

## 电新&公用 Power Equipment & New Energy & Utilities

### 碳化硅需求量高速增长，国内企业产能释放迎机遇

### Capacity Expansion Expected in China to Capture on Rapid Demand Growth of Sic

杨斌 Bin Yang

bin.yang@htisec.com

热点速评 Flash Analysis

(Please see APPENDIX 1 for English summary)

碳化硅(SiC)具有很多优势,作为一种宽禁带半导体材料, SiC 临界击穿电场强度高,约比硅(Si)高 10 倍左右,导通电阻低,可使器件的导通损耗大大降低; SiC 具备较高的载流子迁移率,能够提供较高的电流密度,可减少周边器件的使用,相同功率等级下封装尺寸更小,从而在整体上缩减了系统尺寸; SiC 也有良好的热导率,更容易散热,工作温度可以达到 600°C,而一般的 Si 器件最多能坚持到 150°C; SiC 也能够实现高频开关,减少无源器件的体积和成本。因其这些特性, SiC 被称作第三代半导体材料之一,可被用来制造各种耐高温的高频大功率器件,具有广阔的市场空间和前景。

SiC 是由硅(Si)和碳(C)组成的化合物半导体材料。其结合力非常强,在热、化学、机械方面的性质都非常稳定, SiC 是用石英砂、石油焦(或煤焦)、木屑等原料通过电阻炉高温冶炼而成。目前 Si 器件对于电力电子应用的优化与提升已达到极限,而宽禁带材料 SiC 制成的器件可耐高温高压、有更小的导通电阻、更高的功率密度及不存在拖尾电流,可降低器件的开关损耗。在功率半导体的应用中,硅基 IGBT 与硅基 MOSFET 器件分别只适用于低频率高电压及低电压高频率场景中,而碳化硅 MOSFET 器件可应用于高频率高电压的各种场景中,包括 5G 基站、光伏逆变器、储能逆变器、车载电源、新能源汽车电机控制器、UPS、充电桩、功率电源等领域。目前碳化硅 MOSFET 有两种结构的产品,第一种是平面型构 MOSFET,即 DMOS,还有一种 MOSFET 是沟槽型的构造,即 UMOS。平面型构造的耐压可以做得很好,但是芯片尺寸要做得很大。沟槽式构造可以把晶圆尺寸做小一些,因此价格更低。

SiC 在自然界中储量很少,目前应用的几乎都是依靠人工合成, SiC 产业链中于上游衬底和外延环节价值量最高,衬底约占碳化硅器件成本的 47%,外延环节约占总成本的 23%。因 SiC 衬底及外延价格相对硅片较为昂贵,制备过程中由于一次性价格高昂耗材占比过重, SiC 长晶技术壁垒高及良率低等原因,目前 SiC 器件价格大约是 Si 器件的 4-5 倍。SiC 产业链主要包括衬底、外延、器件设计、器件制造、封测等环节,从工艺流程上看,一般是先将高纯硅粉和高纯碳粉按一定配比混合,在 2,000°C 以上的高温下反应合成,再经过破碎、清洗,制得满足晶体生长要求的高纯度 SiC 微粉原料;再以高纯度碳化硅微粉为原料,使用自主研发的晶体生长炉,采用物理气相传输法(PVT)结晶形成圆柱状碳化硅晶锭;然后将制得的碳化硅晶锭使用 X 射线单晶定向仪进行定向,之后磨平、滚磨,加工成标准直径尺寸的碳化硅晶体;再将晶体切片、研磨、抛光得到碳化硅衬底,衬底经过外延生长得到外延片,外延片经过光刻、刻蚀、离子注入、沉积等步骤制造成器件;器件组合在一起放入特殊外壳中封装组成模组。

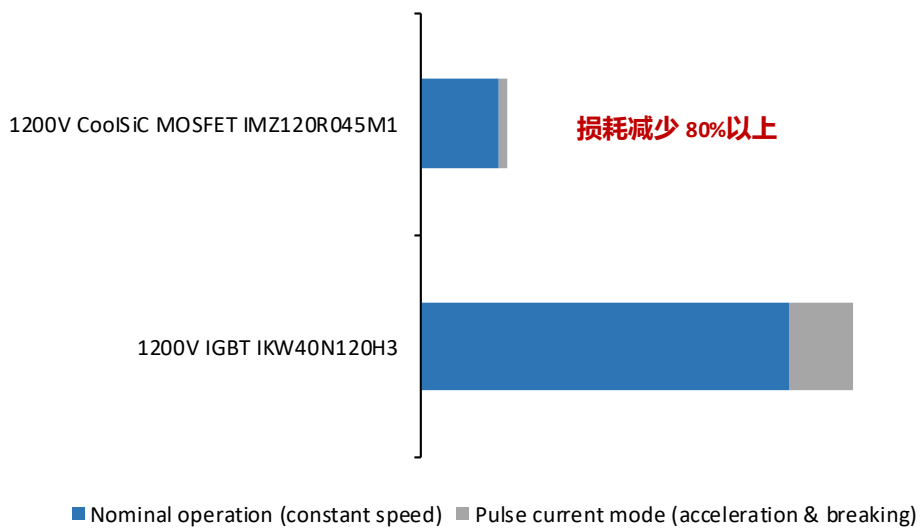
受益于新能源汽车需求猛增,全球碳化硅市场正处于高速发展阶段,据 Wolfspeed 预测,2022 年全球碳化硅器件市场规模达 43 亿美元,2026 年碳化硅器件市场规模有望成长至 89 亿美元。目前海外厂商在 SiC 领域占据先发优势,其中美国占全球 SiC 产量的 70%-80%,欧洲拥有完整的 SiC 衬底、外延、器件以及应用产业链,在全球电力电子市场拥有强大的话语权。国内企业起步较晚,在技术和产能上都与海外企业有一定的差距,但产业正迅速发展,多个碳化硅制造项目已投产。海外企业方面,意法半导体依然占据碳化硅供应商龙头地位,向特斯拉 model Y 供应器件与模块,市占率达到 37%;此外,英飞凌在充电桩业务上取得了出色的进展,进步很快,目前市占率已达到 22%;Wolfspeed 是全球最大的 SiC 衬底制造商,将投资高达 50 亿美元在北卡罗来纳州建造 SiC 材料工厂;罗姆和安森美进步较大,主要供货给模块供应商,罗姆芯片出货给模组的制造商,安森美的主要业务分布在光伏储能、充电桩和新能源汽车。国内企业方面,三安光电是国内首家实现 SiC 垂直产业链布局的公司,具备衬底材料、外延生长、以及芯片制造的产业整合能力,产能目前处于爬坡阶段,公司预计 25 年配套年产能达 36 万片;天岳先进专注于碳化硅衬底,现年产能 6.7 万片,以 4-6 英寸半绝缘型为主。

天科合达衬底产能约为 12-15 万片，以导电型为主，其中 6 英寸和 4 英寸产量比例约为 2:1，4 英寸产能将逐年降低；烁科晶体目前业务主要包括单晶炉设备和衬底，衬底月产能约 8000 片，以 4 英寸半绝缘型为主，6 英寸导电型衬底开始小批量供应，同时 8 英寸导电型衬底也已经实现小批量生产。

**投资建议：**建议关注国内外碳化硅制造龙头企业意法半导体、英飞凌、Wolfspeed、三安光电、天岳先进、天科合达、烁科晶体。

**风险：**碳化硅需求不及预期，成本降低不及预期。

图 1: SiC 器件的导通损耗相比 Si 基器件降低 80% 以上



资料来源: 英飞凌官网, HTI

图 2: 碳化硅器件的广泛应用



资料来源: ASTRI, HTI

## APPENDIX 1

### Summary

SiC has so many advantages. As a wide bandgap semiconductor material, SiC has a high critical breakdown electric field strength, which is about 10 times higher than that of Si. It also has a low on-resistance, which can greatly reduce the conduction loss of the device. SiC carries high carrier mobility and it can provide high current density, which reduces the use of peripheral devices. The package size is smaller at the same power level, thereby it will reduce the overall system size. SiC also has good thermal conductivity and it is easier to dissipate heat. The working temperature can reach at 600°C, while the general Si device just lasts up to 150°C. SiC can also realize high-frequency switching, reducing the size and cost of passive devices. Because of these characteristics, SiC is called one of the third-generation semiconductor materials, which can be used to manufacture various high-frequency and high-power devices with high temperature resistance, and has broad market applications and prospects.

SiC has very few reserves in nature. At present, almost all applications rely on artificial synthesis. In the SiC industry chain, the upstream substrate and epitaxial wafer have the highest value. The substrate and epitaxial wafer account for about 47% and 23% of the total cost of SiC devices, respectively. Because SiC substrates and epitaxy are more expensive than silicon. Due to the high one-time cost of consumables in the synthesis process, high barriers to SiC crystal growth technology, and low yield of production. The current price of SiC devices is about 4 to 5 times higher than Si devices.

Due to the large increase of electrical vehicles' demand, the global SiC market is in a stage of rapid development. According to Wolfspeed's prediction, the global SiC device market will reach US\$4.3 billion in 2022, and the SiC device market is expected to grow to US\$8.9 billion in 2026. At present, overseas manufacturers occupy the advantages in the SiC market, and Chinese enterprises have some gaps in technology and production capacity, But China market is large and increases fast. Among them, the United States accounts for 70%-80% of the global SiC production, and Europe has a complete SiC substrate, epitaxy, devices and application chain. They have a very strong power in the global power electronics market.

Suggestions: Attention on Chinese and global leading SiC manufacturers such as STMicroelectronics, Infineon, Wolfspeed, Sanaan optoelectronics, Sicc, Tankeblue Semiconductor, and Shanxi Semisic Crystal.

Risks: The demand of SiC is lower-than-expected. The cost reduction of SiC is lower-than-expected.

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## 附录 APPENDIX

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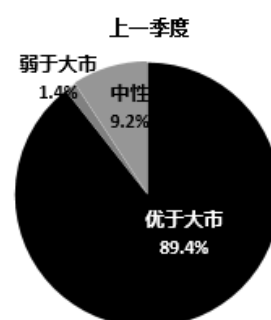
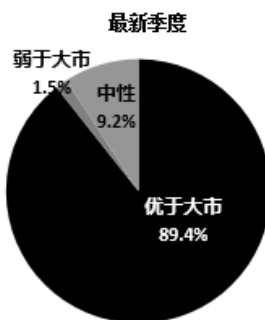
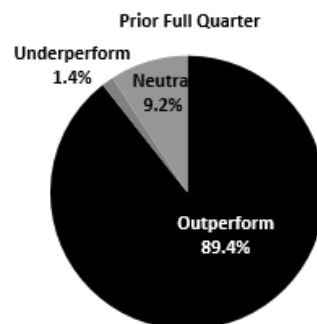
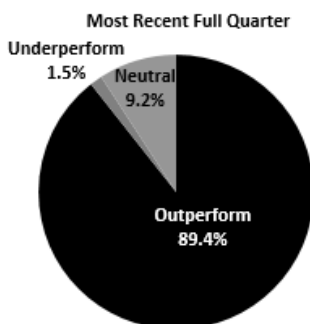
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