Power for the Better

中国电工技术学会电力电子学会第十一届学术年会
大会报告

IGBT器件和模块的发展

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MACMIC

报告内容

芯片

1. IGBT 是什么？
2. 发展过程中遇到的问题
3. 新技术
4. IGBT 衍生器件
5. 新材料
6. 发展方向

模块

1. IGBT 模块的构成
2. 新工艺
3. 发展方向

IGBT 芯片

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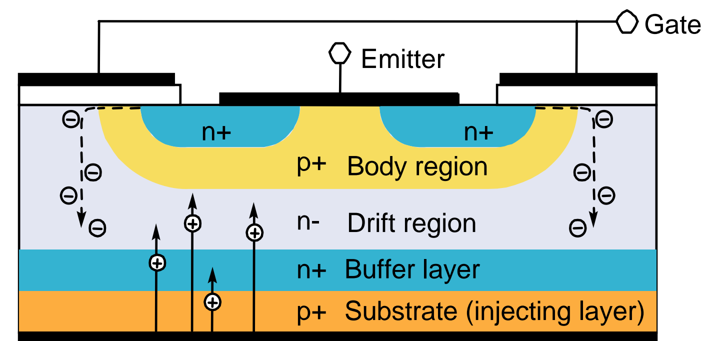
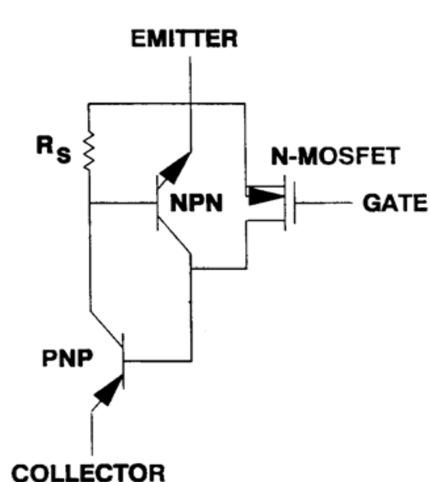
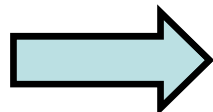
什么是IGBT?

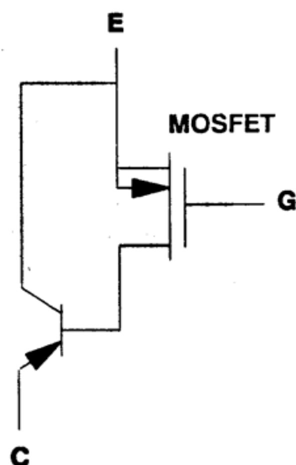
IGBT — 绝缘栅双极晶体管，发明于1982年

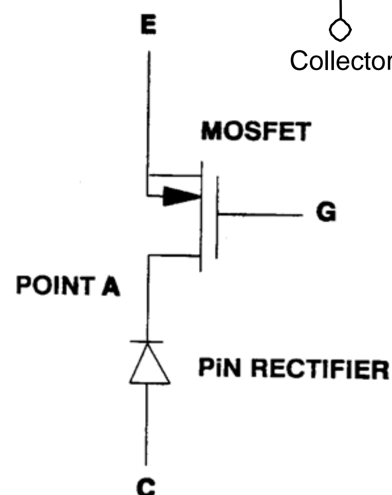
IGBT＝ MOSFET＋PNP双极晶体管
VDMOS＋PN结





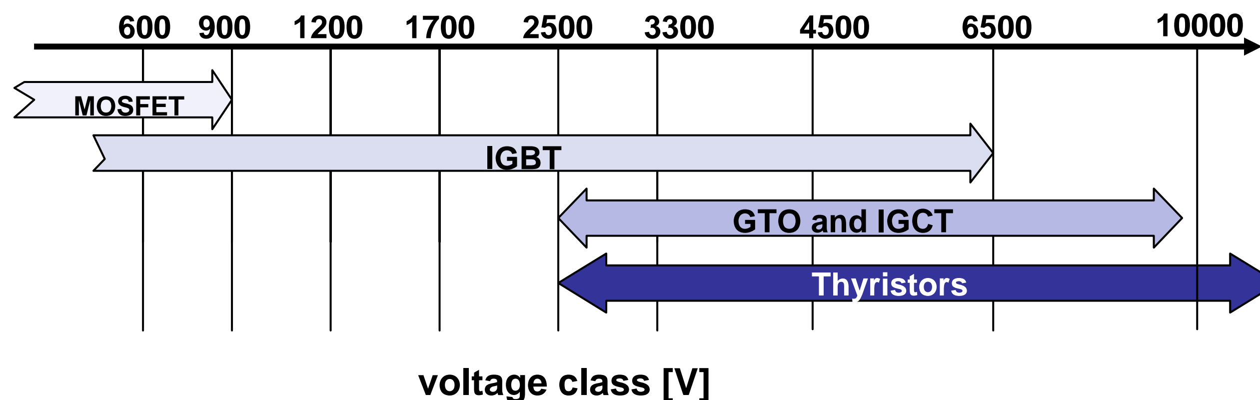






IGBT 的优点

- **MOS栅控制 (电压控制型）,**
- 高频率
  比**GTO**高**3－4**倍，**1200V**，**50KHz**；**600V**，**150KHz**
- 大电流密度
  比 **VDMOS** 高**2-3** 倍
- 高电压能力
  市场：**6500V**， 实验室：**8000V**

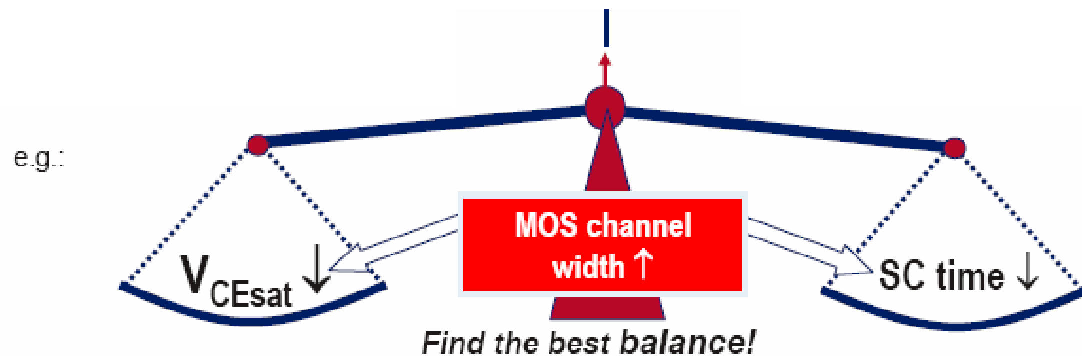


voltage class [V]

IGBT是高压大电流高频MOS控制型双极晶体管

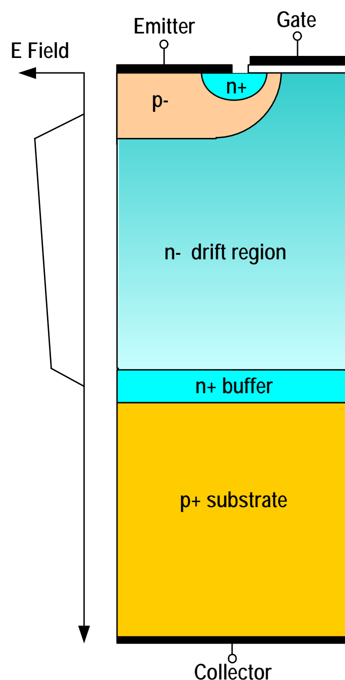
- 闭锁效应 → 可靠性
- 通态压降 → 低通态损耗
- 开关速度 → 低开关损耗
- 温度系数 → 并联均流
- 短路能力 → 可靠性
- 软关断 → 可靠性、EMI
- 热阻 → 可靠性
- 高温特性 → 可靠性

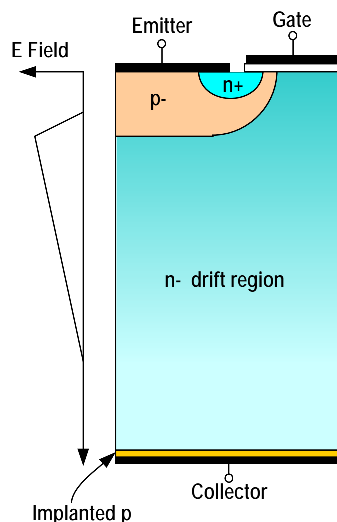
- 通态压降和耐压的关系；
- 通态压降和开关速度的关系；
- 通态压降和短路电流能力的关系。

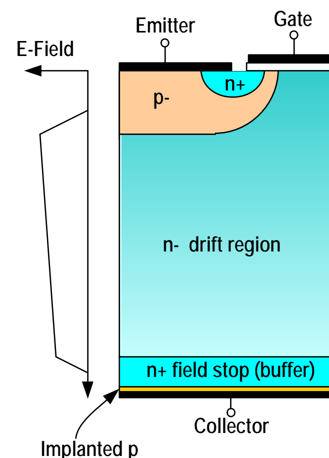


- **NPT 技术** → 正温度系数，高短路能力，低热阻和低成本
- 场阻挡层（薄漂移区）技术 → 低通态，开关损耗和低热阻
- 沟槽栅技术 → 低通态损耗
- 发射极载流子浓度增强技术 → 低通态损耗
- 集电极低空穴注入 → 低开关损耗和高短路能力

IGBT的结构







PT (Punch-Through)
- p+ 衬底，n 外延漂移区
- 电场穿透漂移区，到达n+缓冲层。

NPT（Non-Punch-Through）
- 无外延层
- 薄p发射区
- 电场未穿透漂移区；

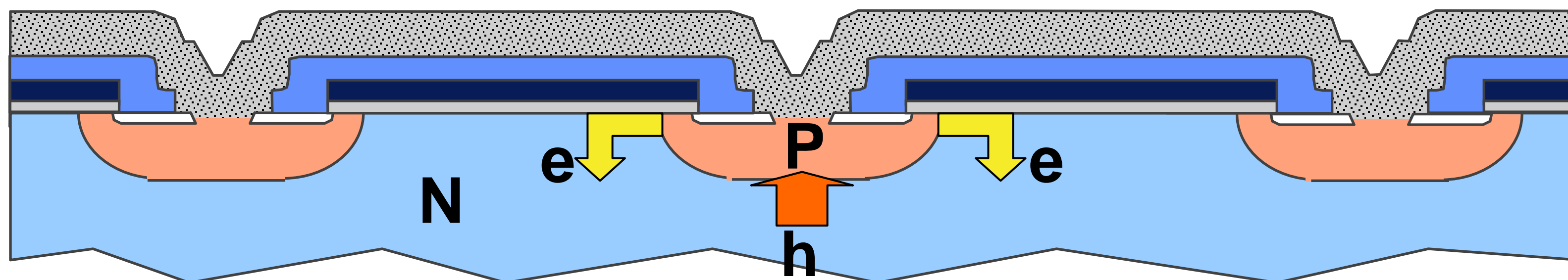
FS (Field Stop)
- 无外延层
- 薄p发射区
- 电场穿透漂移区，到达n+场阻断层。

- 负温度系数
- 材料成本高

- 正温度系数
- 热阻低
- 材料成本低

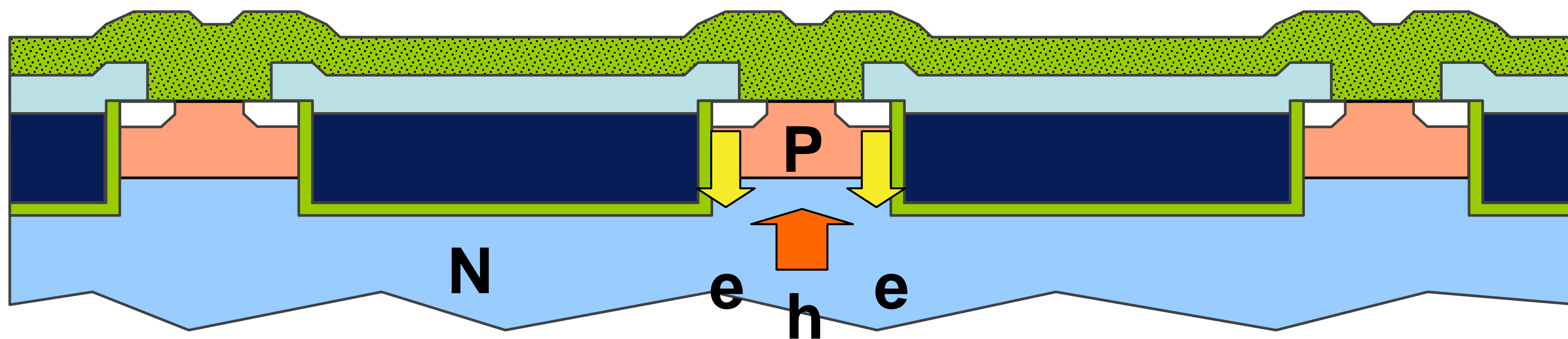
- 拖尾电流小
- 通态压降低

平面栅

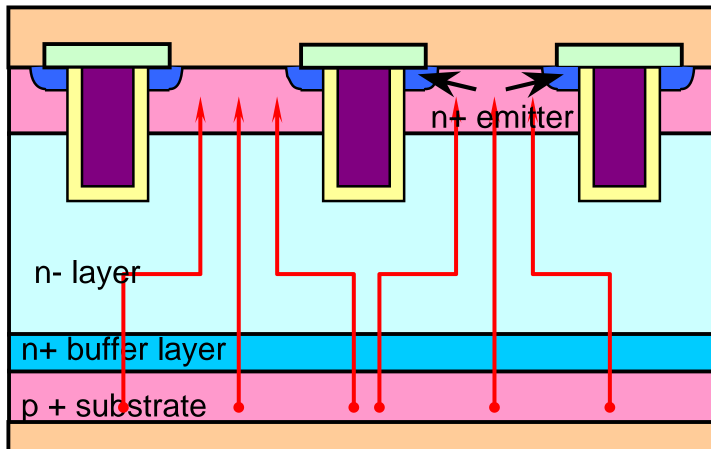


降低
Vceon

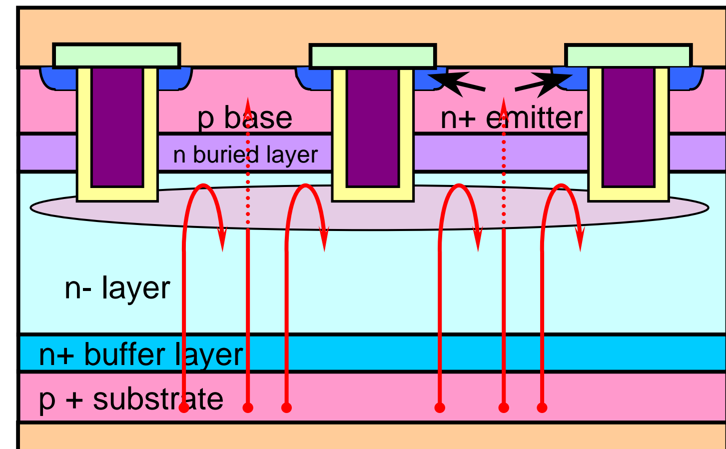
沟槽栅



- **HiGT（Hitachi）**
- **EP（ABB）**
- **CSTBT（Mitsubishi）**
- **IEGT（Toshiba）**



Conventional Trench IGBT

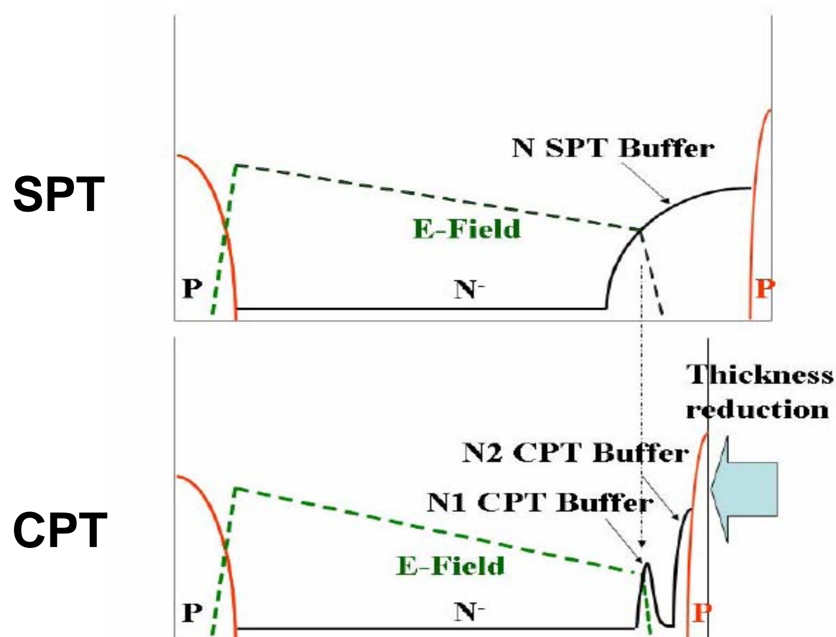


CSTBT™

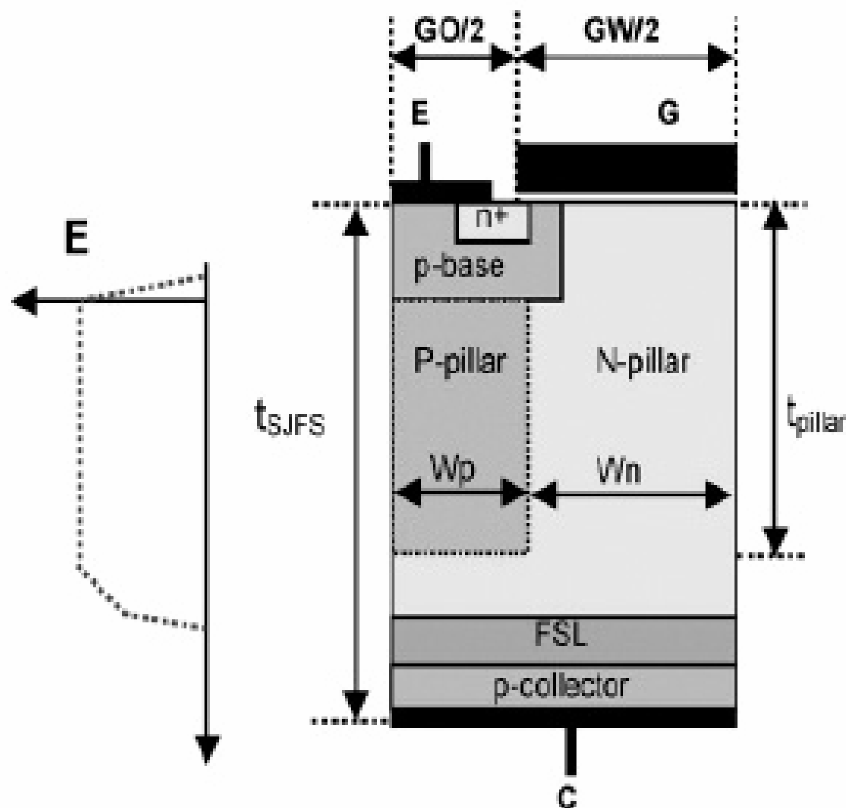
- Field-Stop（Infineon）
- Quick PT（Fairchild）
- Controlled PT（ABB）

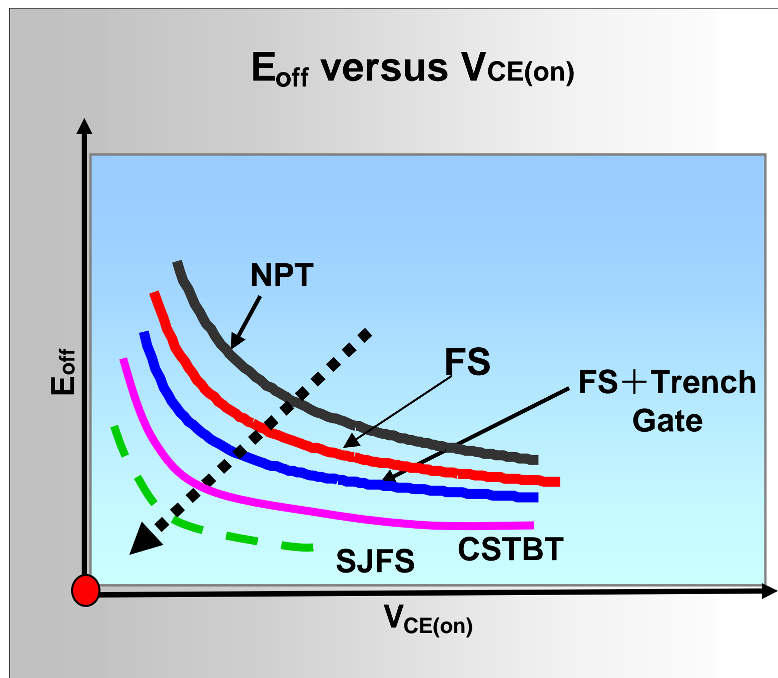
SPT

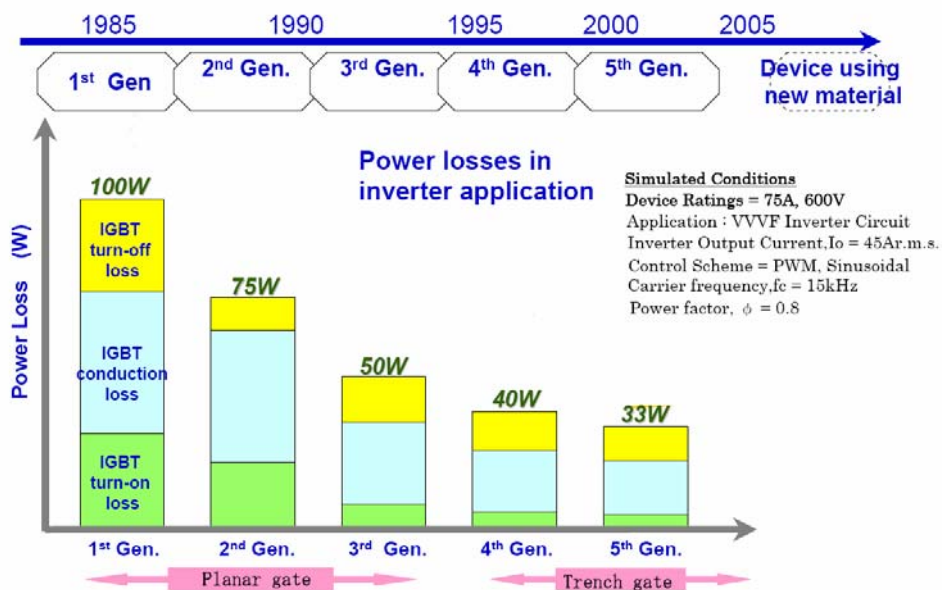
CPT



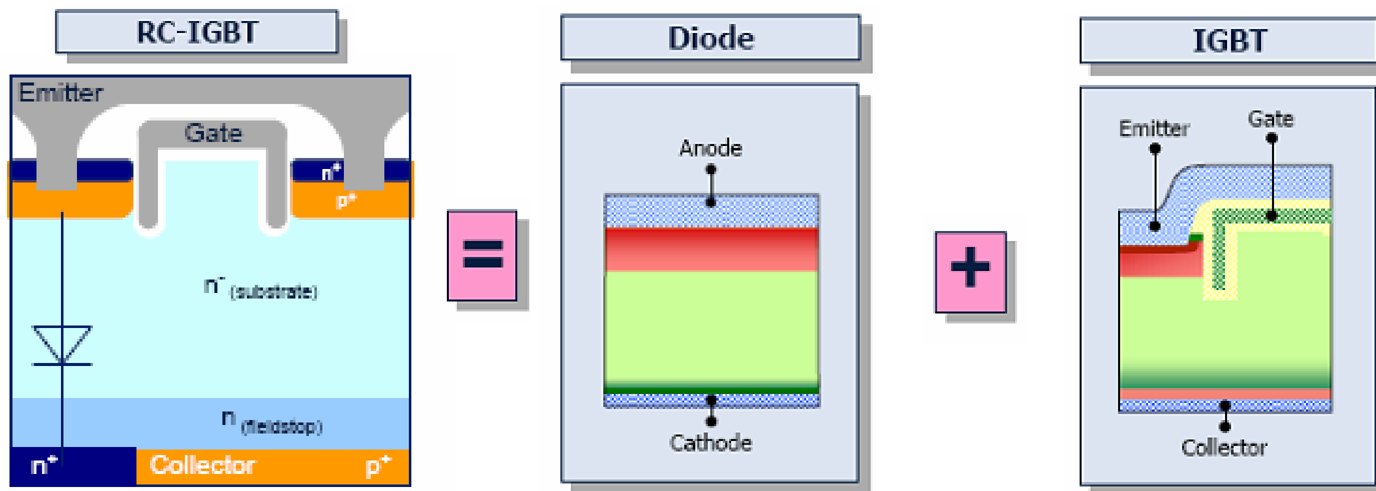
- N1 层阻挡电场；N2 层调整空穴注入效率；
- 1200V: 硅片厚度可由128 um 减少到100um。

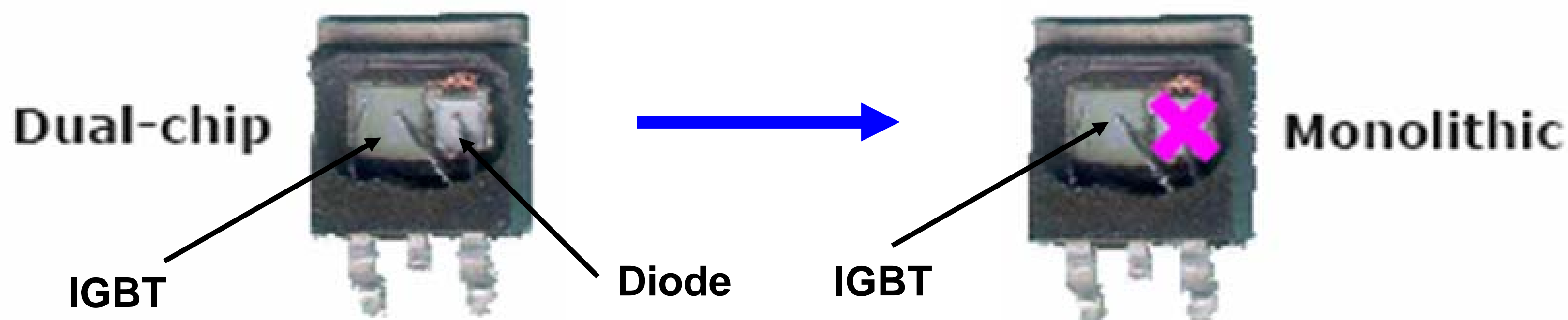

GO/2
GW/2
E
G
n+
p-base
E
P-pillar
N-pillar
t_{SJFS}
t_{pillar}
Wp
Wn
FSL
p-collector
C


Eoff versus VCE(on)
Eoff
NPT
FS
FS＋Trench Gate
SJFS
CSTBT
VCE(on)

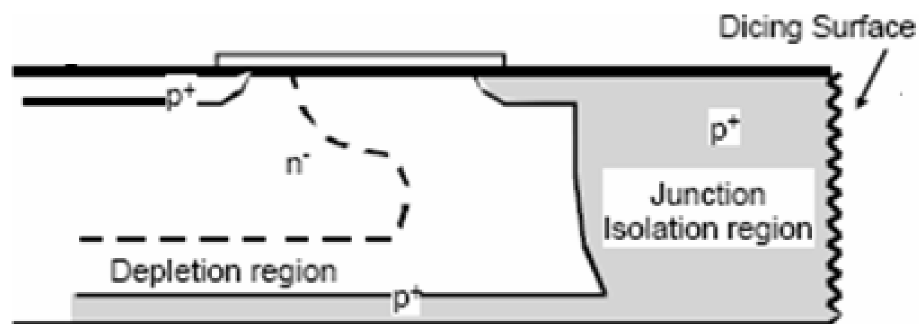

1985
1990
1995
2000
2005
1st Gen
2nd Gen.
3rd Gen.
4th Gen.
5th Gen.
Device using new material
Power losses in inverter application
Simulated Conditions
Device Ratings = 75A, 600V
Application : VVVF Inverter Circuit
Inverter Output Current,Io = 45Ar.m.s.
Control Scheme = PWM, Sinusoidal
Carrier frequency,fc = 15kHz
Power factor, ϕ = 0.8
Power Loss (W)
100W
75W
50W
40W
33W
IGBT turn-off loss
IGBT conduction loss
IGBT turn-on loss
1st Gen.
2nd Gen.
3rd Gen.
4th Gen.
5th Gen.
Planar gate
Trench gate

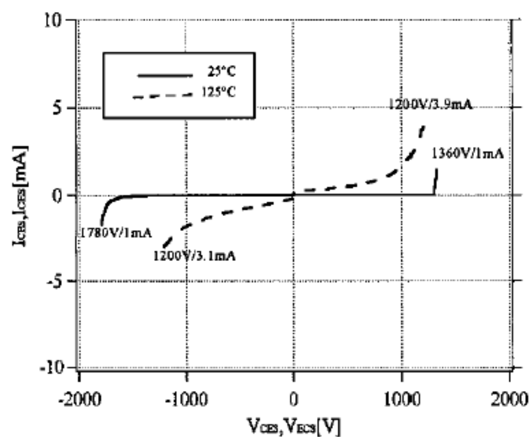
逆导 IGBT



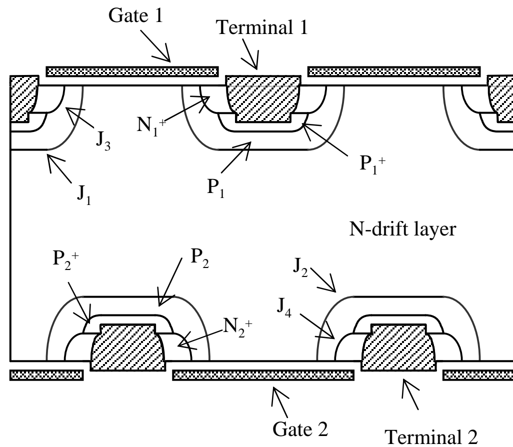


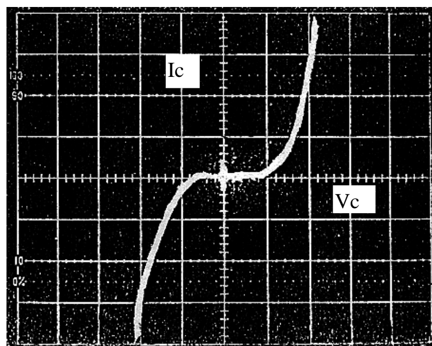
逆阻IGBT

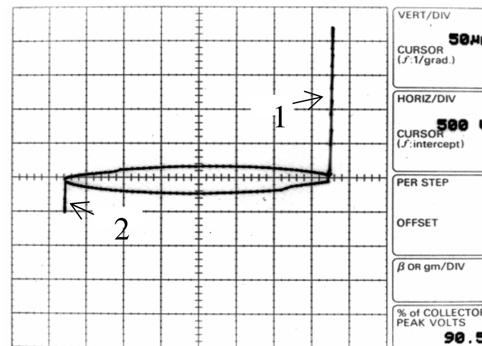


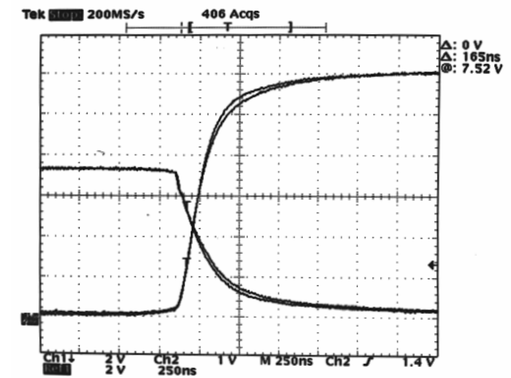


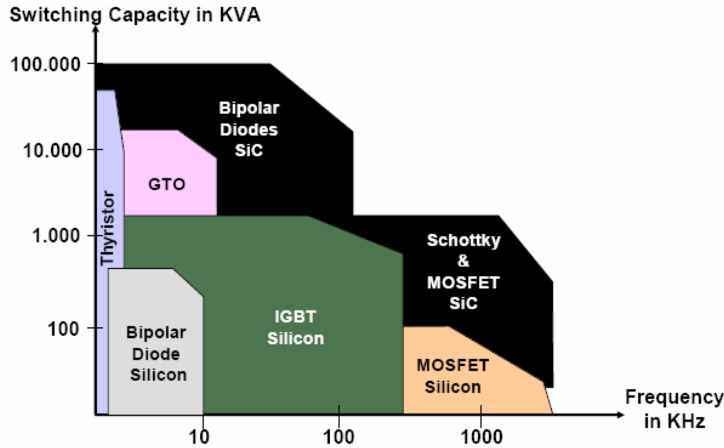
双向 IGBT

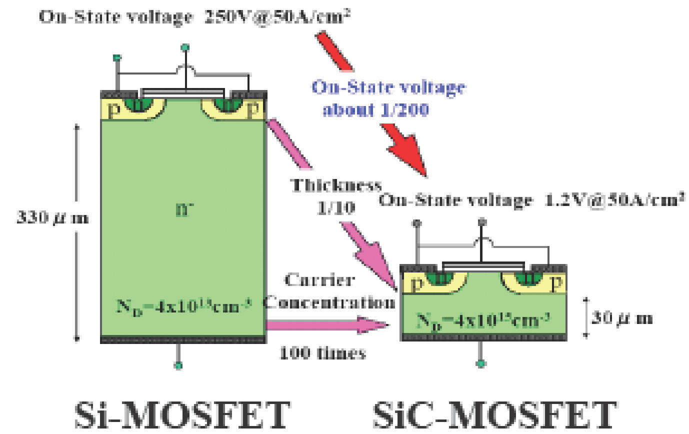


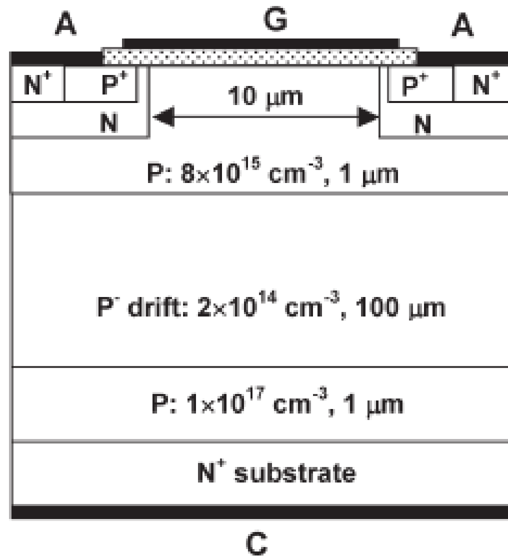


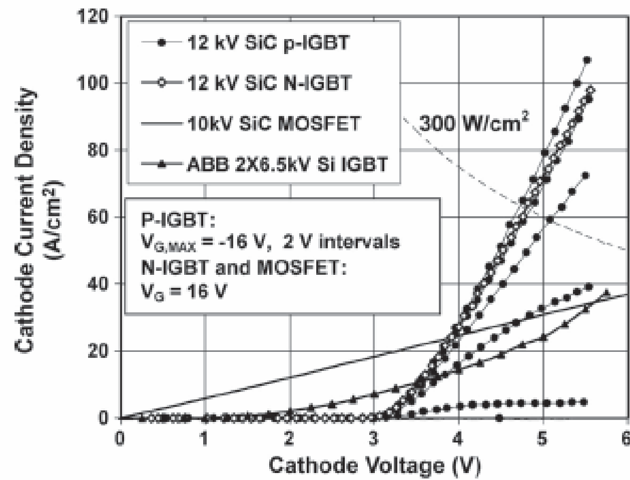






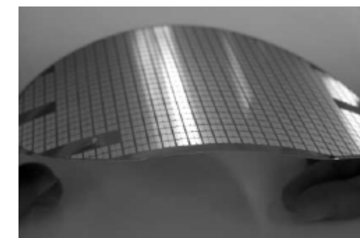


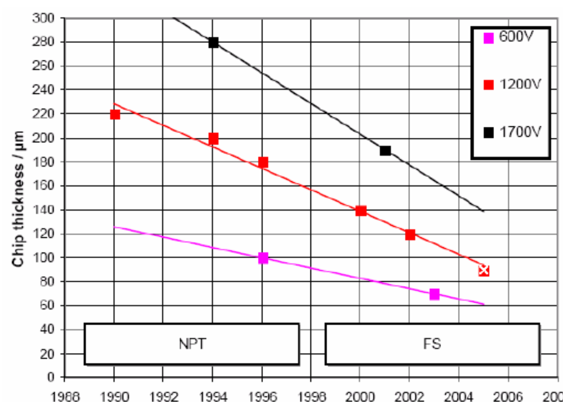


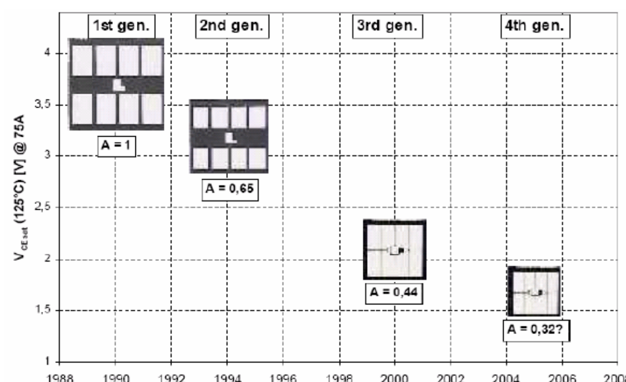


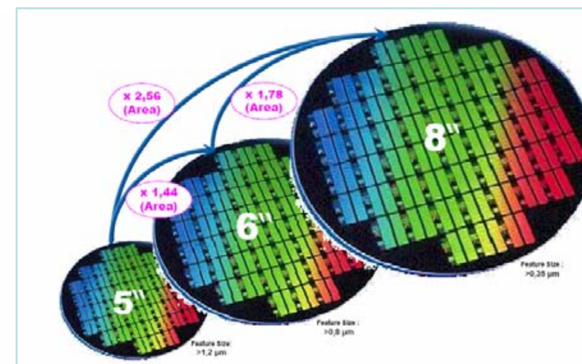
12KV P-沟道SiC IGBT

- 大电流、高电压、低损耗、高频率、功能集成化、高可靠性
- 薄片工艺，**110μm (1200V), 60 μm (600V)**
- 小管芯，**15**年来管芯的面积减少了**2/3**
- 大芯片，**4”—5” — 6” — 8”**
- 新材料：**SiC**









IGBT 功率模块

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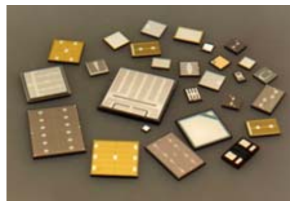
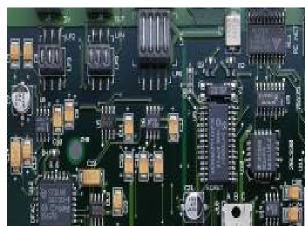
模块的构成

控制电路

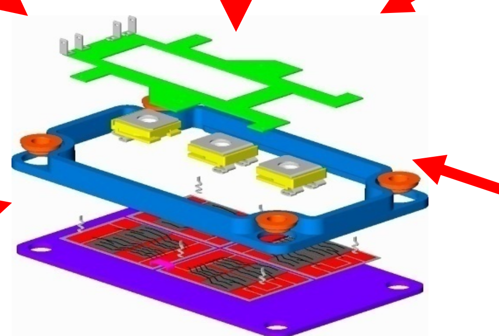
半导体芯片：
IGBT、MOSFET、FRED、SCR

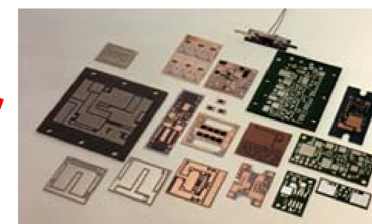




引线电极

封装外壳



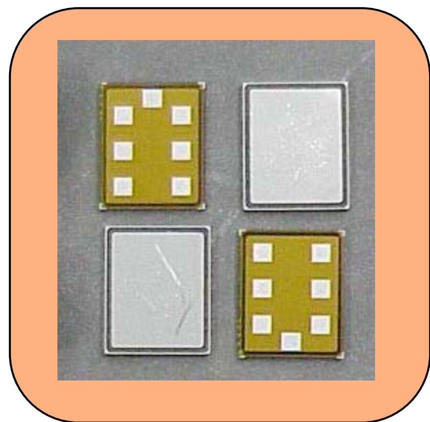


绝缘导热基板 DBC,
铝基板,
模块底板 Cu, AlSiC, CuW, CuMo

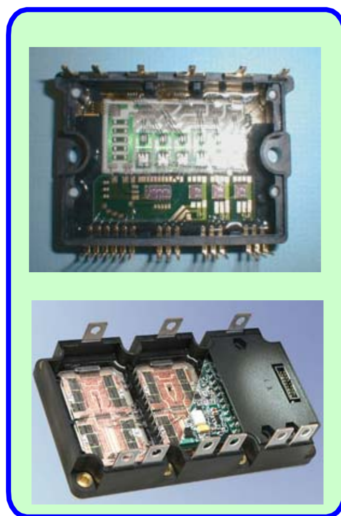
	Material	CTE * (ppm/^{o}C)	Thermal conductivity (W/m.k)	Density (g/cc)	Cost ratio
基板	CuW	6.5	190	17	6
	AlSiC	6.6	175	2.9	5
	Cu	17	393	8.9	1
衬底	Al2O3 (96%)	6.4	25	-	1
	AlN	3.5	170	-	4
	IMS	24.0	-	2.7	0.3
管芯	Silicon	4.1	136	-	
	SiC	2.6	270	-	

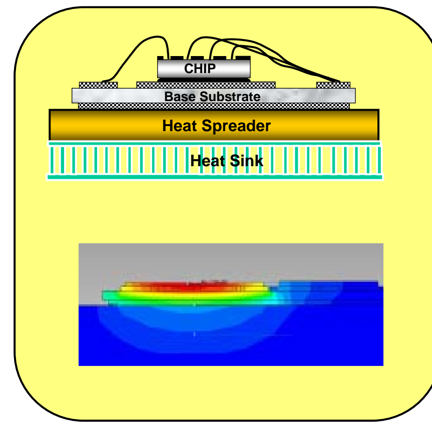
* Coef. Thermal Expansion

模块的构成

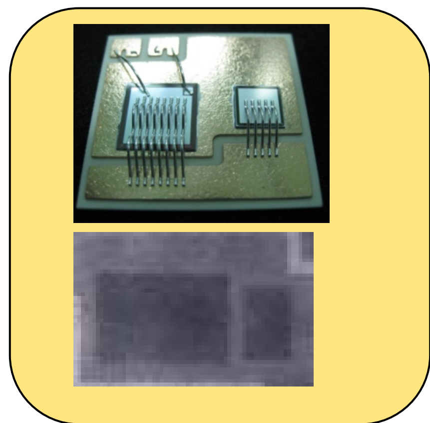


功率半导体器件

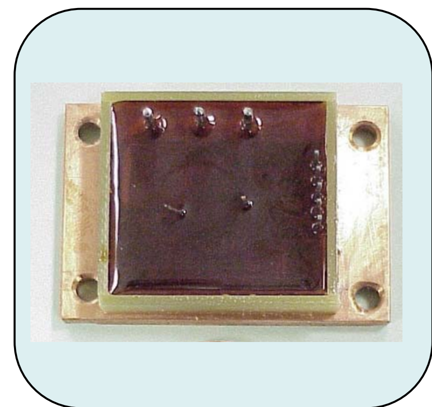




热传导

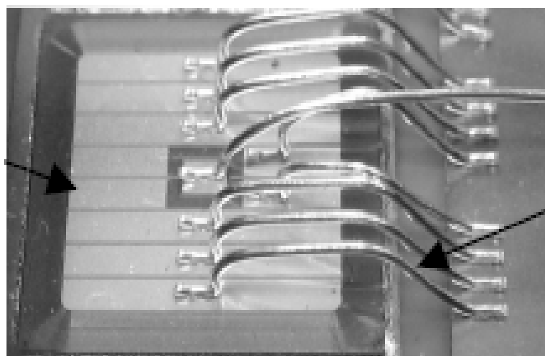


电连接



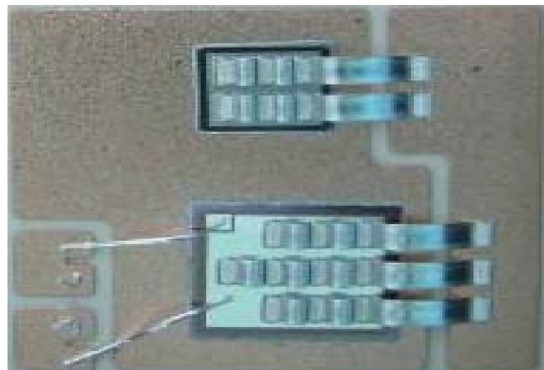
机械保护和电绝缘

铝丝



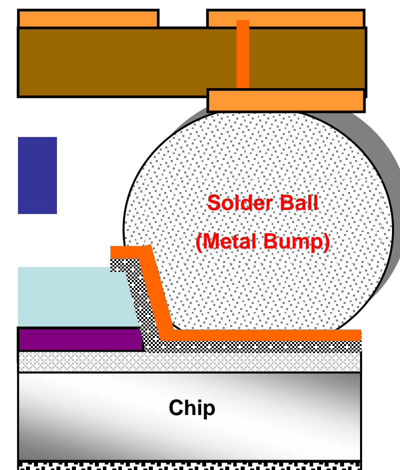
- 通用
- 灵活
- 成本低

铝带



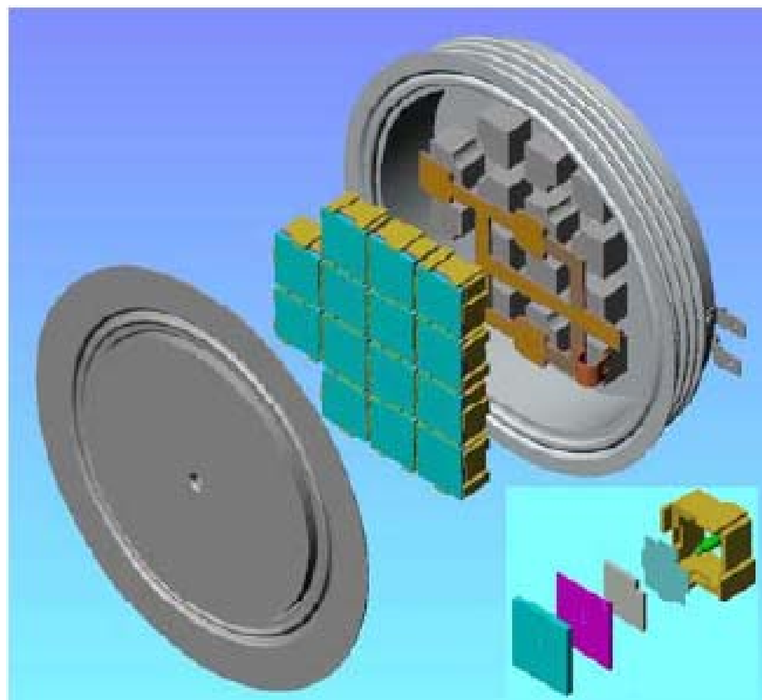
- 耐电流冲击能力高
- 寄生电感低
- 热阻小

焊球



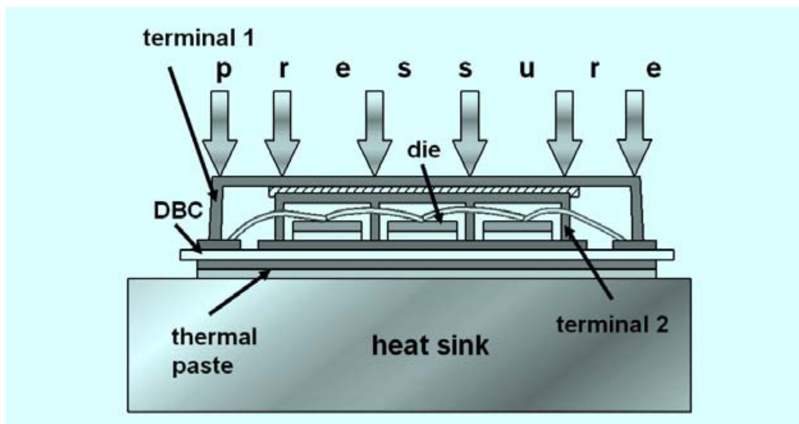
- 小尺寸封装
- 寄生电感更低
- 热阻低

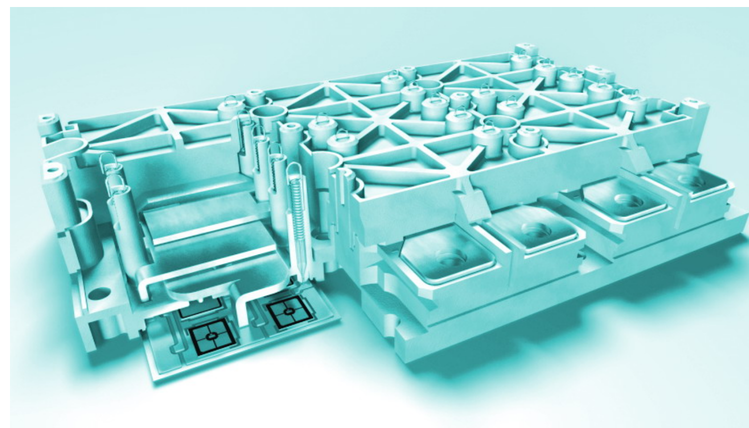
平板压接式



900A, 5200V IGBT

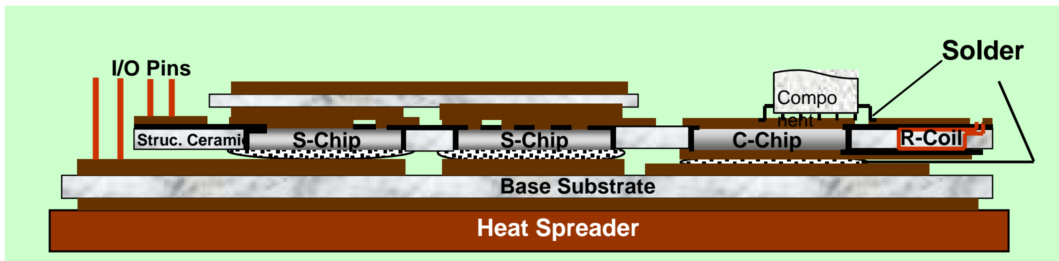
- 双面散热
- 易于串联

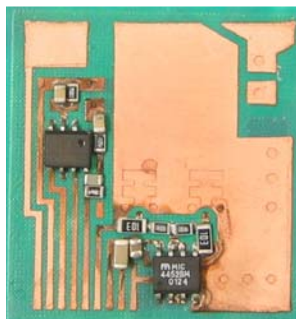


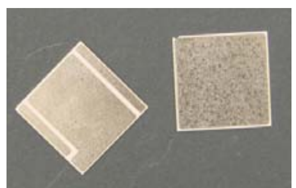


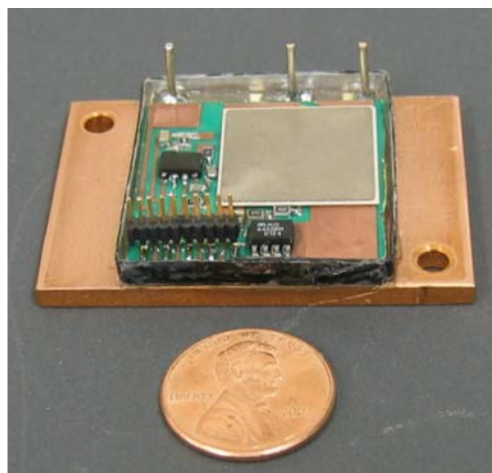
温度循环能力比标准模块高**5**倍

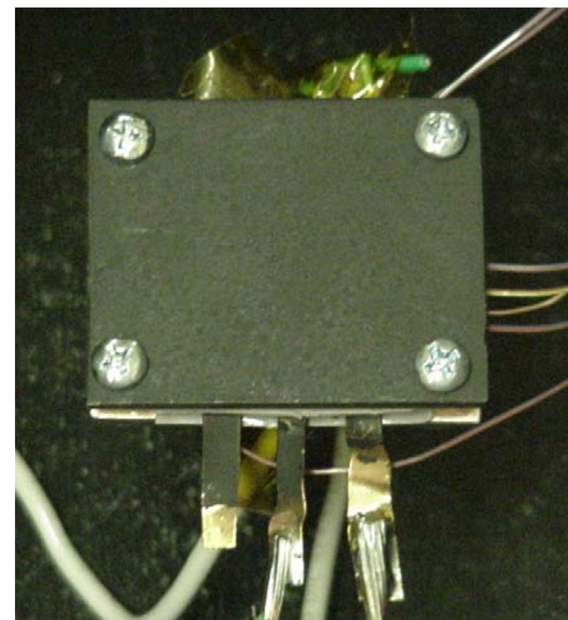
双面散热结构











提高散热效率30％以上

6 x SOT-227 Packages
36 Screws

SP6-P Package
4 screws

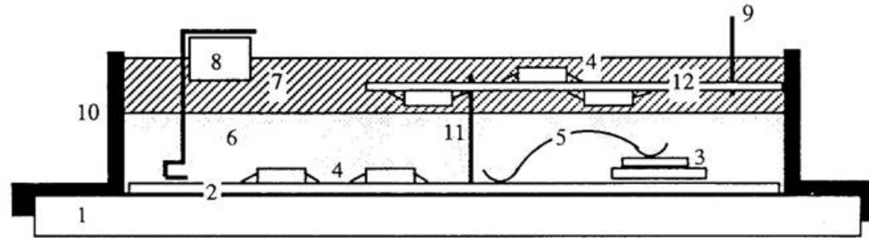
安装简单、成本低

薄型化

D3: 30mm 高，内部引线连接

SP6: 17mm 高，内部 PCB 板连接

寄生电感减少 50%以上



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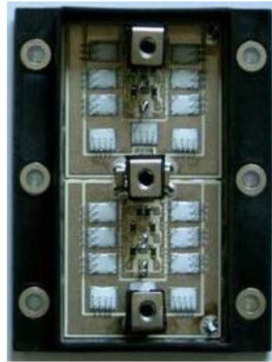

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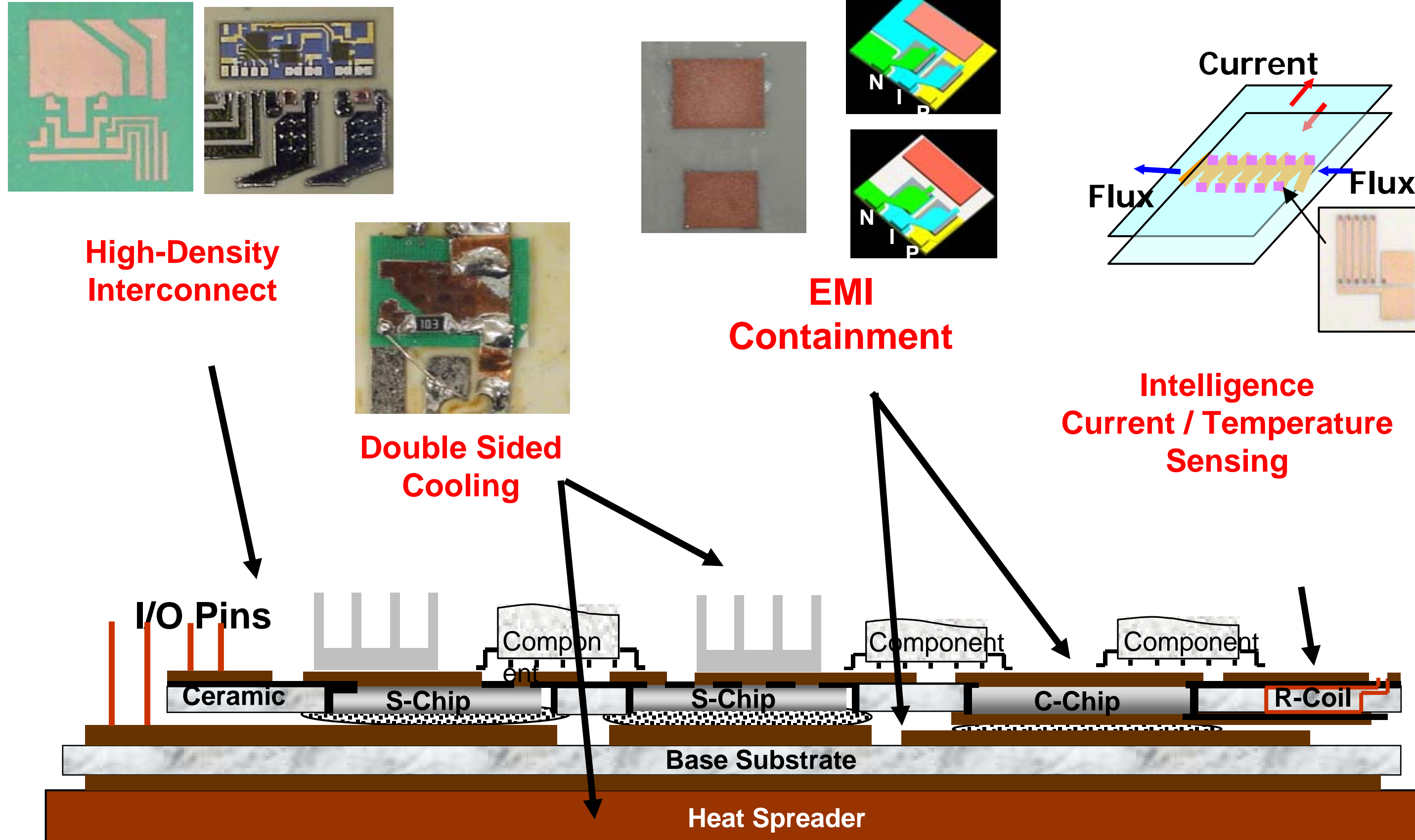
控制板　　主电路　　专用模块

电机调速专用模块:

- **600V / 150A IGBT** 半桥
- 带有 **DC to DC** 变换器
- 硬开关：**100A @ 75KHz**



- ◆器件
  - 裸片
- ◆结构
  - 多层平板布线
  - 双面散热
- ◆功能集成
  - 功率单元
  - 驱动、控制
- ◆工艺
  - 多层薄膜和厚膜

集成功率电子模块（IPEM）

谢谢！

请指教！