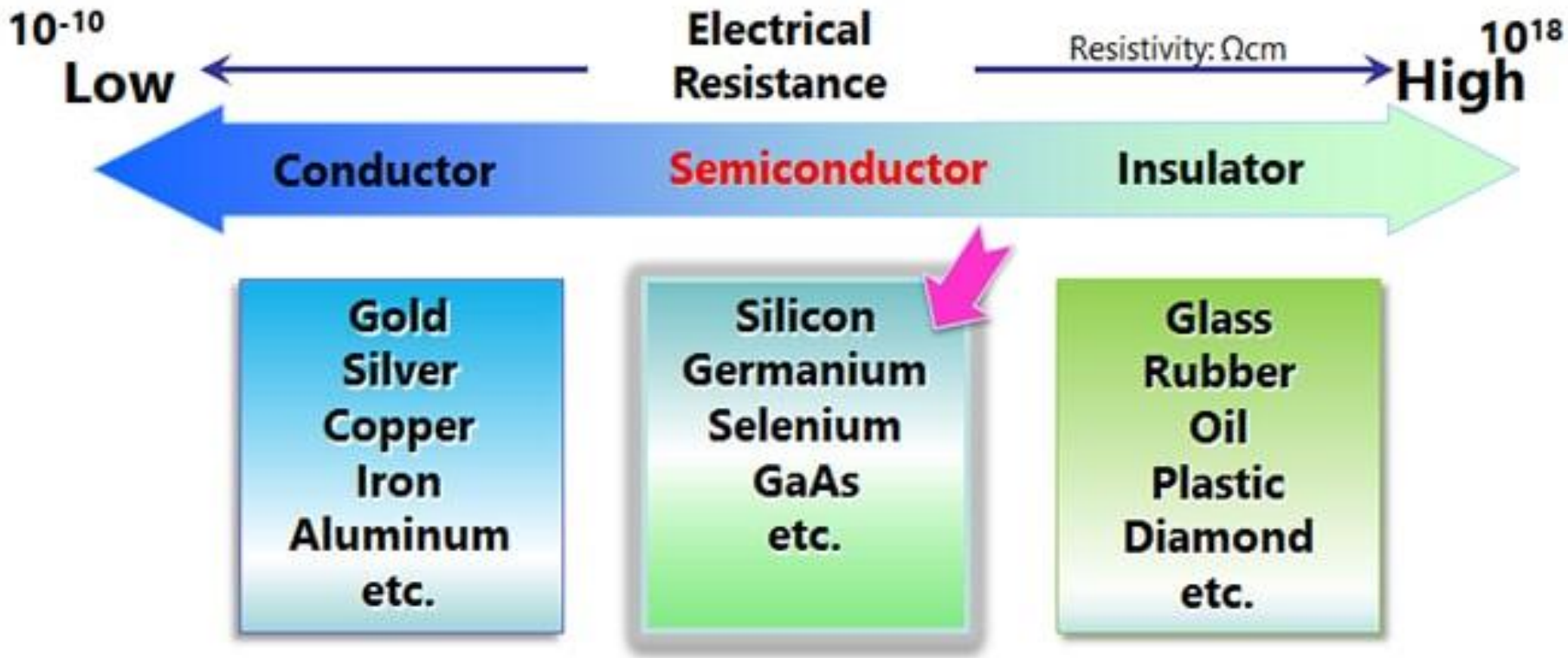


Chip Size 1/4



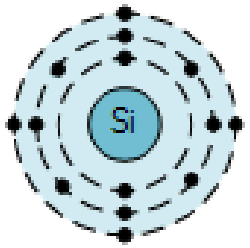
For high power applications, the SiC switches have enormous advantages over the conventional Si power switches. The GaN switches have the best performance among the others for high frequency applications.

Materials Property	Si	SiC-4H	GaN
Band Gap (eV)	1.1	3.2	3.4
Critical Field 10^6 V/cm	.3	3	3.5
Electron Mobility (cm^2/V-sec)	1450	900	2000
Electron Saturation Velocity (10^6 cm/sec)	10	22	25
Thermal Conductivity (Watts/cm^2 K)	1.5	5	1.3

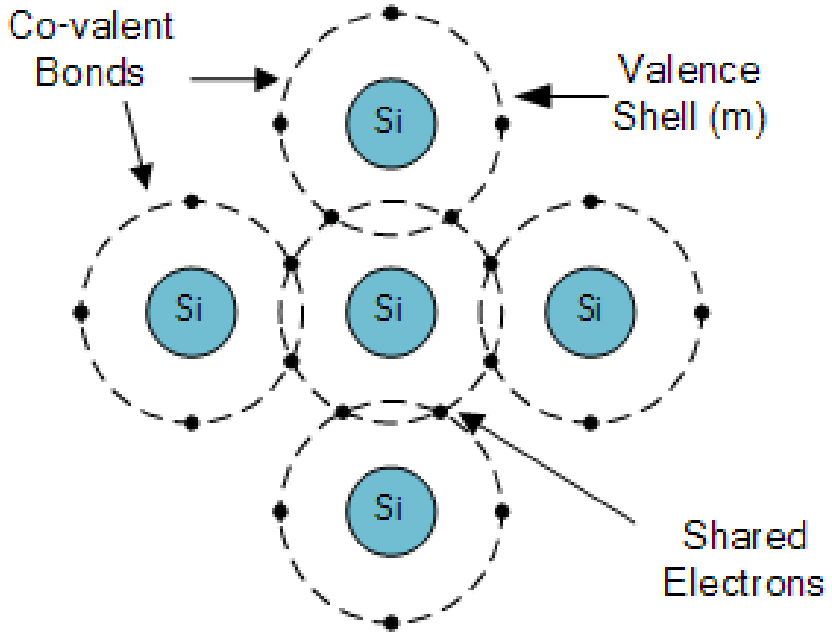

10-10
Low
Electrical
Resistance
Resistivity: Ωcm
1018
High
Conductor
Semiconductor
Insulator
Gold
Silver
Copper
Iron
Aluminum
etc.
Silicon
Germanium
Selenium
GaAs
etc.
Glass
Rubber
Oil
Plastic
Diamond
etc.

Elements Group 13	Elements Group 14	Elements Group 15
3-Electrons in Outer Shell (Positively Charged)	4-Electrons in Outer Shell (Neutrally Charged)	5-Electrons in Outer Shell (Negatively Charged)
(5) Boron (B)	(6) Carbon (C)	
(13) Aluminium (Al)	(14) Silicon (Si)	(15) Phosphorus (P)
(31) Gallium (Ga)	(32) Germanium (Ge)	(33) Arsenic (As)
		(51) Antimony (Sb)

A Silicon Atom,
Atomic number = "14"

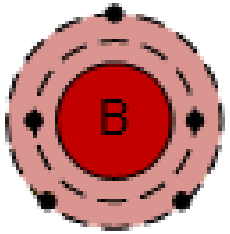


Silicon atom showing
4 electrons in its outer
valence shell (m)

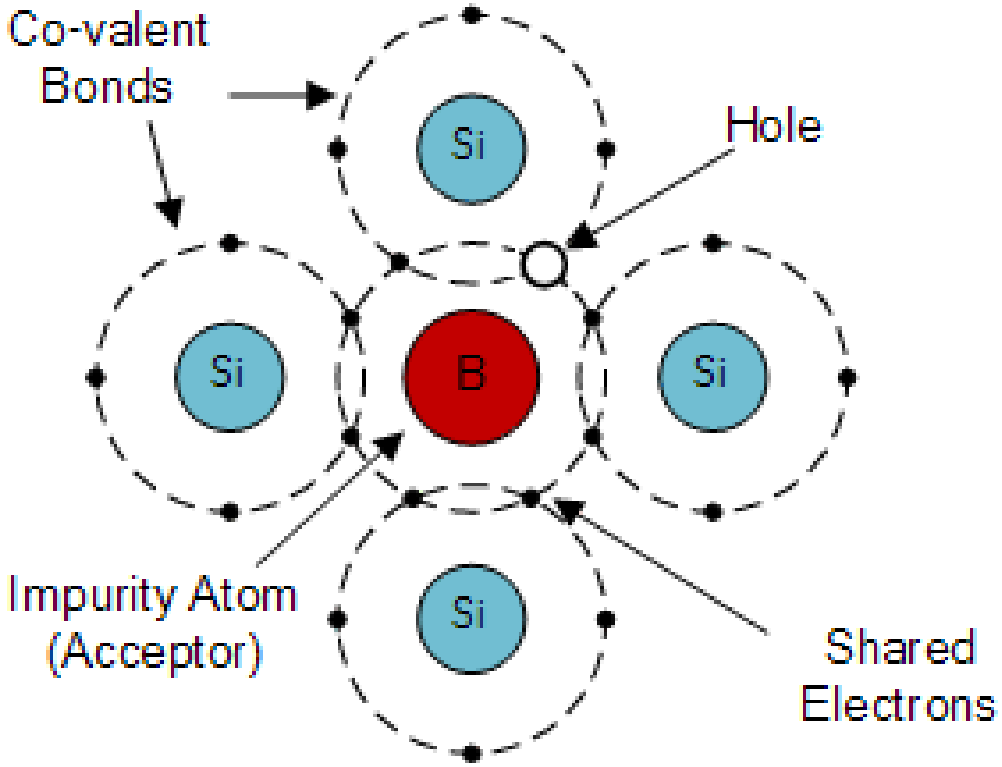


Silicon Crystal Lattice

A Boron Atom,
Atomic number = "5"

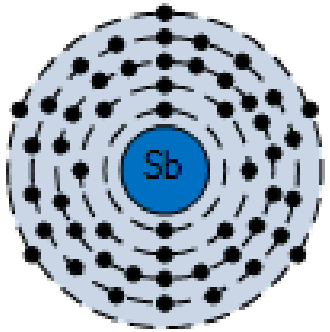


Boron atom showing
3 electrons in its outer
valence shell (L)

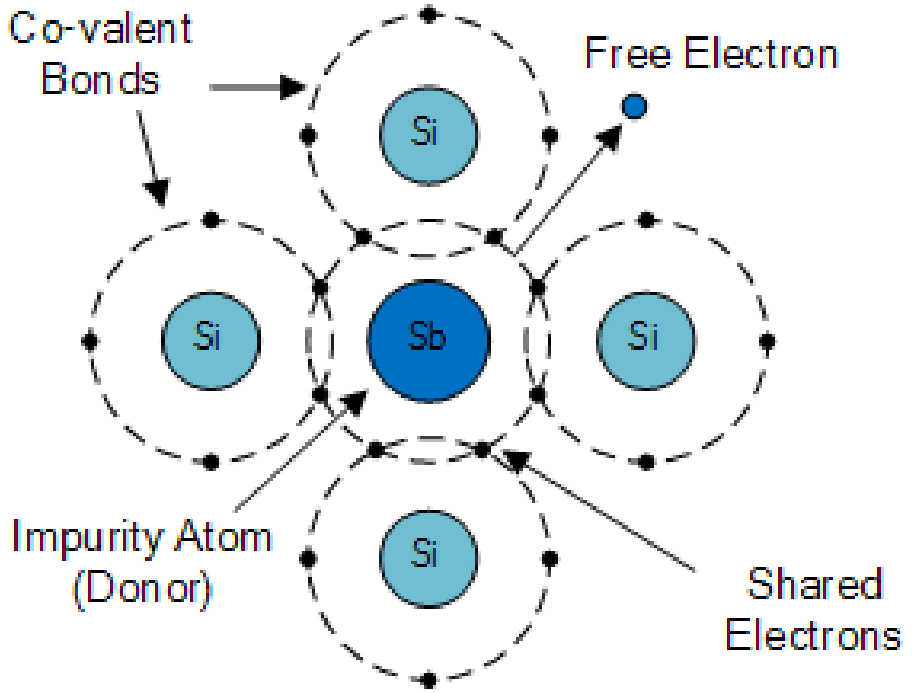


P-Type
Semiconductor

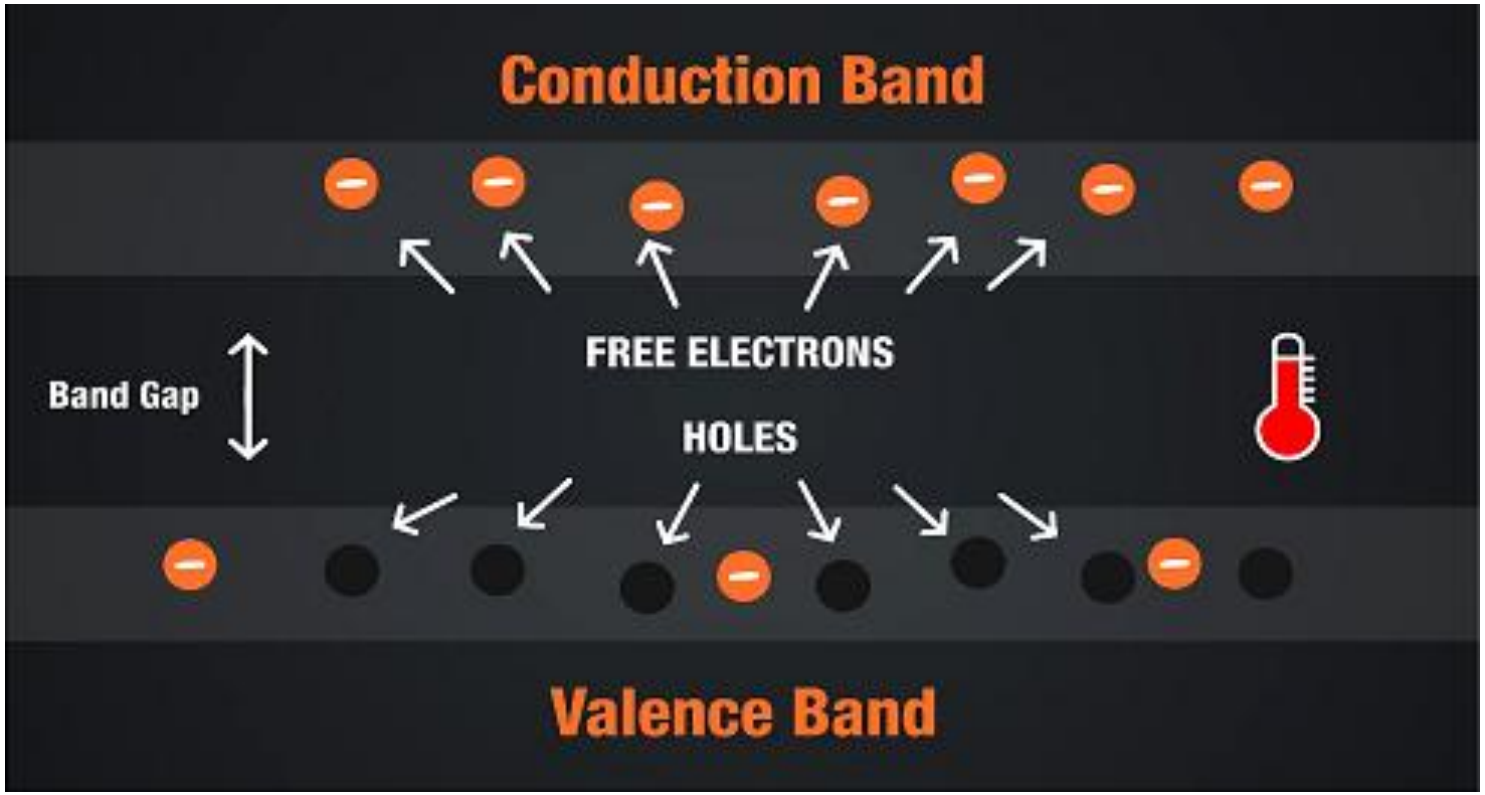
An Antimony Atom,
Atomic number = "51"



Antimony atom showing 5 electrons in its outer valence shell (o)

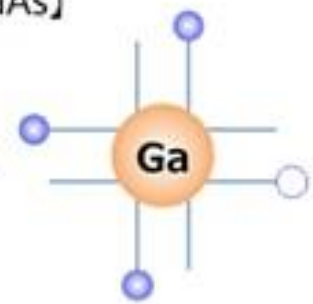


N-Type Semiconductor


Conduction Band
FREE ELECTRONS
Band Gap
HOLES
Valence Band

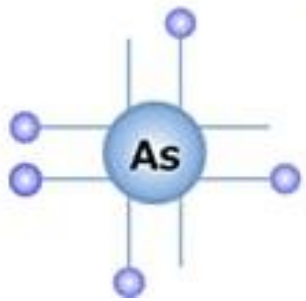
【Example of GaAs】

Gallium:
three valence
electrons

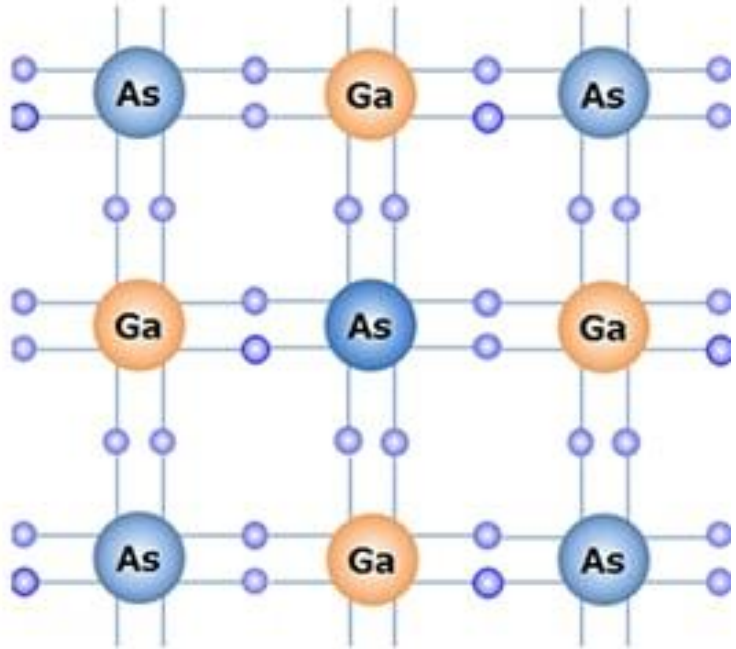


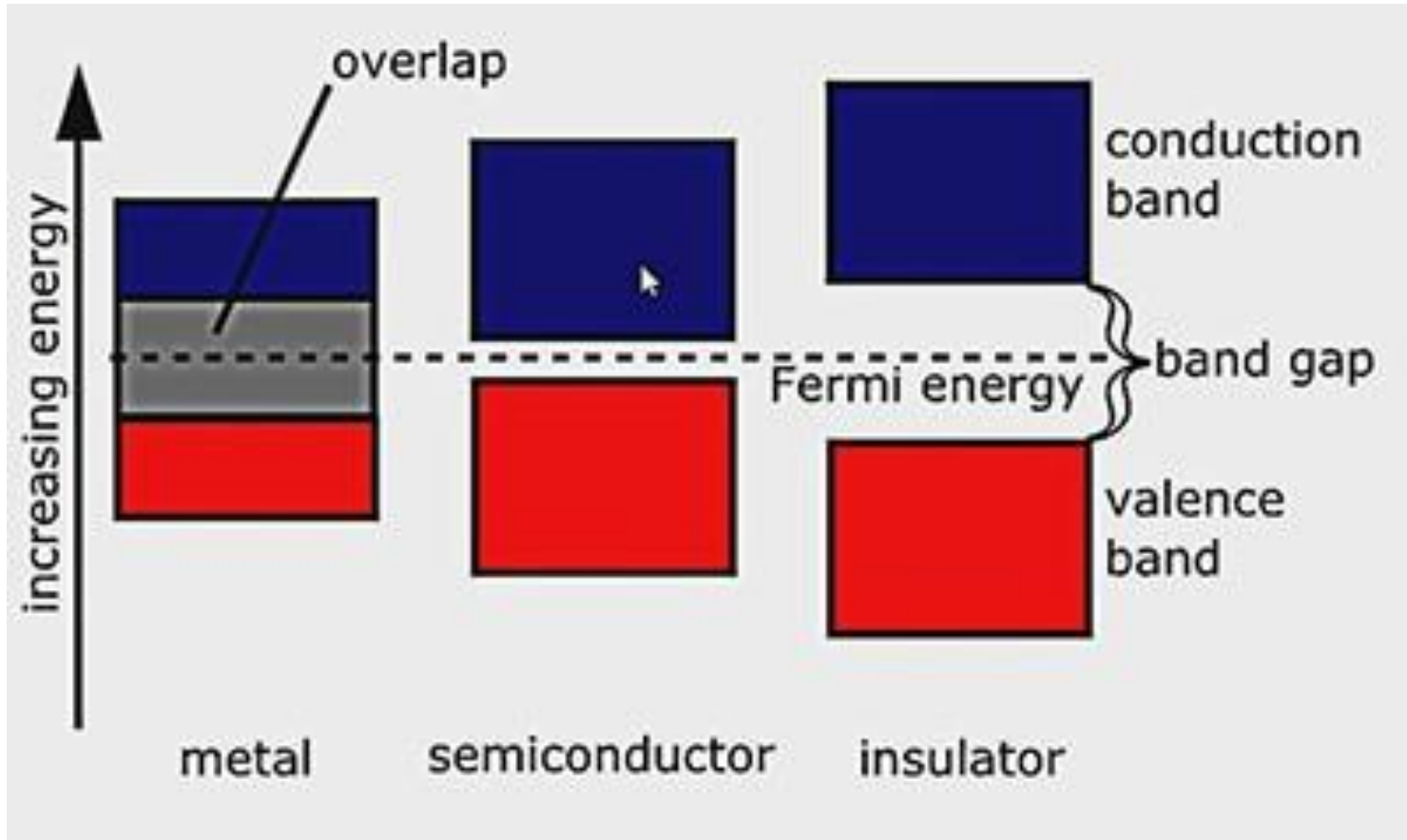
More gallium than arsenic
makes
p-type semiconductor.

Arsenic:
five valence
electrons

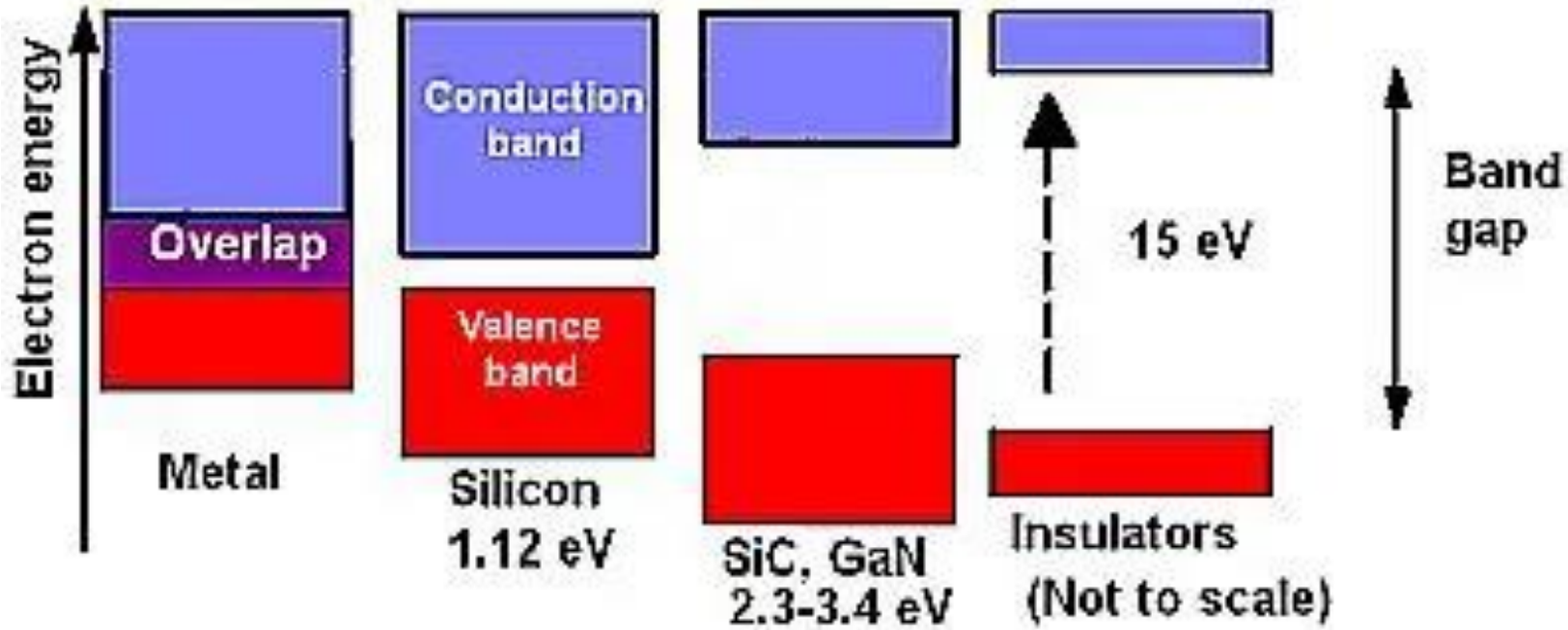


More arsenic than gallium
makes
n-type semiconductor.

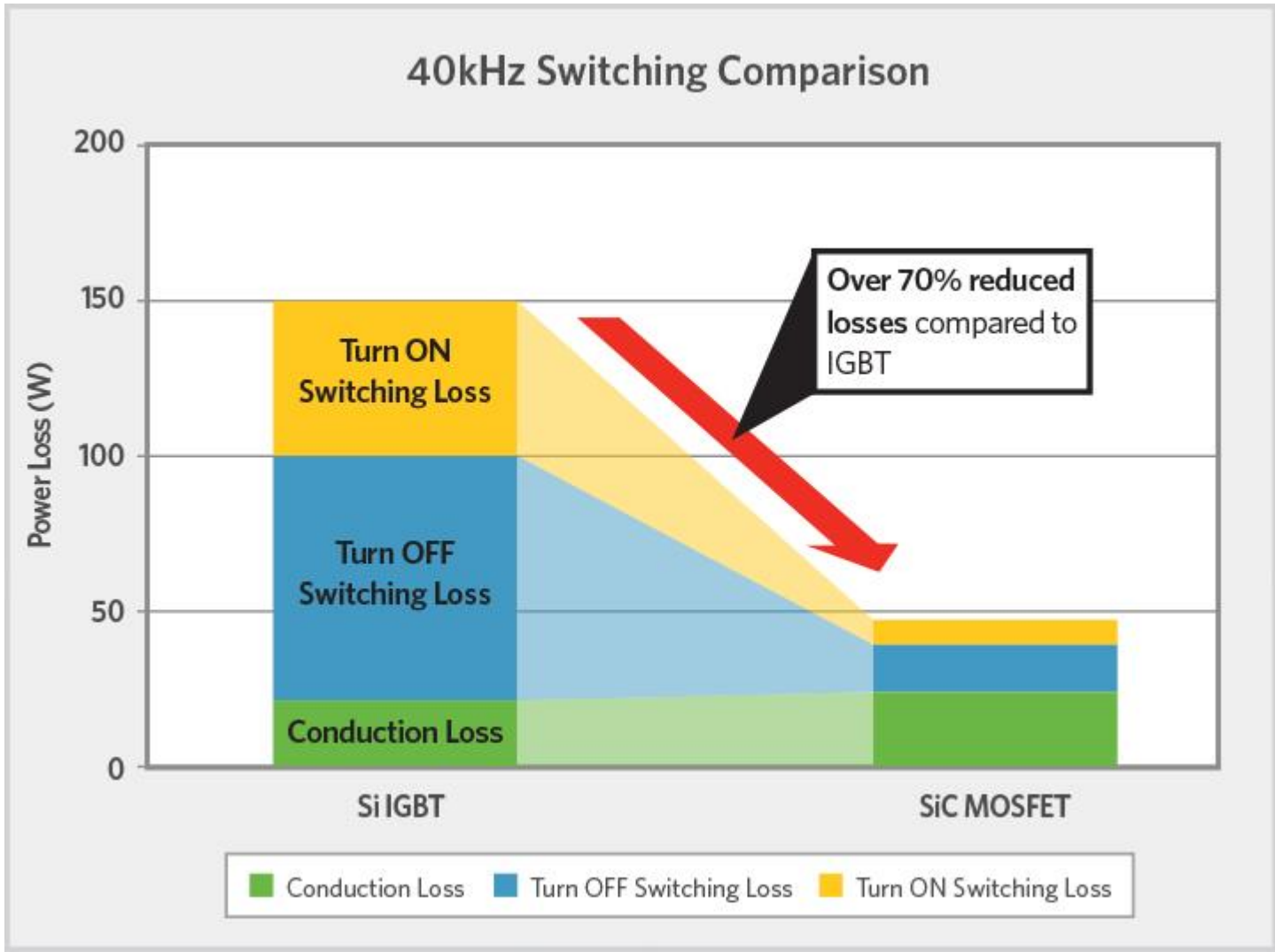


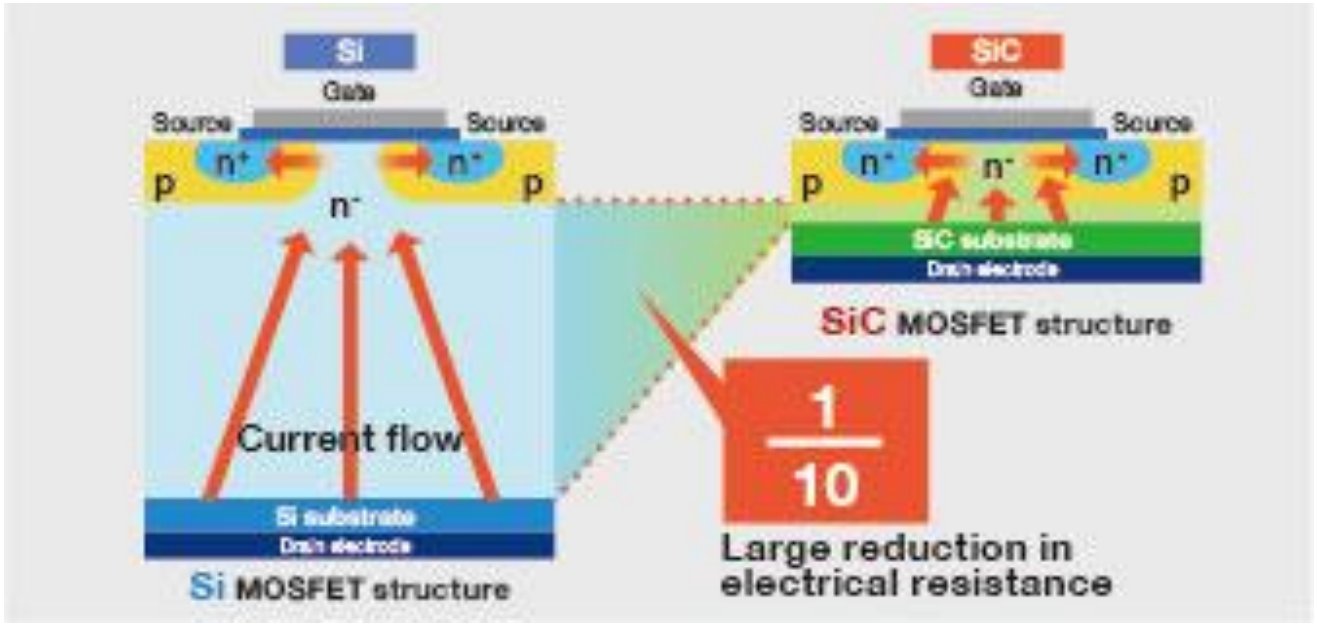

overlap
increasing energy
conduction band
band gap
Fermi energy
valence band
metal
semiconductor
insulator

Sizing up band gaps



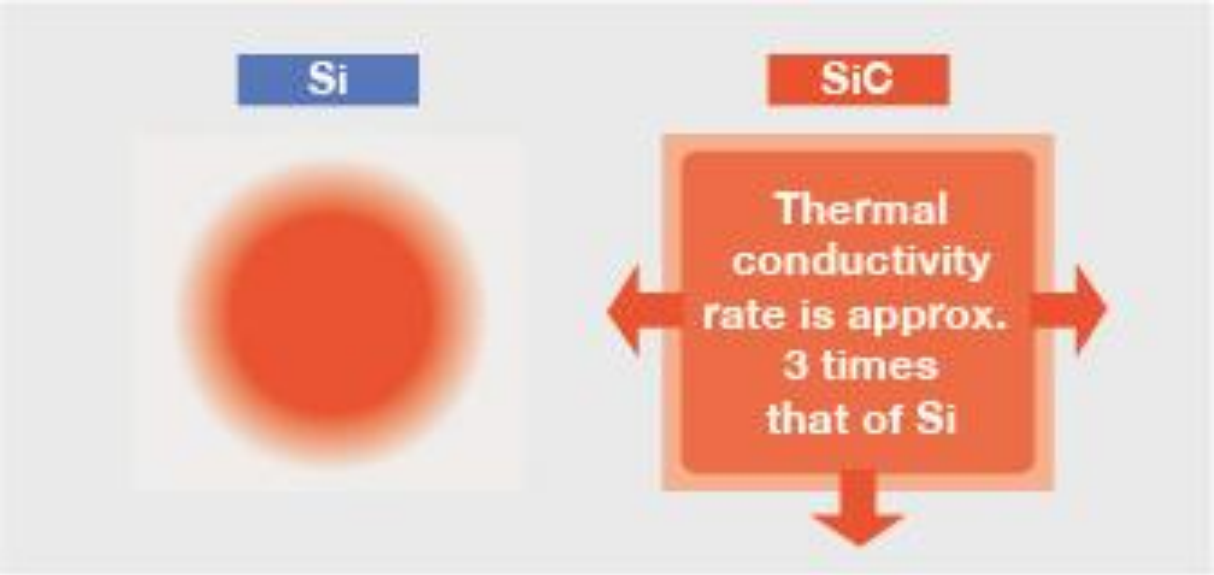
The higher Band Gap energy is going to increase the destroying temprature value of the electron flow channel. For example, while this value is 250-300 C for the conventional Si Power switches, it is 600-800 C for SiC power switches. So, the SiC power switches operate in higher temprature values safely. That flexibility enables to increase the speed of switching frequency thanks to higher thermal limits. The higher frequency levels decrease the size of passive circuit elements as well. In addition, the cost of circuit elements reduces to lower values and the volume is used effective thanks to small size elements.


40kHz Switching Comparison
200
150
100
50
0
Power Loss (W)
Turn ON Switching Loss
Turn OFF Switching Loss
Conduction Loss
Over 70% reduced losses compared to IGBT
Si IGBT
SiC MOSFET
Conduction Loss
Turn OFF Switching Loss
Turn ON Switching Loss



The SiC semi conducter has superior performance with resistance to electric field. It enables us to constitue more thiny layers. For this reason, the cross section area of it diminishes to lower value considerably. It means that conductance resistance R_{DS} will reduce to the its 1/10 value.

Furhermore, the power losses of switches will reduce to lower values as depended on the operation mode of power switch.



The higher heat transfer ratio enables us to reduce the size of the sink.

And also, it makes the operation at higher frequency levels easy and safe.

Characteristics of Silicon / SiC /GaN

Substance		Si	SiC	GaN
Bandgap	eV	1.1	3.3	3.4
Electron Mobility	cm^2/Vs	1350	700	1500
Electric Field for Breakdown	MV/cm	0.3	3.0	3.3

SiC and GaN have similiar characteristics based on bandgap anergy level and electric field breakdown. But GaN presents superior performance at electron mobility that reduces the time of on and off states. For this reason, it is possible to achieve higher frequency levels compared to conventional Si and SiC power switches.

REPLACING SI with SIC

Some changes are needed at driver circuits

Mosfet gate voltage must be increased to 20 V from 15 V.

Since the system permits to operate at higher frequency levels, If the isolation is used, the speed of circuits/devices must be rearranged.

Protection measurements in the drive circuits must be increased for keeping threshold voltage a bit lower to avoid self conduction mode.

KAYNAKLAR

1. Comparison Between Competing Requirements of
GaN and SiC Family of Power Switching Devices, IOP conference
2.Mitsubishi coorporation, 2019
3. Fırat Deveci.com