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Innovation China
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创新中国微型论坛
Jiangsu & Hunan, China | 13-14 Nov 2023

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Shanghai Emerging Industries Foundation
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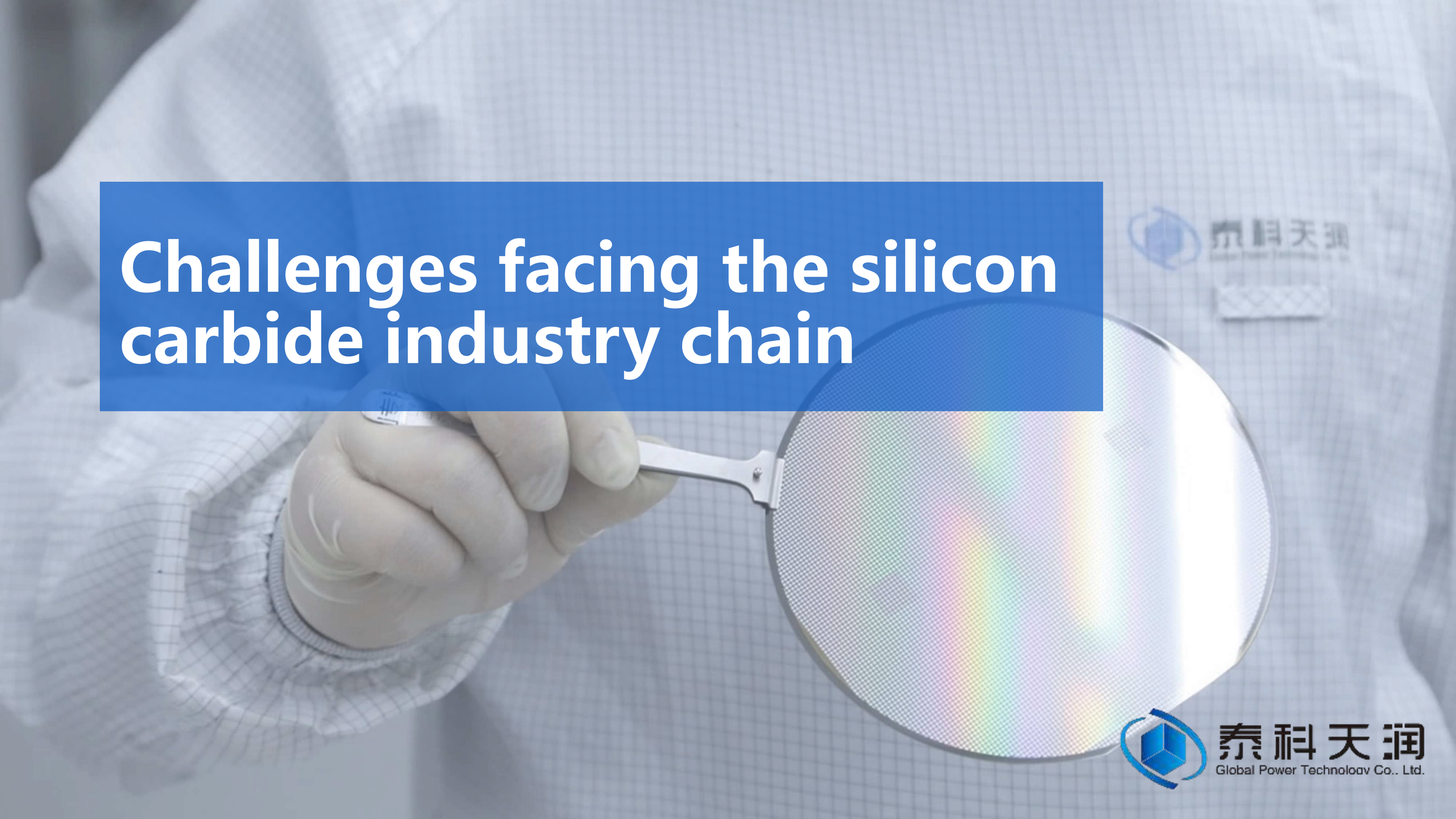
'3rd Generation Semiconductors' 第三代半导体论坛

14 Nov 2023

The Development of SiC power devices

Tong Chen，CEO，GPT

Challenges facing the silicon carbide industry chain



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Silicon Carbide Supply Chain

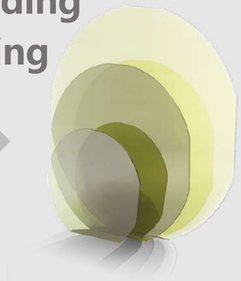
Material

Silicon carbide powder

single crystal growth

Silicon carbide ingot

Cutting, grinding and polishing



Silicon carbide substrate

Epitaxy

Silicon carbide epitaxy

Device

photolithography, cleaning,
Annealing, Doping, Etching, Thin Film, Oxidation

Front process

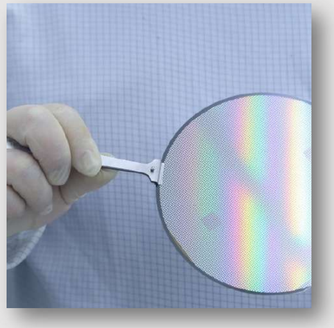
Device Design

Product Definition
Device Design

Silicon Carbide Wafer

Post-processing (I)

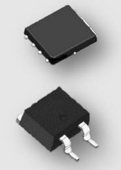
Grinding, Slicing, Flip Chip



Bare Die

Post-processing (II)

Select the chip, package,, testing



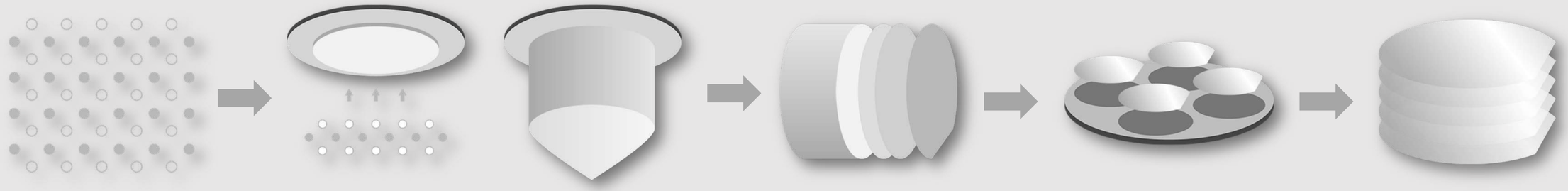
Discrete device

power module

Application

system applications

SiC Material



SiC powder | crystal growth | cut | grinding and polishing | epitaxy

Single crystal growth cycle is long, easy to include crystal defects

- PVT 0.2-0.4mm/h，HT-CVD 0.3-1.0mm/h，LPE 0.5-2mm/h
- Defects include microtubules, crystal inclusions, dislocations, stacking faults, etc., and there is mutual influence and evolution

Substrate quality directly affects downstream epitaxy and devices

- Good quality of substrate can reduce defect in epitaxial growth
- If there are defects on substrate will lead to the degradation of device performance, resulting in an increase in on-resistance and leakage current.

Difficult to control

- **Thermal field control**– The growth heat field is above 2300℃, and there is a temperature gradient, which leads to defects such as dislocation and stacking fault
- **Crystal control** – SiC includes more than 200 crystal forms, and only 4H crystal form is required for mainstream production, which is difficult to control stably
- **Doping control** –The introduction of external impurity must be strictly controlled to obtain directional doped conductivity-type crystals
- **Surface control** – High hardness and brittle material, there are problems such as easy cracked

Device Design and Manufacturing

Carbon film sputtering machine

High temperature oxidation furnace

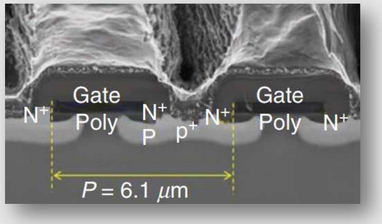
High temperature annealing furnace

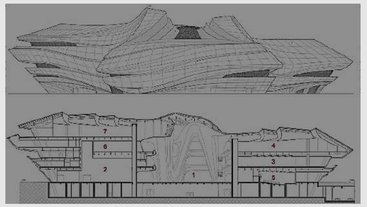
High temperature ion implanter

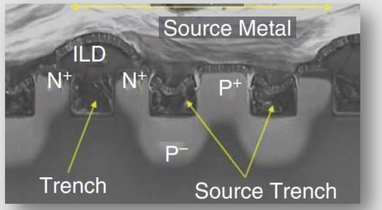
Material property	Processes Difficulties	Industrialization problem
Lattice is difficult to diffuse	Silicon carbide has no diffusion, and doping requires high-energy implantation. Generally, the implantation energy is 300KEV, and it even needs to be second-order to more than 700KEV.	High manufacturing cost and low tape-out efficiency
	Need to implant AL, and high temperature annealing process is required	Cannot learn from silicon industry, and the process exploration and equipment support are relatively limited. High temperature furnaces are easily to be contaminated and poor long-term stability
double element	The gate oxide process has to face the reaction of carbon atoms, which will form carbon-related impurities, which requires a high-temperature oxidation process, which is very difficult.	Cannot learn from silicon industry, and the process exploration and equipment support are relatively limited. High temperature furnaces are easily to be contaminated and poor long-term stability
transparent	It is difficult to adapt to the lithography process, and it is difficult to position the equipment when wafer transferred and taken.	Unstable process, low transfer efficiency, high fragmentation rate
hard	Dry etching is difficult, and the etching process is one of the top-level difficulties of the silicon carbide devices process.	The consistency and stability of the deep etching cannot be guaranteed
crisp	It is easy to crack when transferring or drying , and it is difficult to adapt to the thinning process.	Low production efficiency and high fragmentation rate

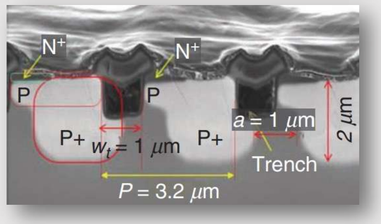
Design and Manufacturing

- **Device Design** Device structure design, selection of some process conditions, simulation verification
- **Wafer fabrication** Turn designs into reality based on equipment and mature process capabilities
- **Weak foundation** Insufficient knowledge of materials, inaccurate models, large differences between design and actual
- **Cant meet design demand** Limited by insufficient process capability, unable to meet design requirements









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Technical barriers bring development constraints

Device level: wafers are not easy to do

high temperature process and characteristic process need to be integrated and explored
MOSFET Threshold Voltage Drift Degradation with Temperature and Time

Insufficient production capacity will not be alleviated in the short term
There are still many defects in the material
Long cycle and high cost
Affect device reliability and yield

not enough data
Feedback exposes material issues

There is not enough demand volume to reduce costs,
Not enough data feedback to improve the device

Insufficient production capacity will not be alleviated in the short term
Price drop rate is limited

Expensive, can't afford it
High failure rate, dare not use

Some parameters of the device are not good enough further difficulty in use

Not enough usage to reduce costs
Insufficient data feedback to expose material issues

Material level: the material is hard to grow

high temperature growth, low production efficiency of vapor deposition
defects are numerous and complex, the threshold for industrialization is high, and production capacity increases slowly

Insufficient production capacity will not be alleviated in the short term
Price drop is limited

Application level: high-speed use is not good

High-frequency applications generate various interference and crosstalk in the circuit
Silicon carbide MOSFET is falsely turned on, which will lead to power application prolem

Material, process and application technology breakthrough threshold is high, the upstream and downstream feedback closed-loop is time-consuming and labor-intensive

The Road to SiC Industrialization in China

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Industrialization Development Issues of SIC Devices in China

Criteria for the success of industrialization

Low cost, high quality, high volume

planned layout **Investment scale**

≠

actually achieved **Production capacity**

≠

achievable **Supply Capacity**

≠

available **Market revenue**

Its own industrial technology level is immature

The process and products are immature and have not been verified by large-scale applications

The ability of upstream and downstream industries to cooperate is immature

The substrate material cannot be supplied, the cost cannot be reduced, and the downstream products cannot be sold by themselves

Industry status determines the small scale

Being crushed by foreign manufacturers, customers are reluctant to be guinea pigs and have been in a spare tire position for a long time

The fundamental contradiction between slow industry and urgent capital return

The main contradiction of slow upstream maturity and rapid downstream demand growth

The practical contradiction of slow output and urgent planning

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Fabless and Foundry

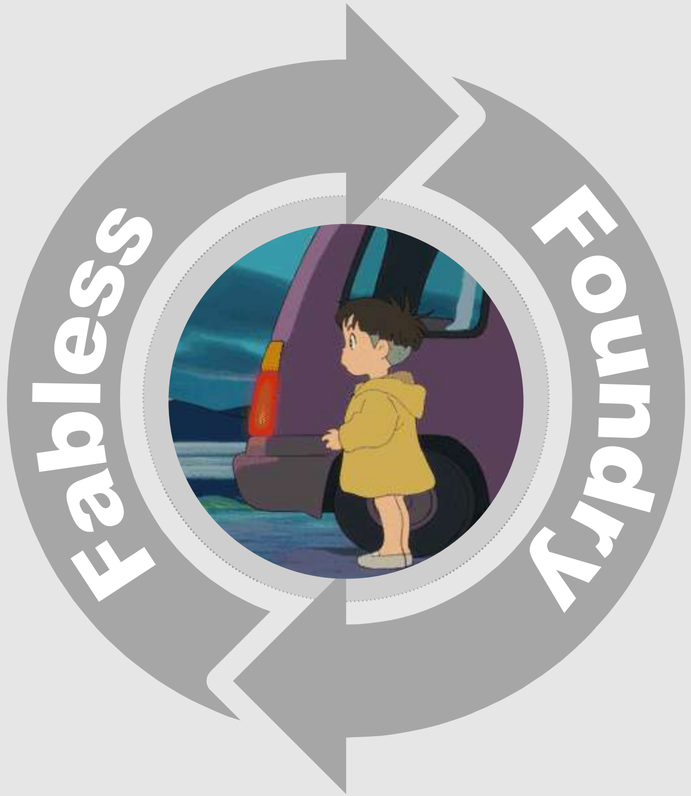
package
wafer
design
epitaxy
substrate

International Fabless

- Asset-light, less investment, less burden
- Focus on device design
- Fast product introduction based on Foundry process capabilities

Chinese Fabless

- Cooperation with international and Chinese Foundry partners
- Some companies stick to Fabless
- Some enterprises have transformed to IDM



International Foundry

- start early
- Relatively mature process technology

Chinese Foundry

- started late
- The process is not yet mature

XFAB EPISIL SMIC GTA

package
wafer
design
epitaxy
substrate

IDM

package
wafer
design
epitaxy
substrate

Don't ask "advantages", focus on "shortcomings"

A rare opportunity in the industry window in ten years, hurry up to invest and build a factory
Seize the wind of the industry and grasp the big cake of the market outbreak

The size of the layout is too large

- The amount of investment is too large, the burden is too heavy, and the operating cost is extremely high
- Rapid blood loss, cash flow breaks

The scale of the layout is not enough

- Insufficient scale effect and low customer acceptance
- High device cost and insufficient market advantage
- Repeated investment is time-consuming and expensive, and new investment cannot be attracted

Annual production capacity	Major equipment set Number	clean room area (100, 1000, 10,000 level)	Land	Basic operating cost per year	fixed depreciation
50,000 wafer	100 sets	3000㎡	40,000㎡	~40 million	~40 million
100,000 wafer	200 sets	7000㎡	60,000㎡	~100 million	~100 million
200,000 wafer	400 sets	12,000 ㎡	100,000㎡	150 million	~150 million

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The whole industry chain

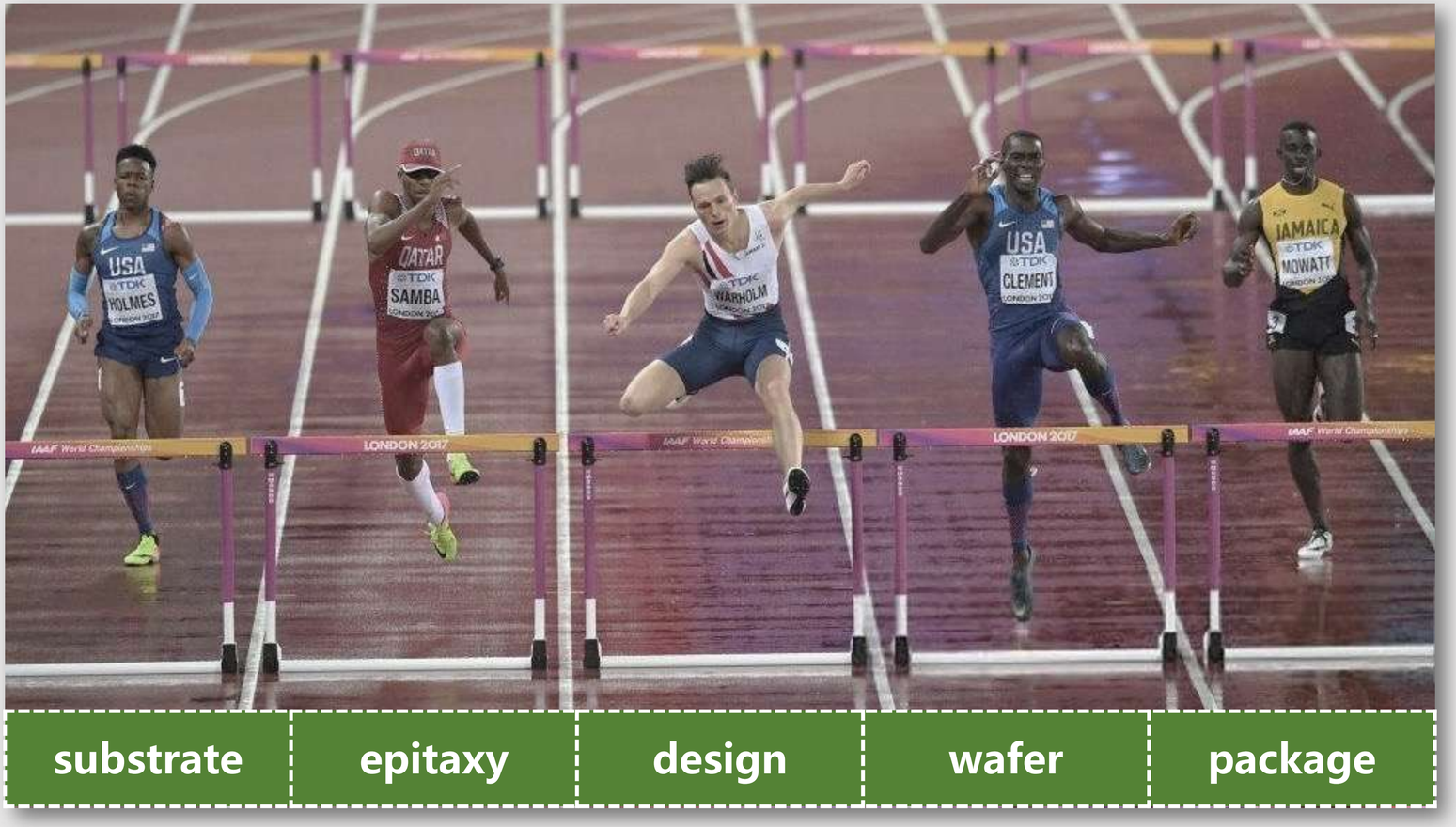
Control all aspects of the industrial chain and become an international giant

Wolfspeed ← CREE
2021.10 1987

ROHM SEMICONDUCTOR + SiCrystal A ROHM Group Company
2009.07

ST + NORSTEL
2019.02

onsemi + GT ADVANCED TECHNOLOGIES
2021.08



substrate	epitaxy	design	wafer	package

Development Route of Domestic Device Industrialization

substrate → epitaxy → design → wafer → package

★★★★★ ★★★ ★★★ ★★★★ ★★★

TANKEBLUE
SICC
同光晶体 SYNLIGHT CRYSTAL

瀚天天成 电子科技(厦门)有限公司
TYSiC

Seek stable epitaxy supply

Fabless

- Asset light
- Focus on device design
- Fast product launch
- Need to be bound with Foundry

Foundry

- high investment threshold
- Focus on process
- Need to have enough orders to maintain the line
- Seek future expansion into devices with own brand

IDM

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- high investment threshold
- It takes 3-5 years from the establishment of the factory to the large-scale supply
- longer payback period
- Master SiC core technology
- Product differentiation advantage
- special product development
- Independent quality control
- Guaranteed output and lead time
- favored by customers

Whole supply chain

- High investment threshold
- The whole industry chain runs through a long time
- longer payback period
- **Facing technical challenges in all aspects**
- **Need to solve many problems asap otherwise conflicted company may not cooperate with them**
- Guaranteed output and lead time
- cost advantage
- favored by customers
- The whole industry chain is independent and controllable
- Strong anti-risk ability

Global Power Technology Co., Ltd.

GPT's IDM model

Established 2011-04

Registered capital 250 million yuan

Company Target

The third generation semiconductor material silicon carbide device Manufacturing and Application Solutions Provider

Development Vision

Filling the gap in China's silicon carbide field.Leading the core technology for the next 50 years

Changsha 6-inch wafer line
Established in 2019,
mass production in 2021
The first-phase investment is 300 million yuan, 60,000 6-inch wafers per year

Changsha discrete device packaging line
Q1 start in 2022, 35kk/year

Beijing R&D Center
started in 2022

Beijing 4-inch wafer line
Established in 2011, mass production in 2013
Investment of 120 million yuan, 8,000 4-inch wafers per year

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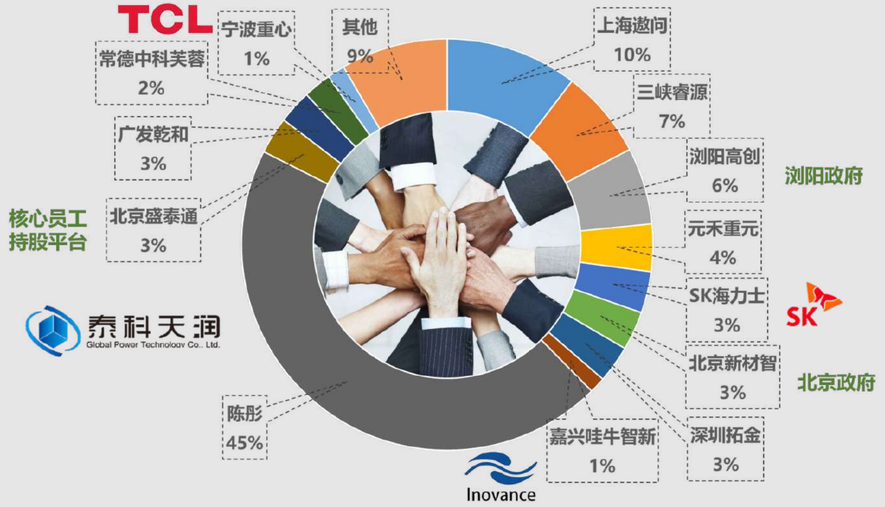
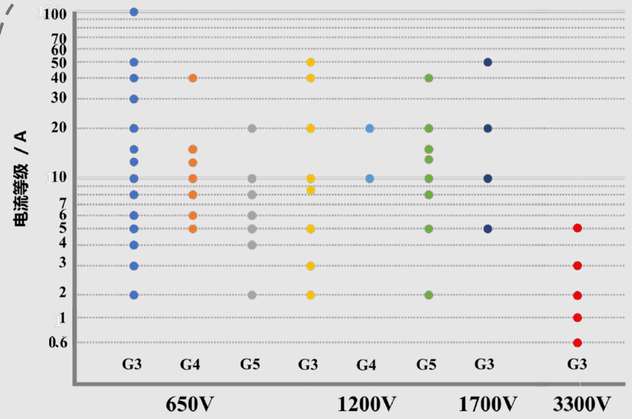
6-inch silicon carbide wafer production line
Mass production and delivery in September 2021

Launch in 2019
The first phase investment is 300 million yuan
The first phase of 6-inch wafers 60,000 / year

Complete the D round of investment in 2021
E-round investment is about to start

Capital continues to be optimistic
Support from upstream and downstream parties





IATF 16949

AEC-Q101

PC power

Mining machine power supply

Server power

LED power

electric car

Photovoltaic

electrical tools

adapter

Charging module

UPS

HVDC module

Micro inverter

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Thanks!

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