功率半导体器件与功率集成电路
——现状及展望

电子科技大学

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功率半导体概述－定义

Power → **Power Management**

- Power Magnification
- Power Management
- Voltage Conversion
- Current Conversion
- Frequency Conversion

Semiconductor → **Semiconductor Devices**

- Power Rectifiers
- Power Switches
- Power ICs

System → **Power Integration**

- SoC+PMU
  Power Management
- Power System on
  Chip (PSoC)

Traditional power semiconductor devices

Power Semiconductor Devices

- **Power Rectifier**
- **Power Bipolar Transistor**
- **Thyristor**

Industry Application

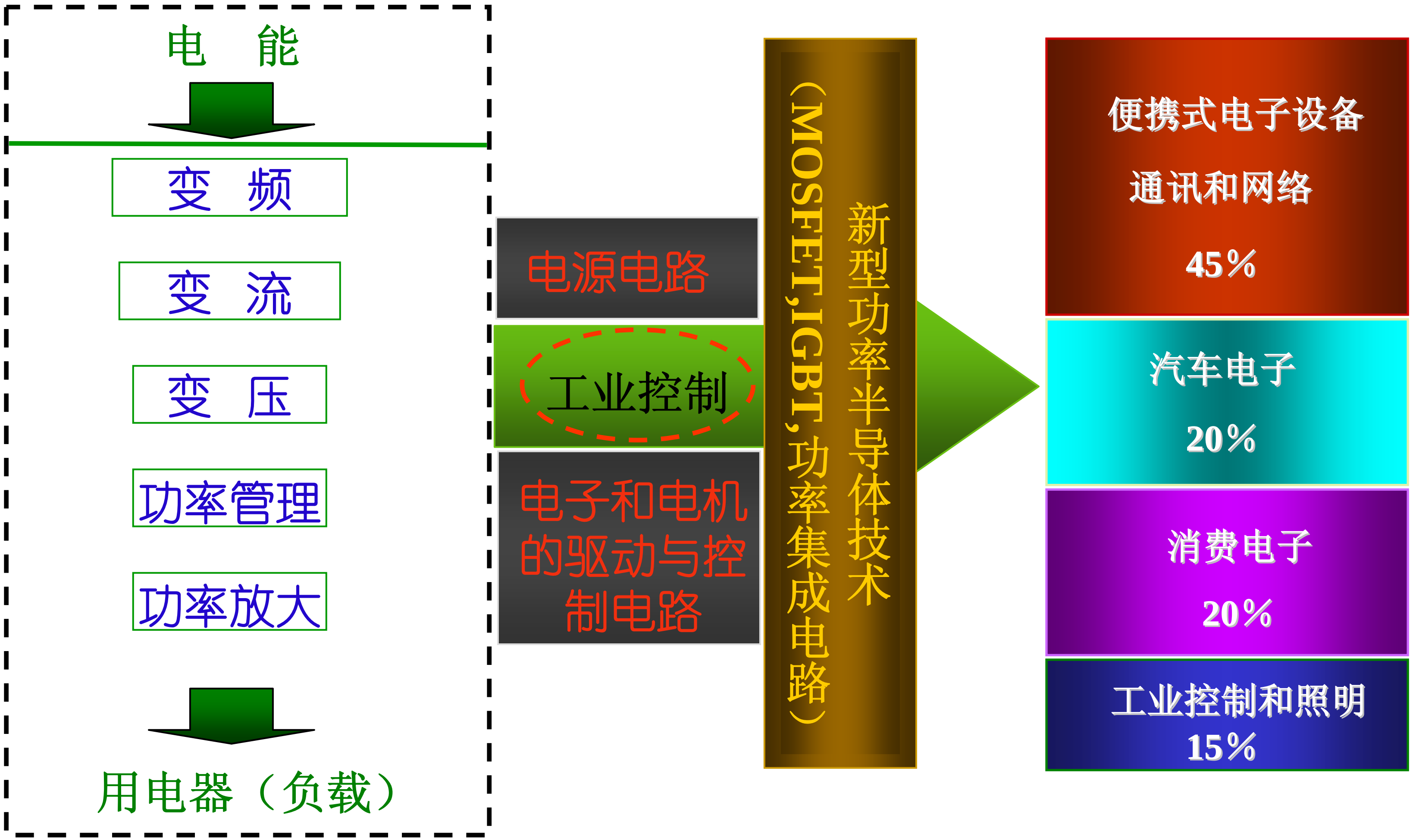
Modern power semiconductor devices

Modern Power Semiconductor Devices

- Power MOSFET
- IGBT
- IGCT
- Power IC

Applications

功率半导体是一门更好利用电能的科学，由于新型功率半导体技术的发展，它的应用范围从工业控制延伸到信息电子



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2.3　功率半导体集成技术发展

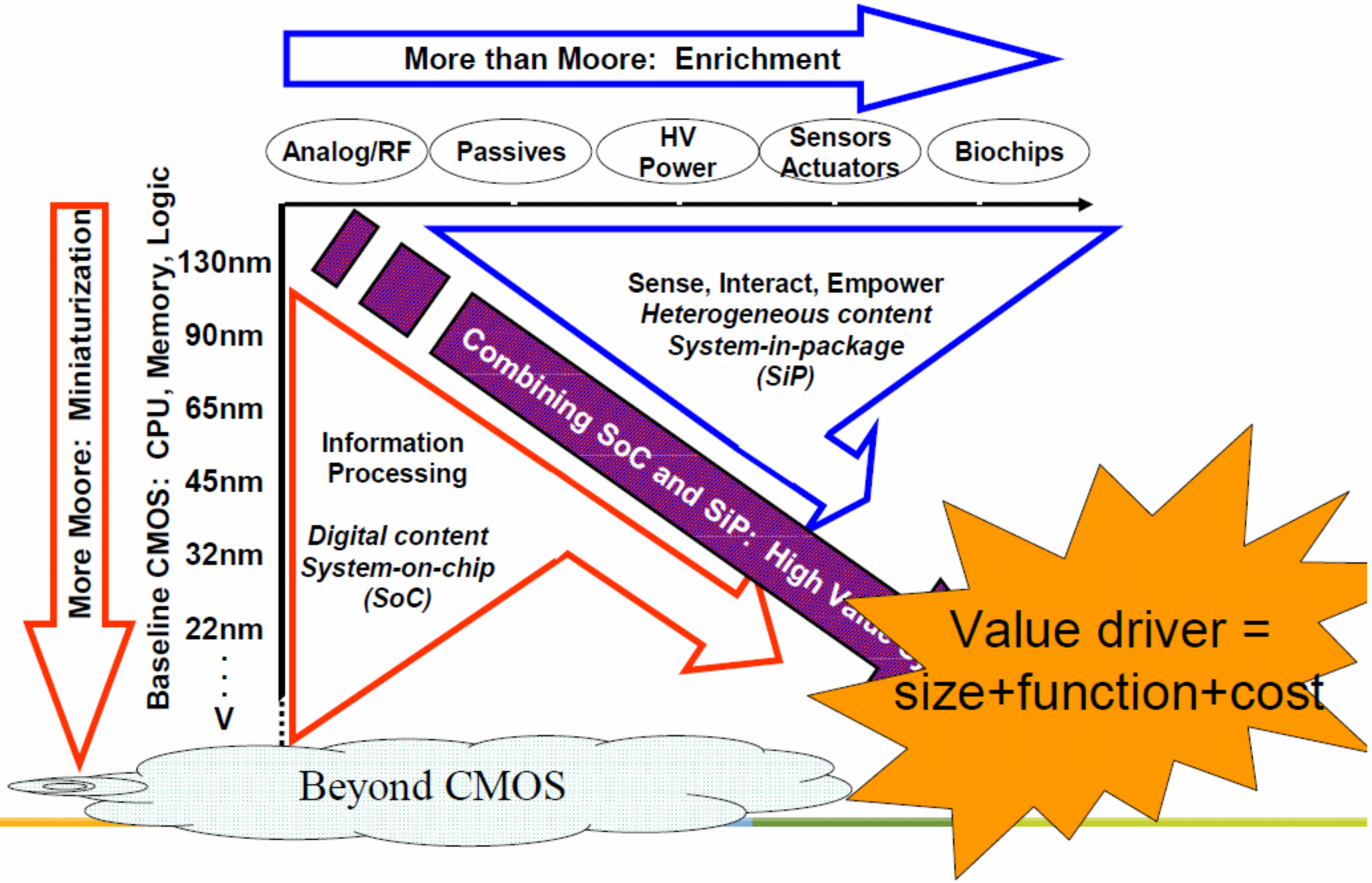
2.1　半导体技术发展蓝图

（1）More Moore

（2）More than Moore

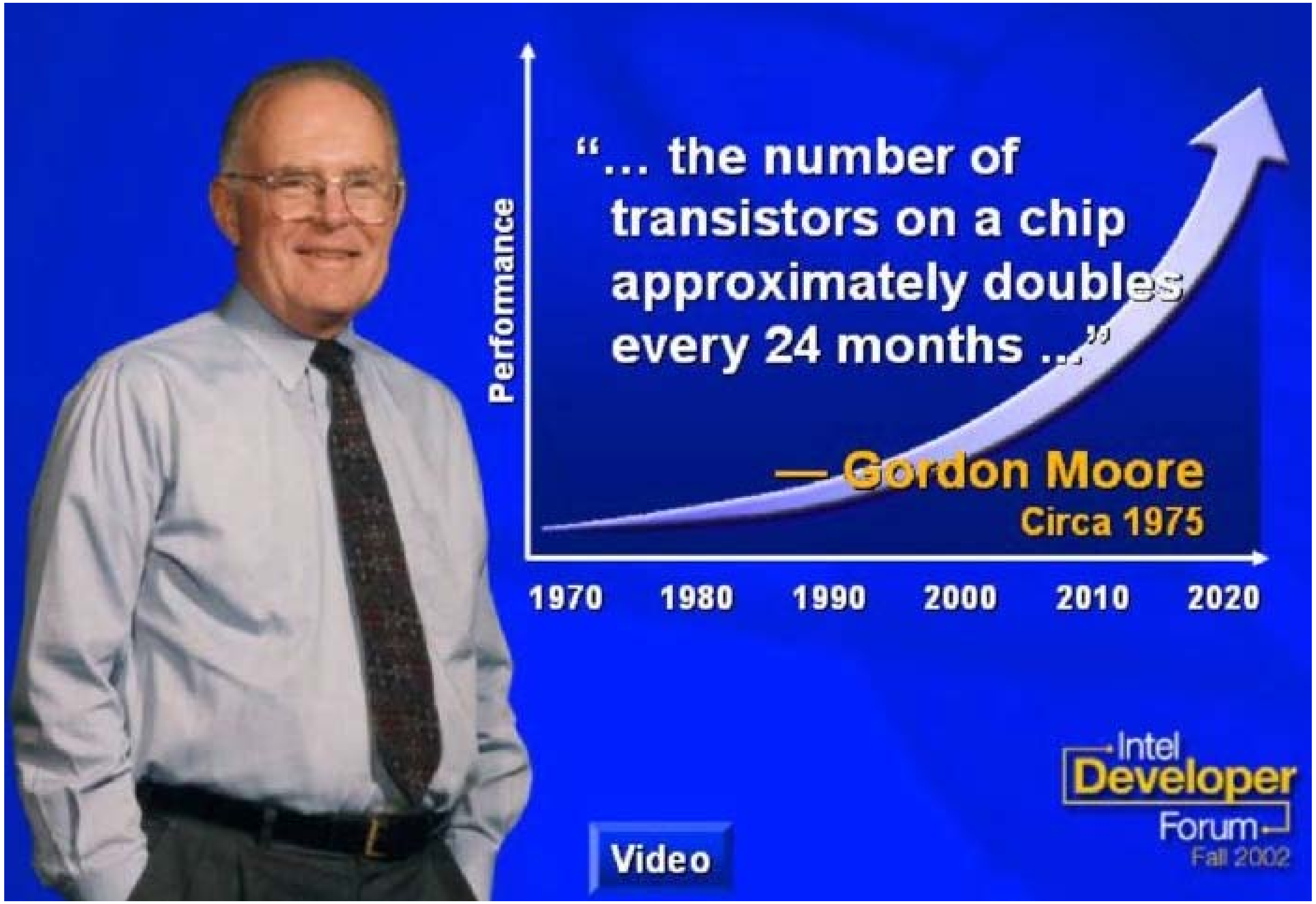
2.1 半导体技术发展蓝图

The New Landscape of Nanoelectronics Tech: Moore's Law & More than Moore

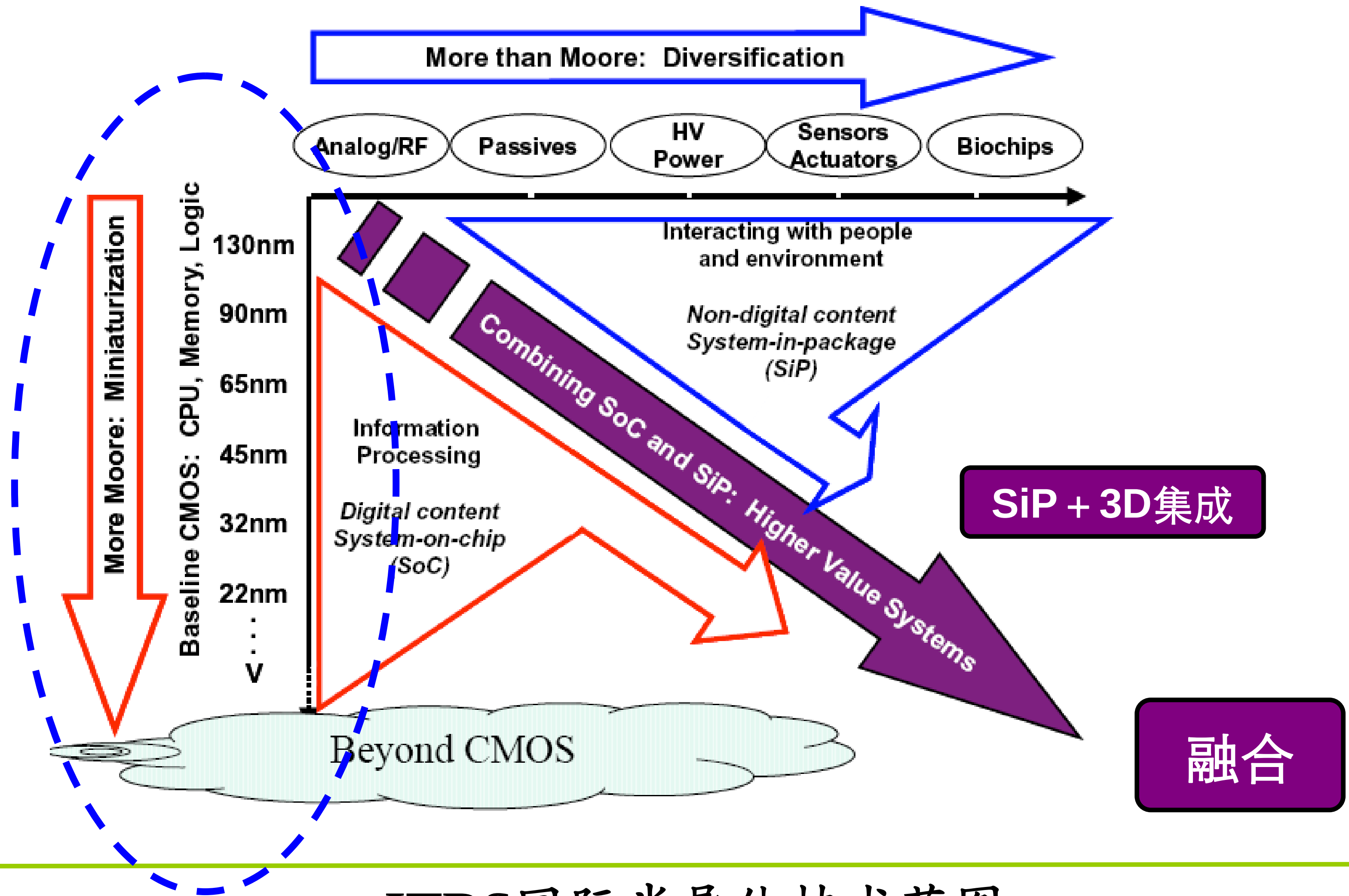


2.1 半导体技术发展蓝图

The Moore's Law

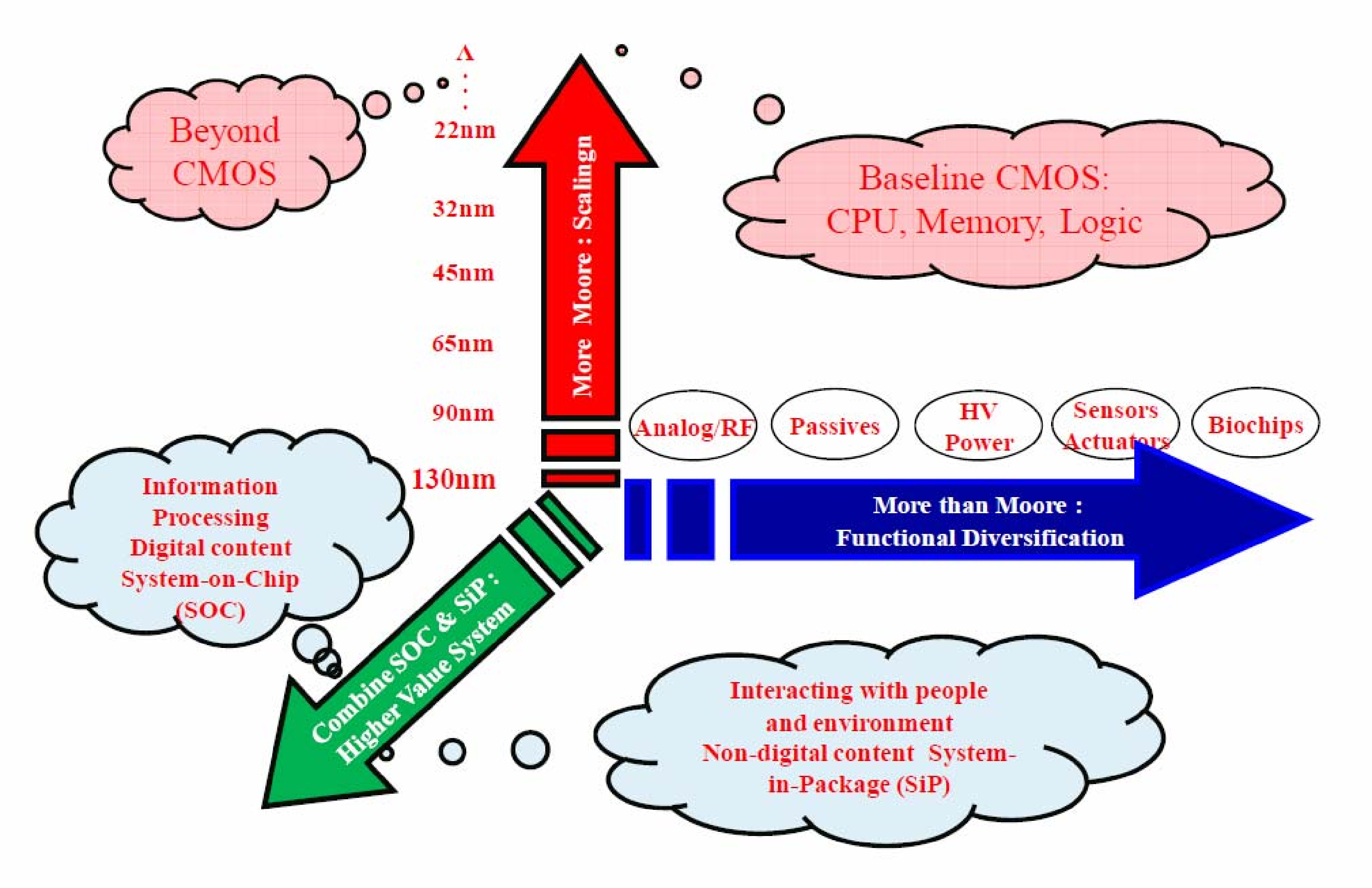


2.1 半导体技术发展蓝图



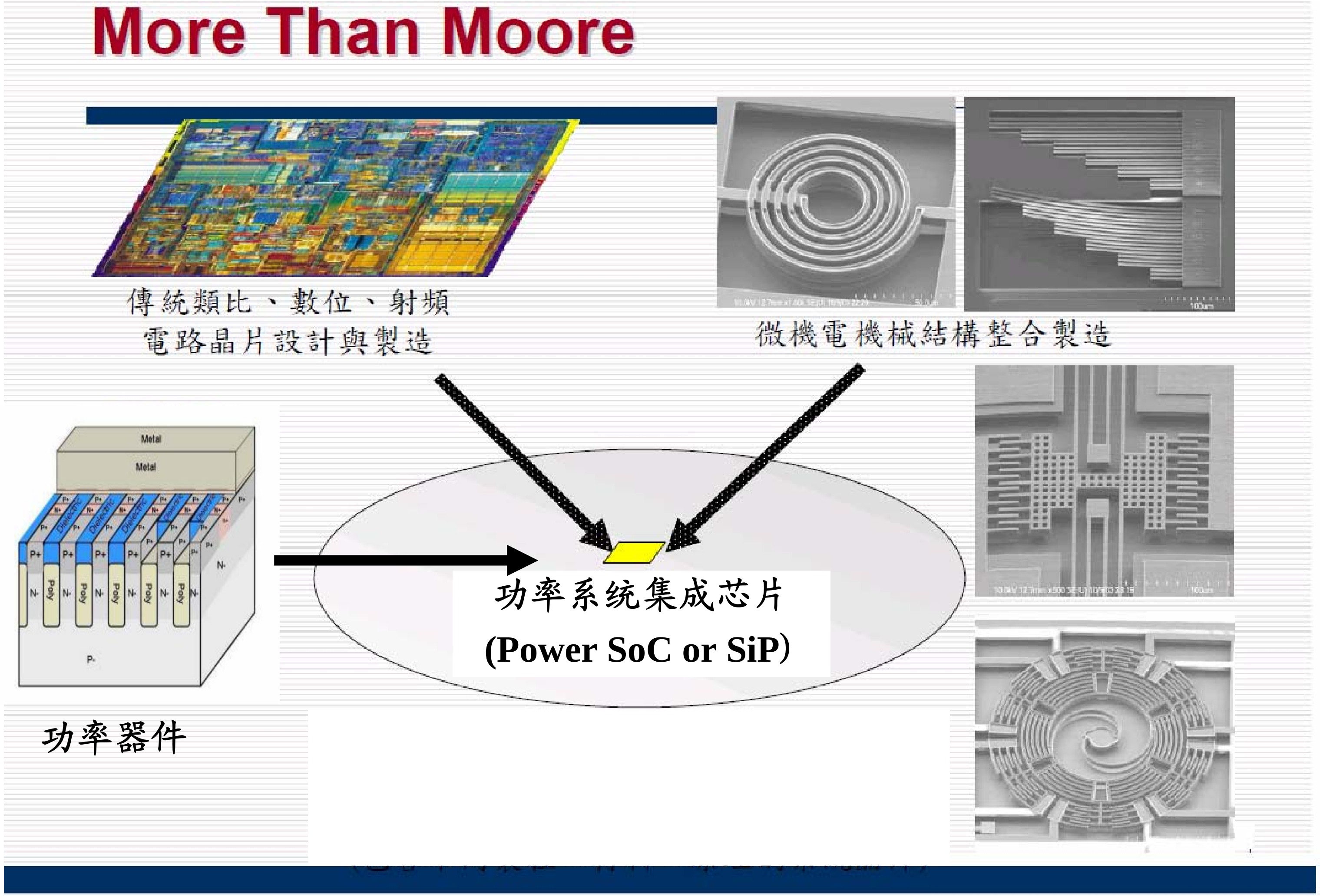
ITRS国际半导体技术蓝图

2.1 半导体技术发展蓝图



ITRS国际半导体技术蓝图

More Than Moore



2.2 功率半导体器件发展趋势

(1) 新结构（新机理）

(2) 新材料

(3) 更多功能的集成

Power Rectifier

- New material
- New Structure
- New Mechanism

Power Rectifier Based on New Material

- GaAs SBD
- SiC Rectifier
- GaN SBD

Power Rectifier Based on New Structure

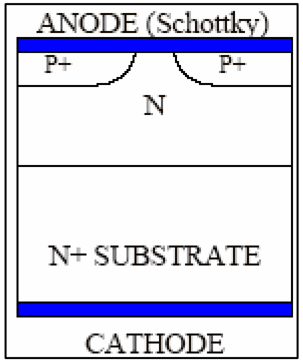
JBS、MPS、TMBS、TMPS

Merge the advantages of PiN diode and schottky barrier junction.

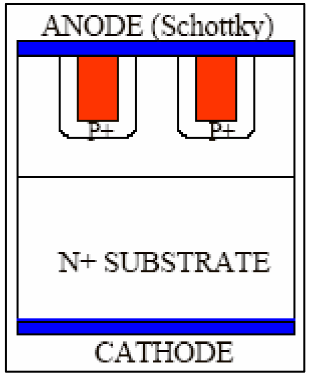
SSD、SPEED、SFD、ESD、BJD

Optimize the exceeding carriers and their extracting path.

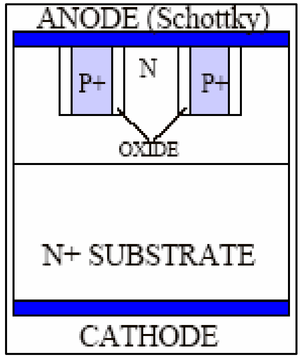
JBS/MPS Series



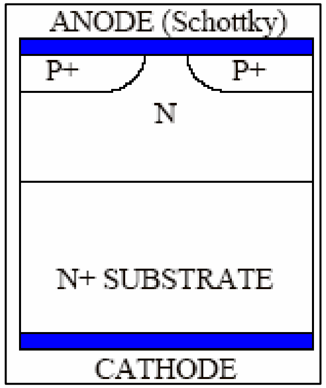
Si JBS Rectifier (1980)



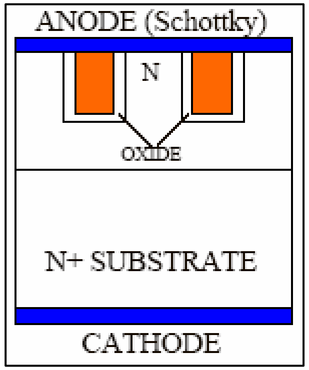
Si TJBS Rectifier (1990)



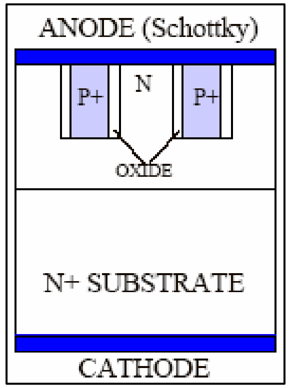
Si TSOX JBS Rectifier (1998)



Si MPS Rectifier (1987)

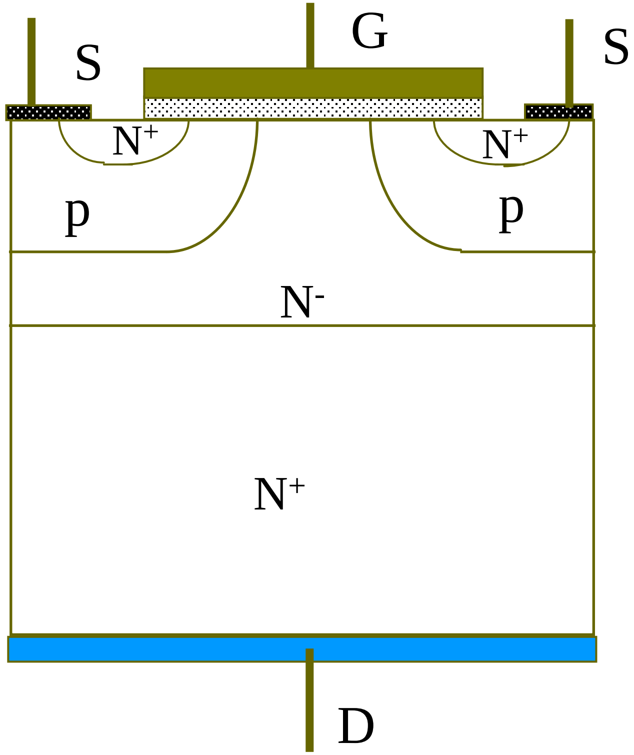


Si TMPS Rectifier (1990)



Si TSOX MPS Rectifier (1998)

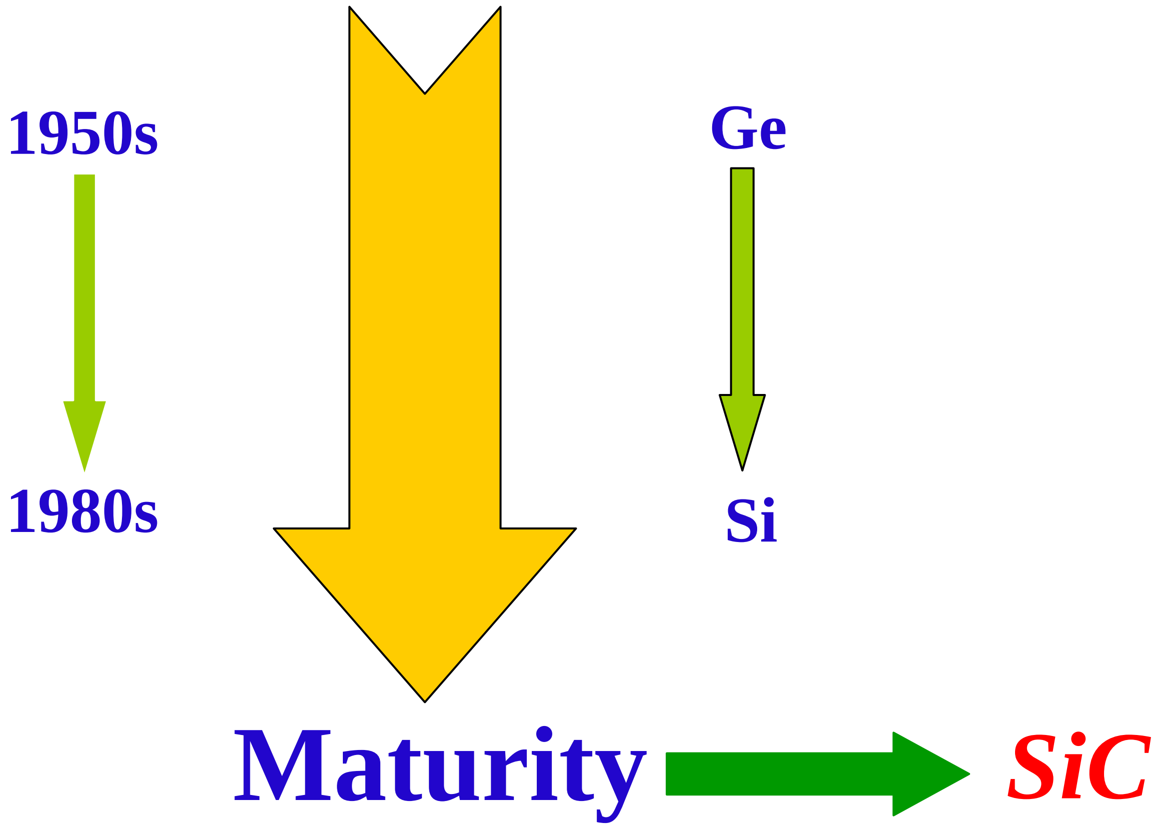
Synchronous Rectifier



Si DMOS Synchronous rectifier (SR)

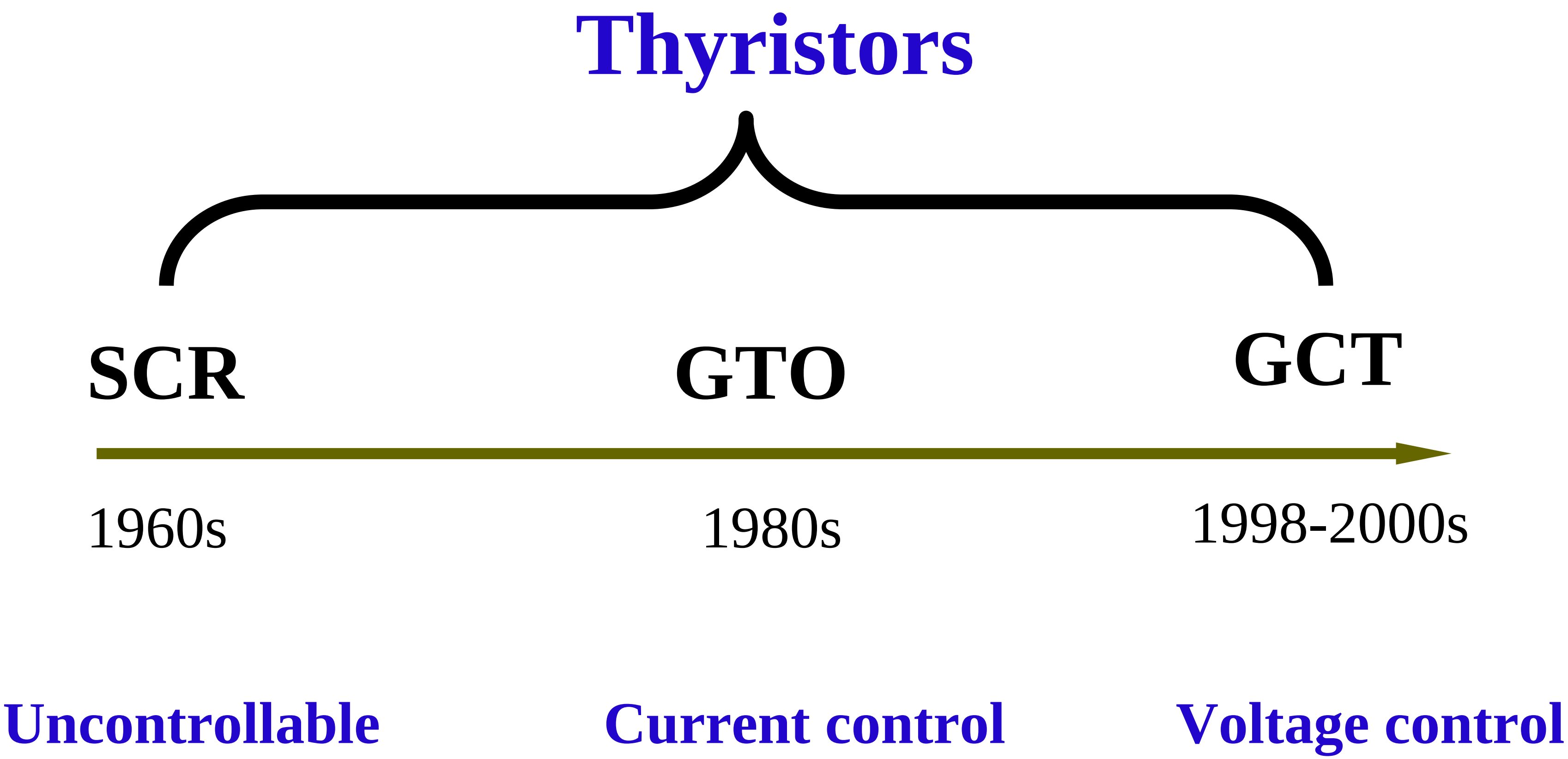
功率双极晶体管

Power Bipolar Transistor



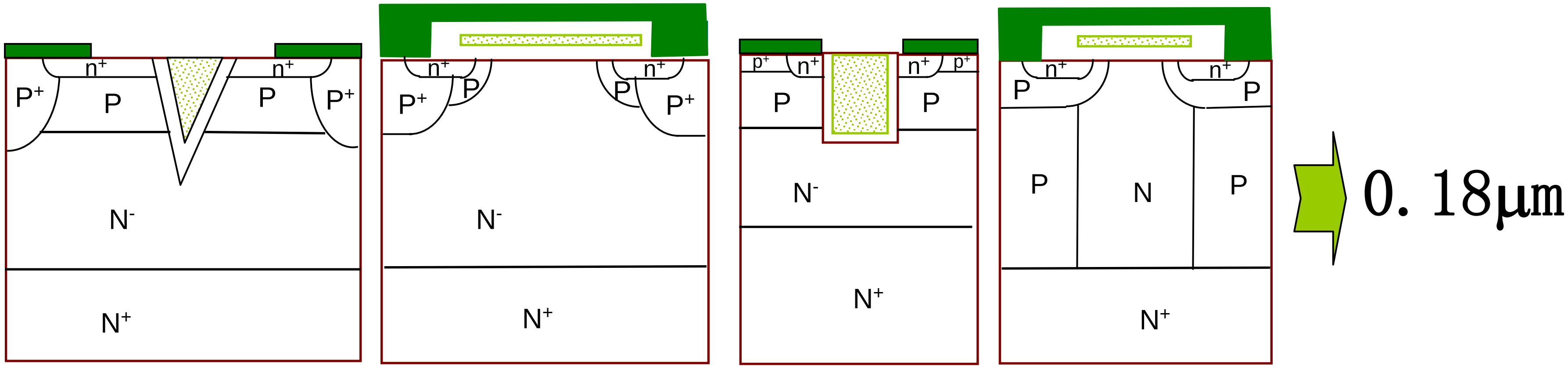
GTR: 600A/150V、400A/550V、50A/1000V

Thyristor



Thyristors
SCR
GTO
GCT
1960s
1980s
1998-2000s
Uncontrollable
Current control
Voltage control

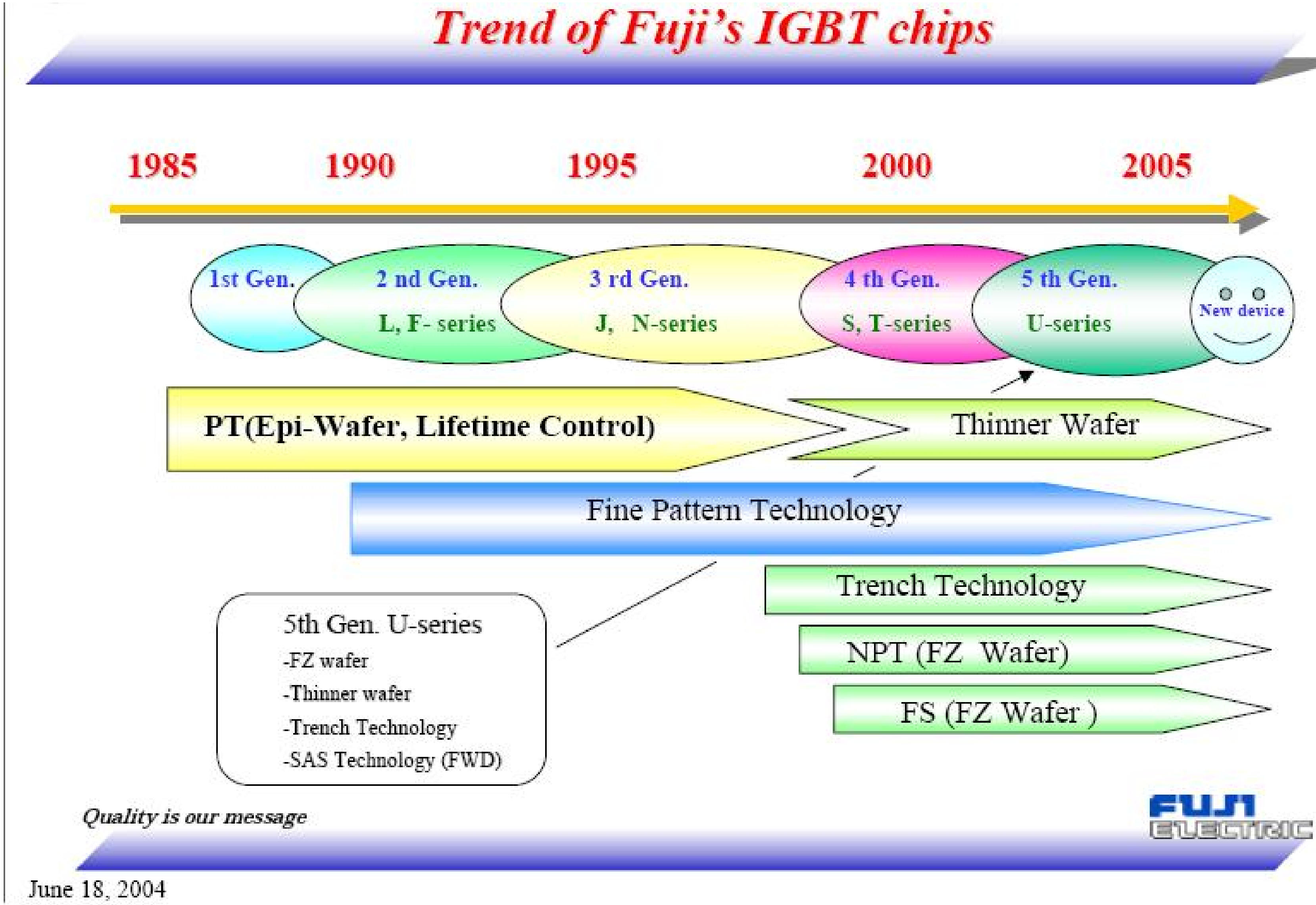
Power MOSFET



40 µ m	20 µ m	6 µm	
VVMOS	**VDMOS**	**Trench MOSFET**	**Super Junction**
1975	1980	1990	1997

•10 µ m to VDSM design rule: 120M Cells/inch^2(Gen–8) HEXFET)
•60 V device: 7 mΩ-cm^2 to 0.75 mΩ-cm^2(normal structure)

IGBT

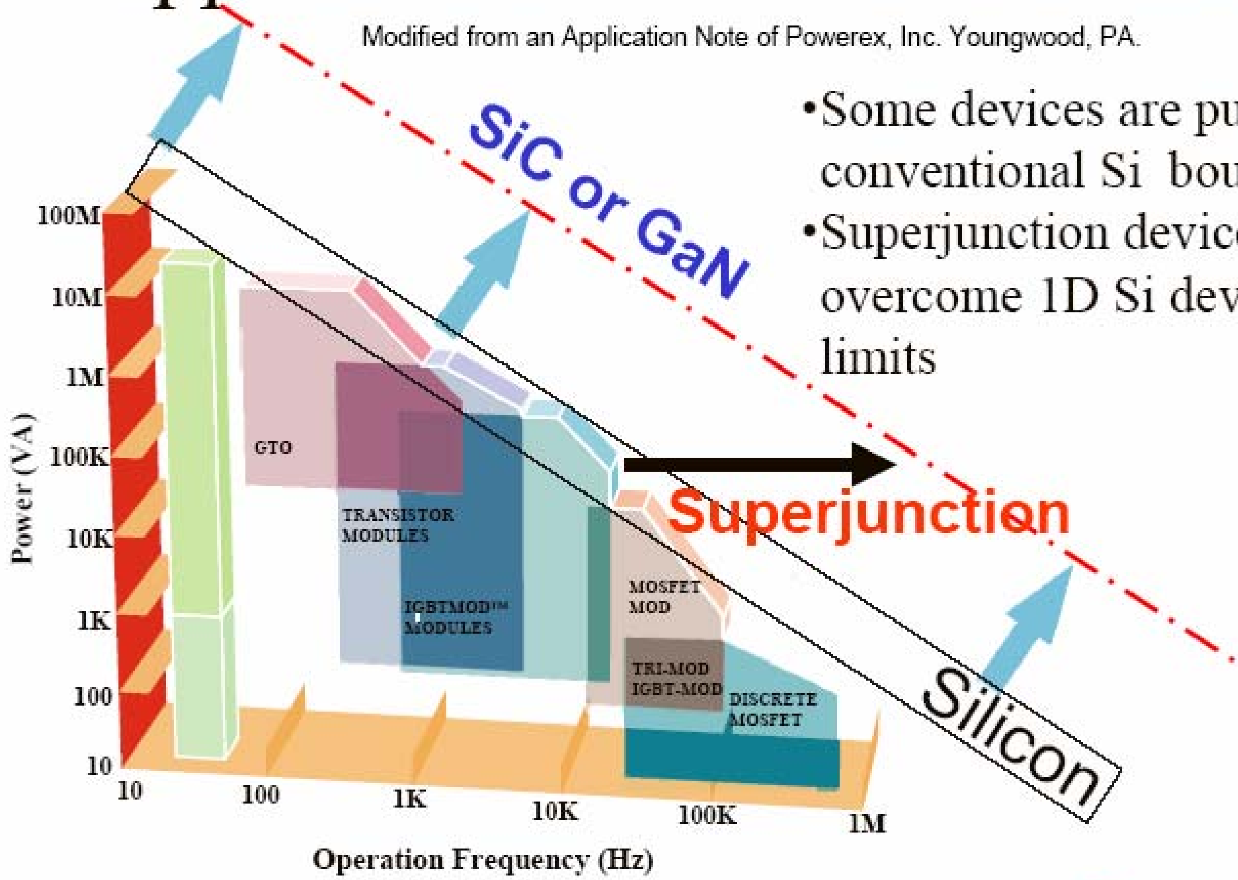


Trend of Fuji's IGBT chips
1985
1990
1995
2000
2005
1st Gen.
2 nd Gen.
L, F- series
3 rd Gen.
J, N-series
4 th Gen.
S, T-series
5 th Gen.
U-series
New device
PT(Epi-Wafer, Lifetime Control)
Thinner Wafer
Fine Pattern Technology
Trench Technology
NPT (FZ Wafer)
FS (FZ Wafer)
5th Gen. U-series
-FZ wafer
-Thinner wafer
-Trench Technology
-SAS Technology (FWD)
Quality is our message
FUJI ELECTRIC
June 18, 2004

新材料－宽禁带半导体

Applications of Power Devices

Modified from an Application Note of Powerex, Inc. Youngwood, PA.



- Some devices are pushing conventional Si boundary
- Superjunction devices overcome 1D Si device limits

2.3 功率集成技术的发展

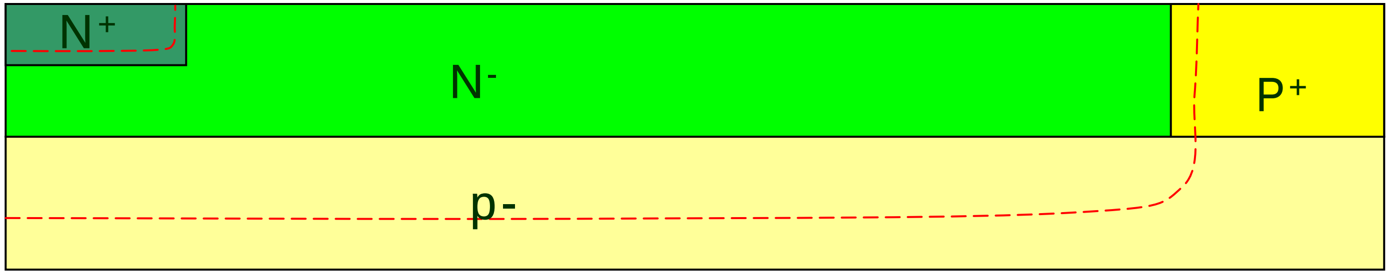
（1）可集成器件的发展

（2）BCD工艺集成技术

（3）Power SoC

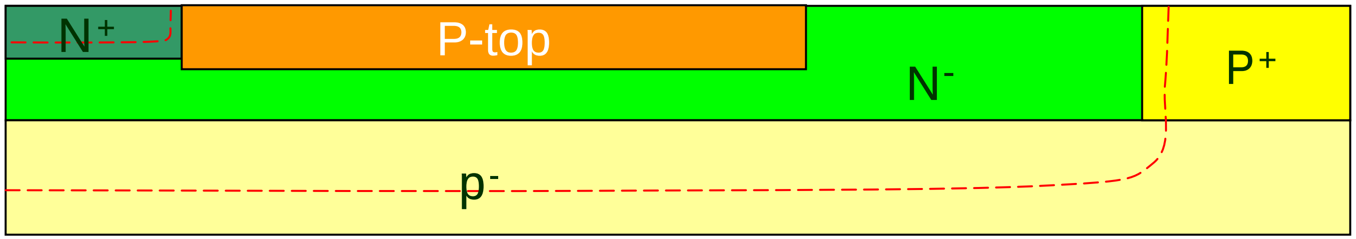
可集成器件的发展

$E_s < E_C$



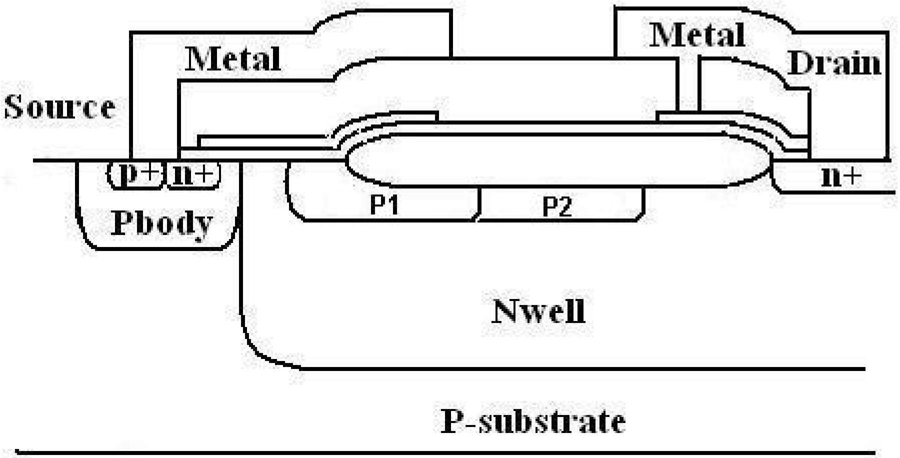
Single-Resurf

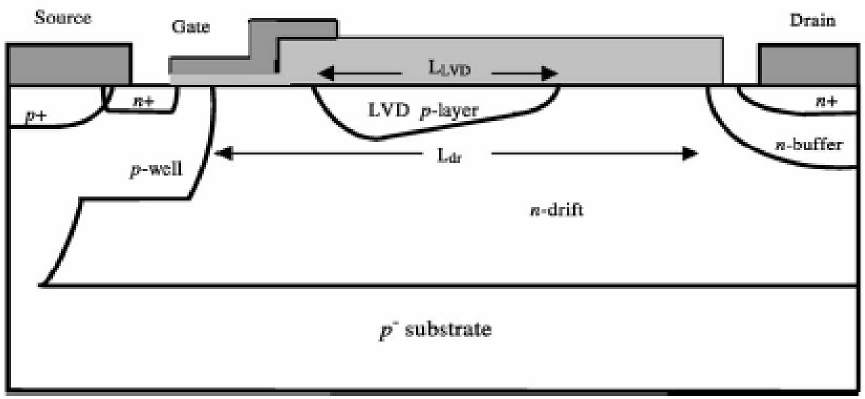
$E_s < E_C$

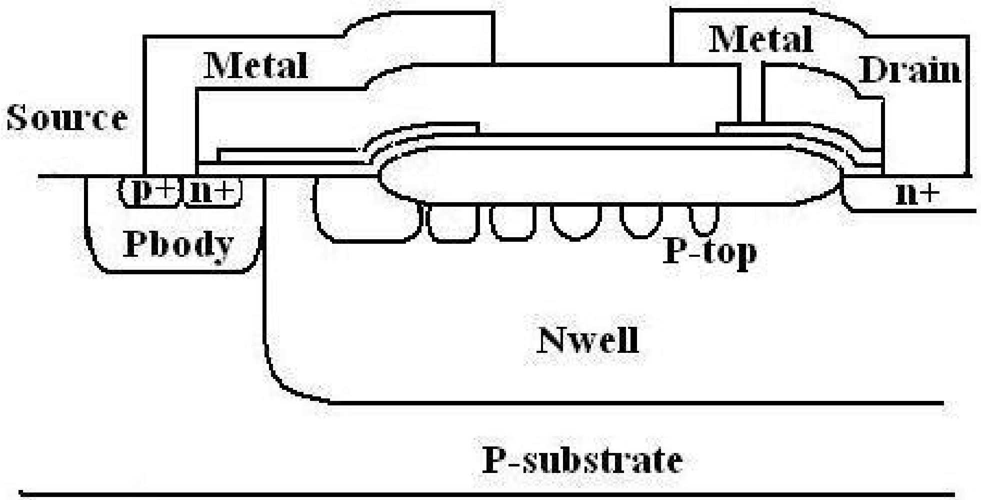


Double-Resurf

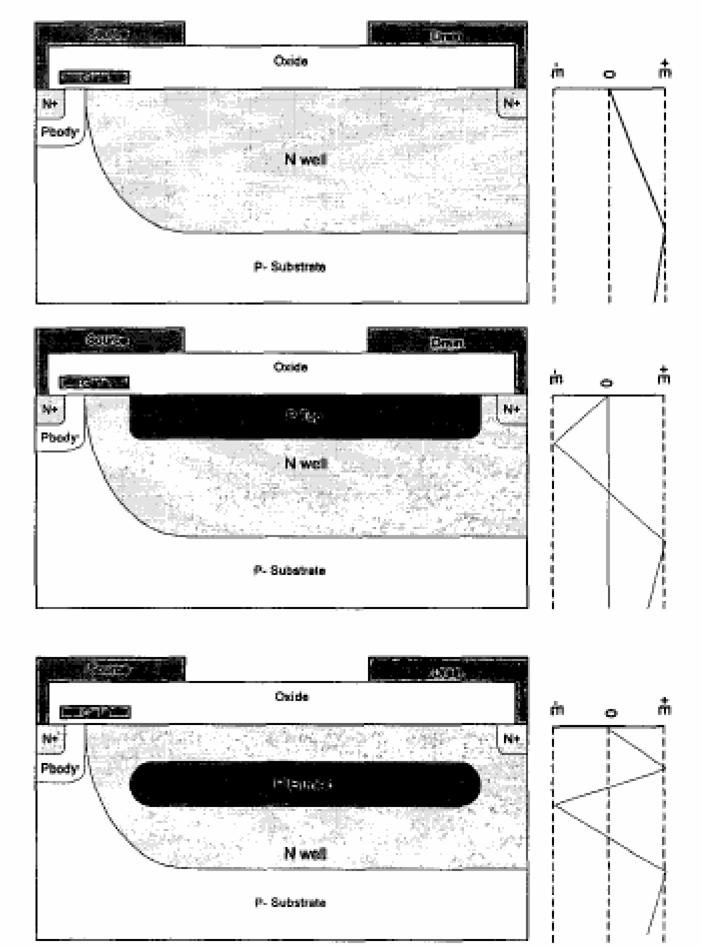
Double RESURF with Non-Uniform P-top



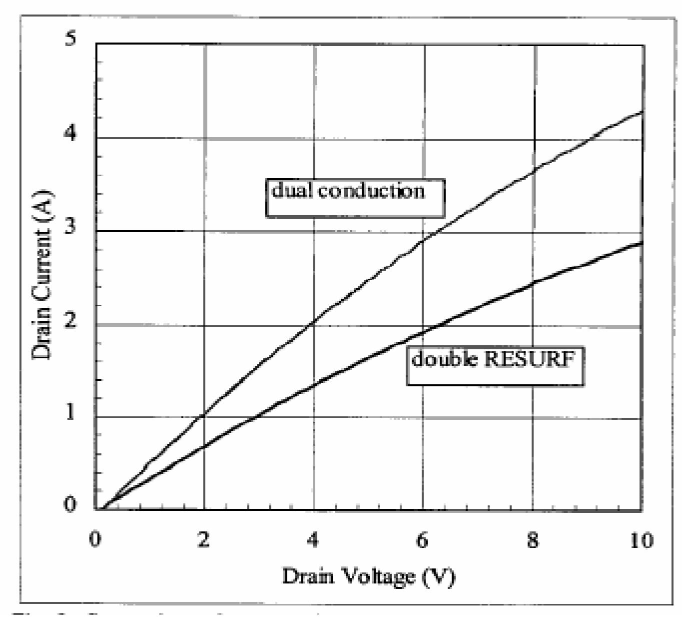




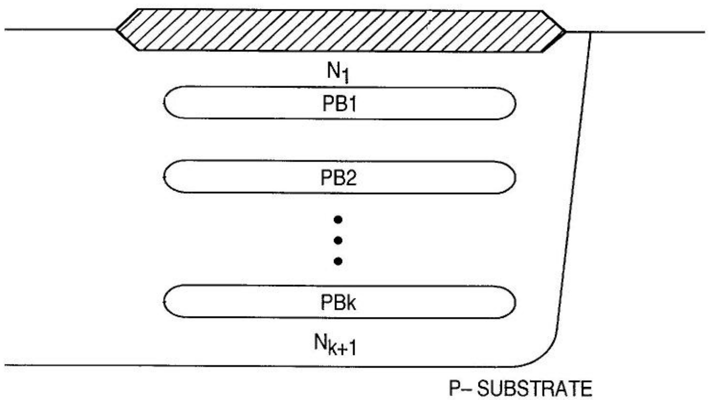
LDMOS with dual conduction paths

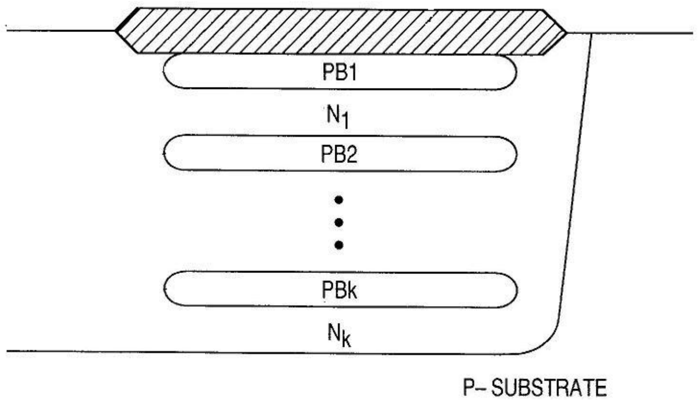


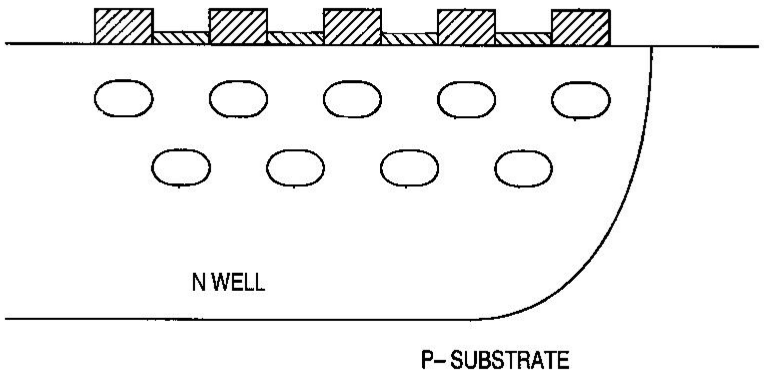
Z.Hossain, M.Imam, J.Fulton, and M.Tanaka, "Double RESURF 700V N-channel LDMOS with best-in-class on-resistance", in Proc. Int. ISPSD Conf., p.137 2002



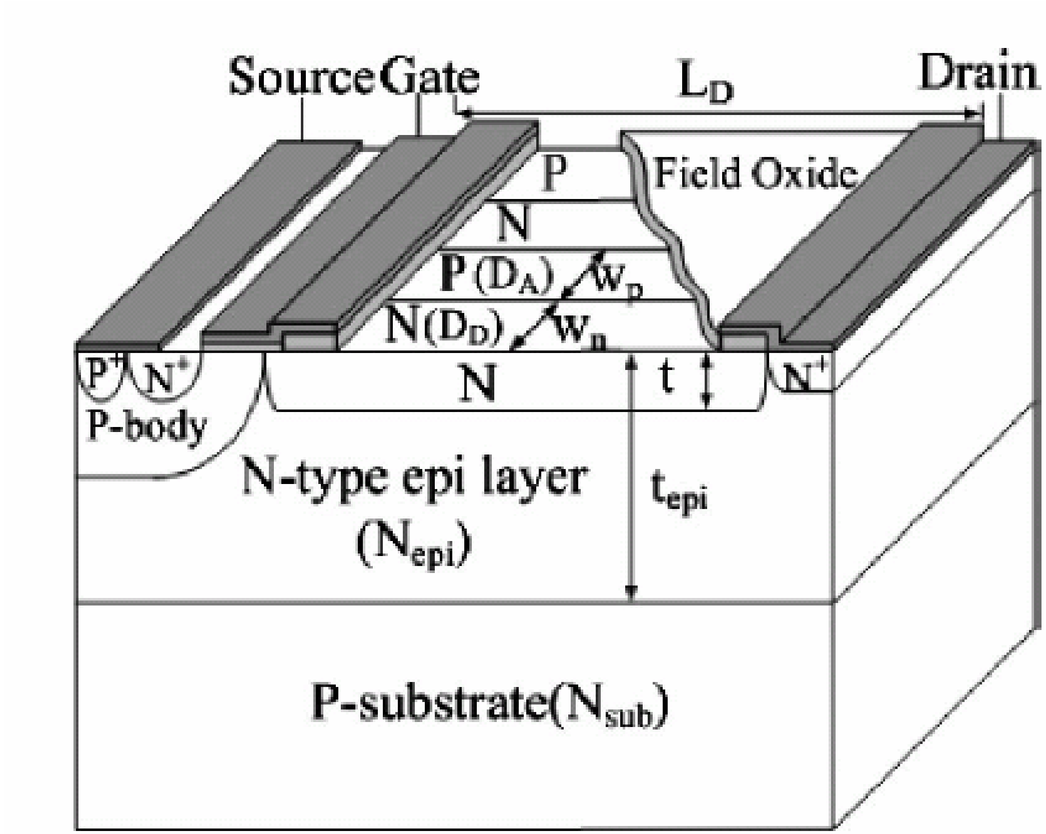
High-voltage transistor with multi-layer conduction region







3D RESURF



Bo Zhang, et. al., High-Voltage LDMOS With Charge-Balanced Surface Low On-Resistance Path Layer, ***IEEE ELECTRON DEVICE LETTERS***, VOL. 30, NO. 8, 2009

REBULF for bulk silicon lateral high-voltage devices

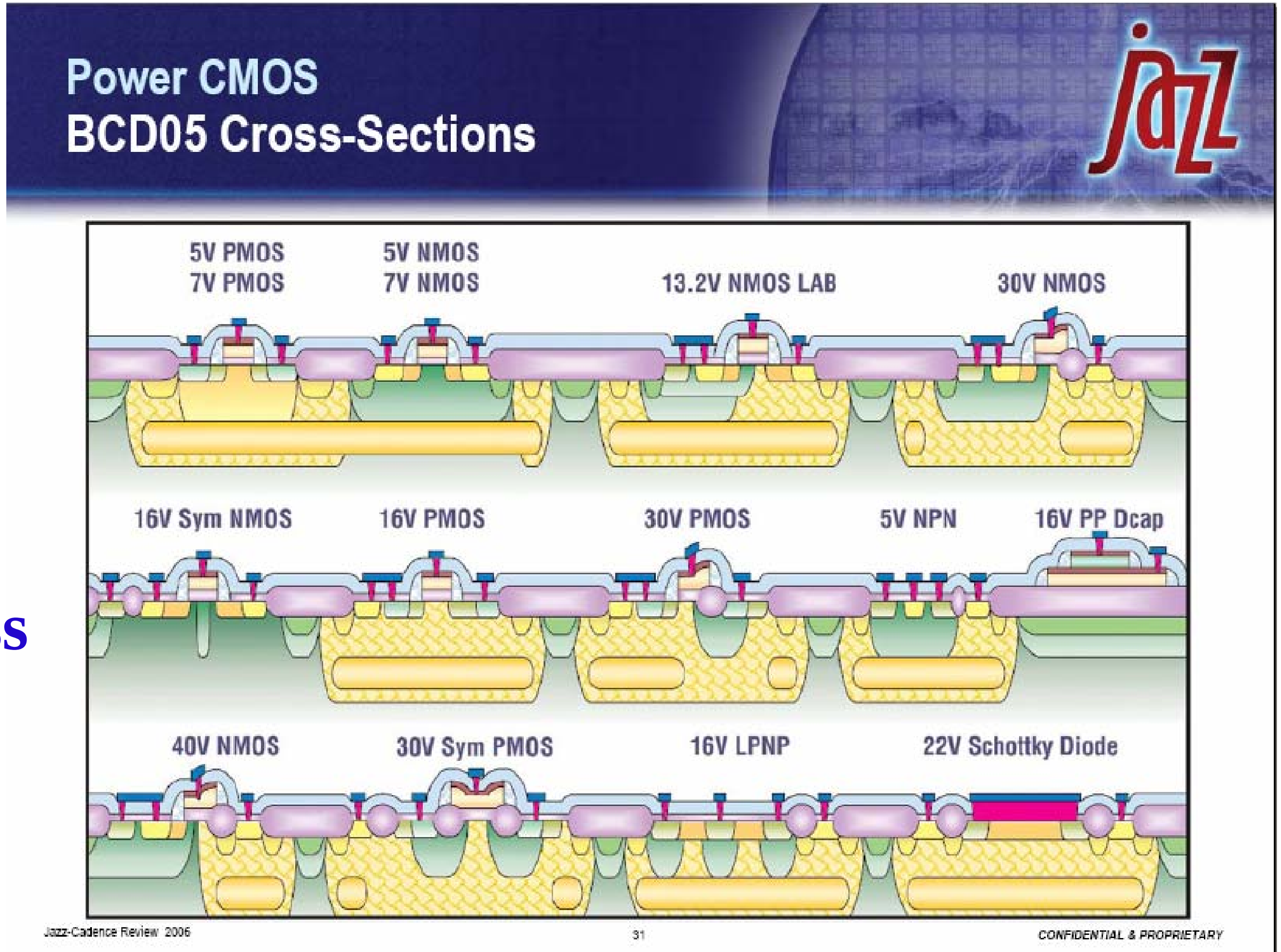
ENDIF for SOI lateral high-voltage devices

- **REBULF ----- Reduced Bulk Field**
- **ENDIF ----- ENhanced DIelectric layer Field**

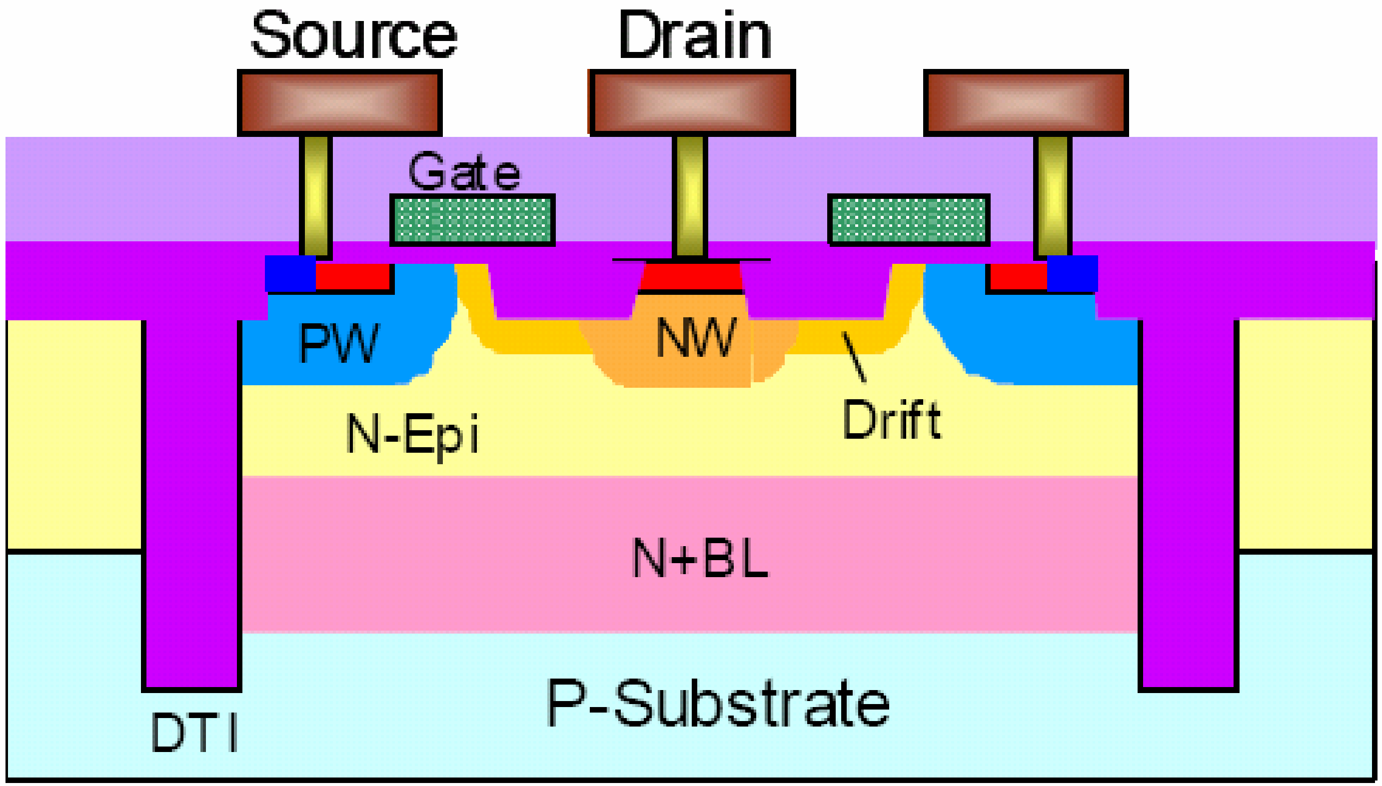
Bo Zhang, et. al., “Field Enhancement for Dielectric Layer of High-Voltage Devices on Silicon on Insulator”, to be published in ***IEEE on Trans. Electron Devices.***

BCD工艺集成技术

Si基
BCD Process

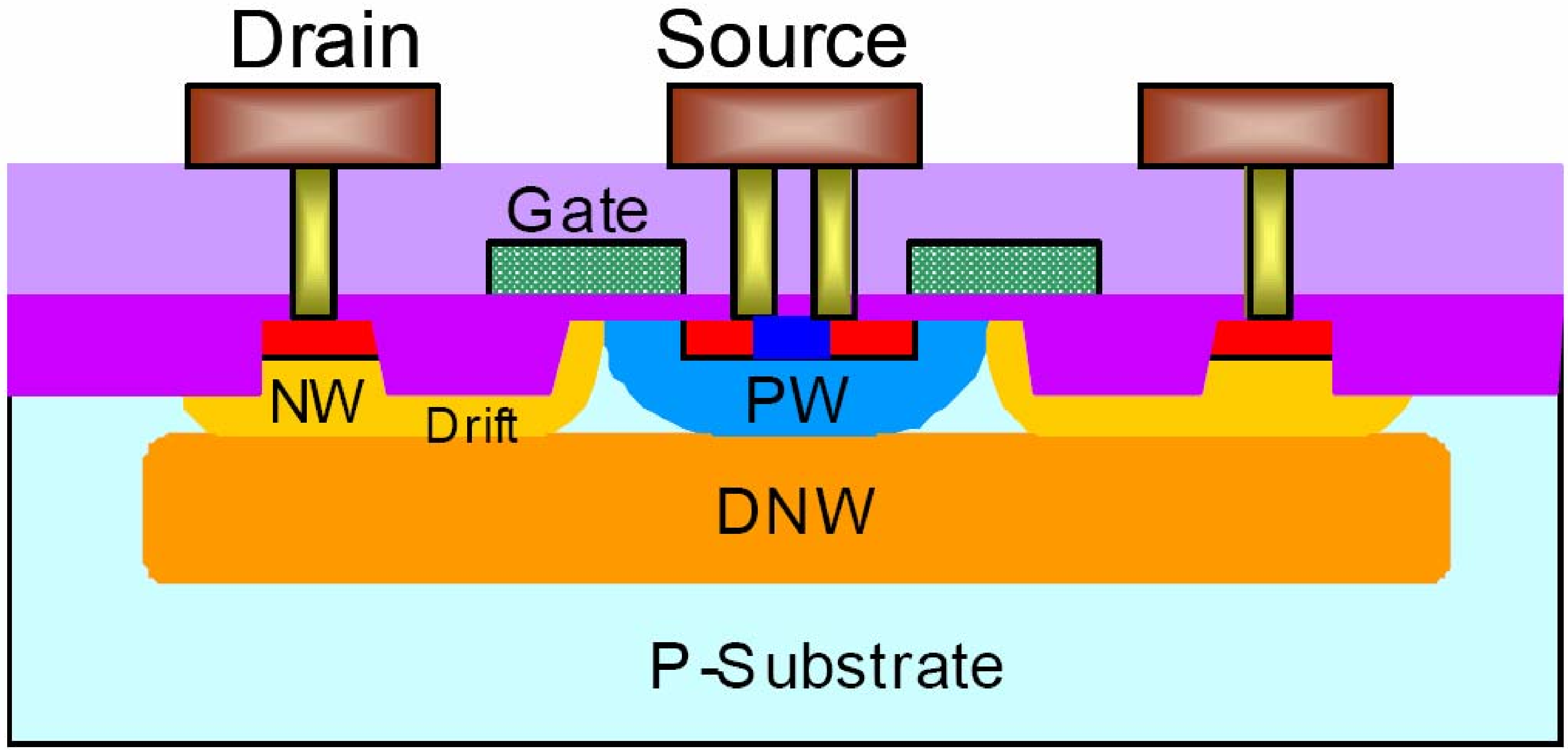


Toshiba's 5th generation 60V 0.13μm BCD Process



Toshiba, ISPSD'2009

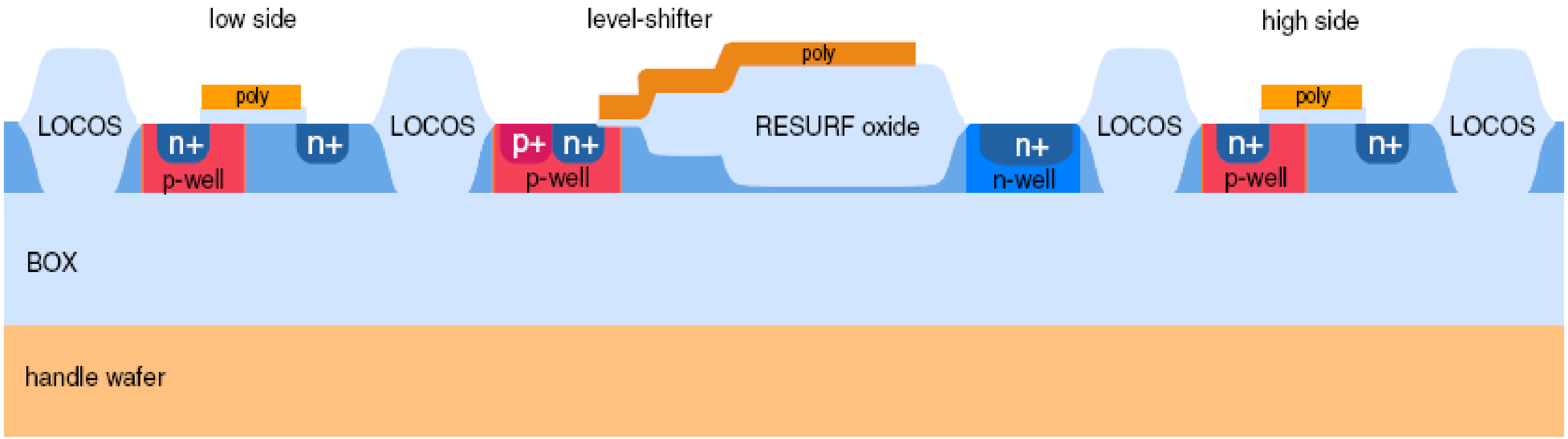
Toshiba's 5th generation 18V 0.13μm CD Process



Toshiba, ISPSD'2009

BCD工艺集成技术

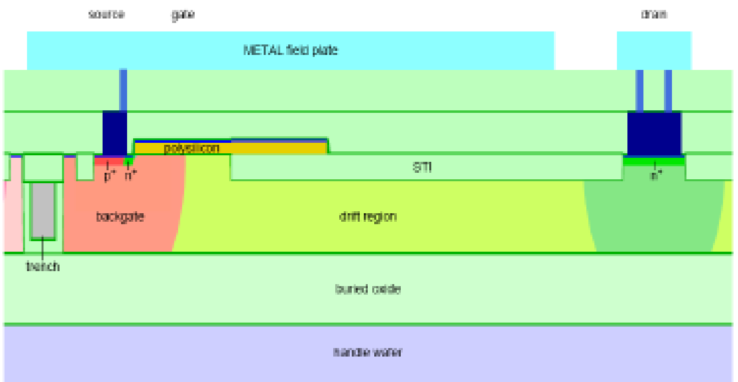
SOI基BCD Process

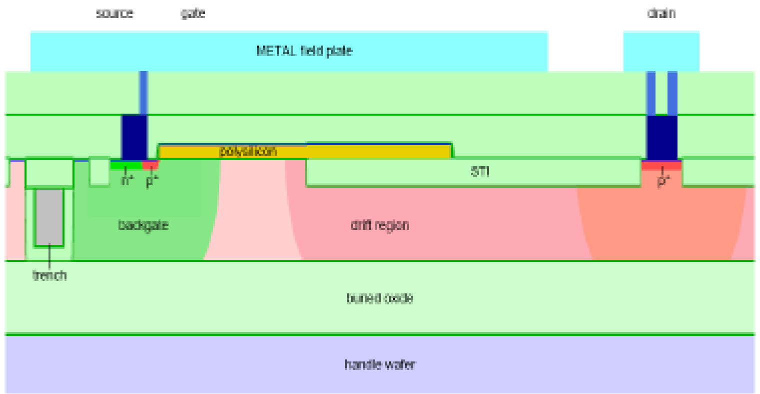


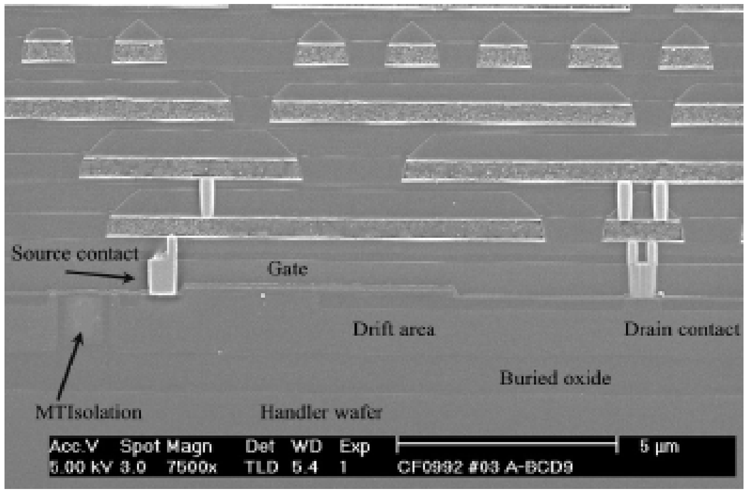
Philips Corporation

BCD工艺集成技术

SOI基BCD Process







Wessels P, Swanenberg M, Claes J, et al. Advanced **100V, 0.13μm BCD** process for next generation automotive applications. 2006 International Symposium on Power Semiconductor Devices and ICs, Vol.18: 197-120

Philips Corporation

目　　录

我国功率半导体发展现状

- 普通二极管、三极管国内的自给率已经很高，但是在高档的功率二极管，大部分还依赖进口，国内的产品性能还有不小的差距。

- 在功率管领域，逐步有国内的企业技术水平上升到MOS工艺，并逐步上量，进口替代已然开始。

- 在电源管理领域，前十名都见不到国内的企业。

我国功率半导体发展现状

- IGBT已从封装向芯片发展，从PT结构向NPT发展。
- BCD工艺已从无到有，从低压向高压发展，从硅基向SOI基发展。


谢 谢！