FONDAZIONE BRUNO KESSLER

CENTER FOR SENSORS & DEVICES

CHIP ACT nella Fondazione Bruno Kessler: QBit e il futuro della microelettronica

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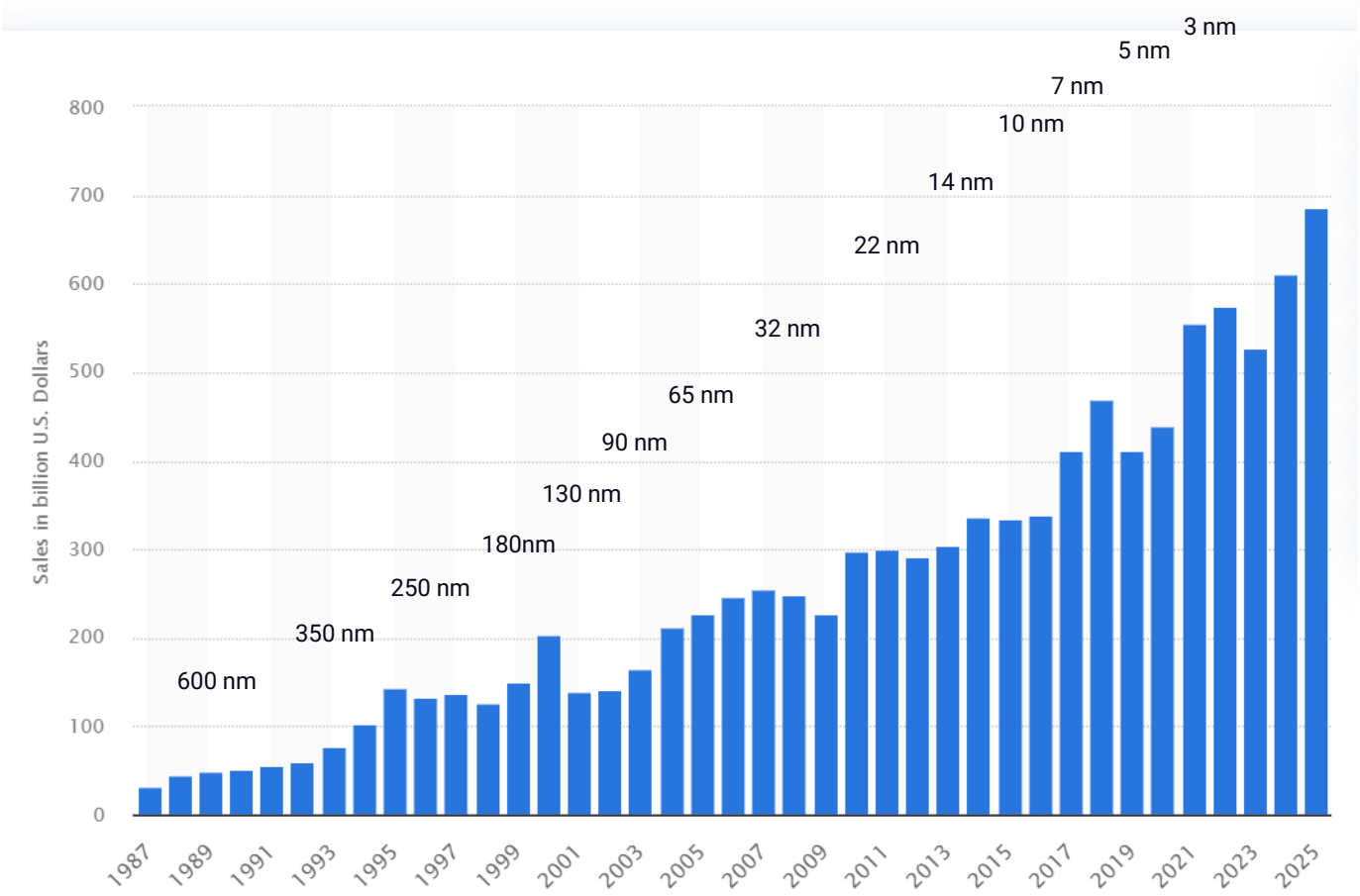
Once upon a time

- Long Time Ago
- Far Far Away

Microelectronics

- Microelectronics is transforming from an emerging scientific field into an industrial and commercial sector of global significance, laying the foundations for the third industrial revolution
- Fore Runners **Fairchild Semiconductor**, **Texas Instruments** and **Intel**
- In 1980, with the introduction of the 8086, microelectronics entered everyday life
- First European companies STMicroelectronics, Siemens, Philips



OLIVETTI

The turning Point

Delocalisation

Technically, delocalisation refers to the transfer of the production of goods or services from companies located within the territory of a given country to other companies located abroad.

Globalisation

Globalisation is the process of increasing interconnectedness and interdependence among countries, economies, cultures, and societies through the exchange of goods, services, information, and ideas, facilitated by advances in technology, trade, and communication.

Microelectronic delocalization

80 Decade

- Japan
- Malesya; South Korea, Taiwan

90 Decade

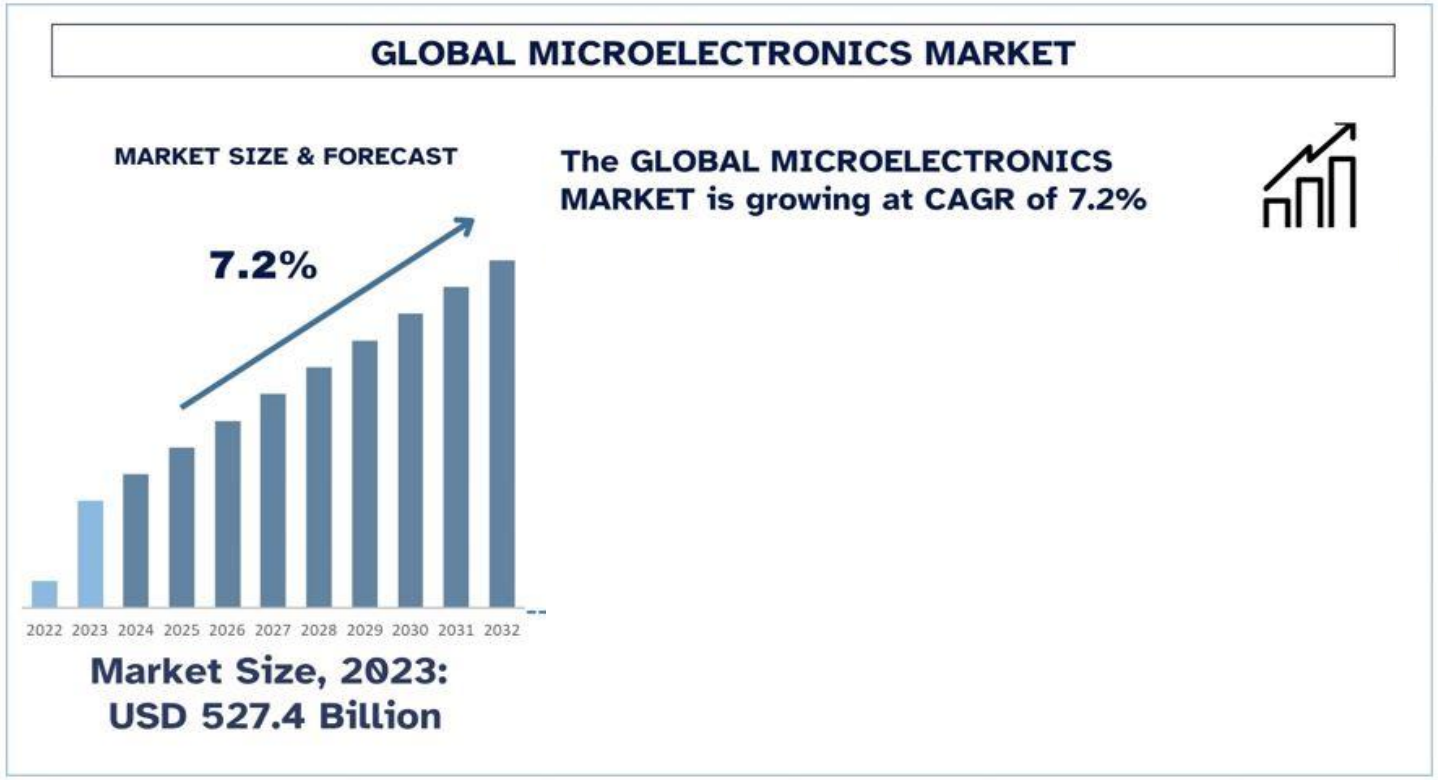
- China

2014-2025 China Integrated Circuit Industry Investment
B€ 150

The Dragon Raise

Dragon Effect

- 75% production in East Asia
- China focused the production of raw material for microelectronics
- In Europe few strategic factors
- EU market is below China one



2022 Supply chips crisis

Hero wake up

EU Chip Act

B€ 34

Strengthening research and innovation among European research institutes

Strengthening design and production

New Rules on State Aid

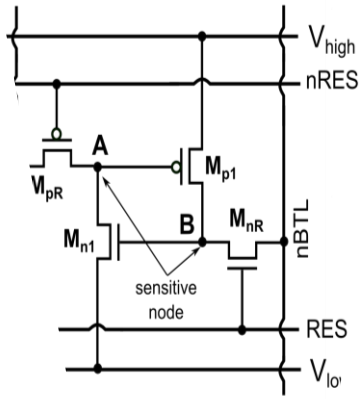
FBK Strategy

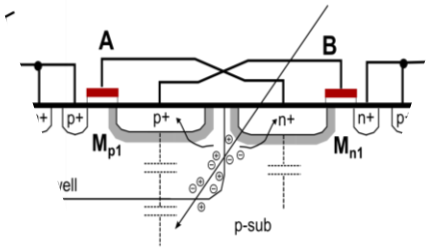
➢ More than More	➢ IPCEI M€ 14
➢ Q-Bit	➢ IPCEI ME/CT M€ 57
➢ Wide Band Gap Materials	➢ FESR 2 M€ 6
➢ Photonics	➢ WBG M€ 15
	➢ Phot PL M€ 4

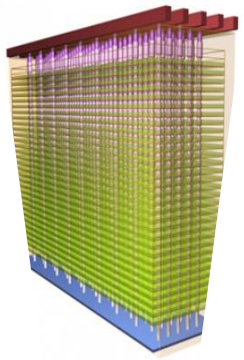
More than More

A fully digital circuit sensitive to the charge induced by ionising particles removes the need for oversized analogue amplifiers.

These sensors can allow a nanometer resolution





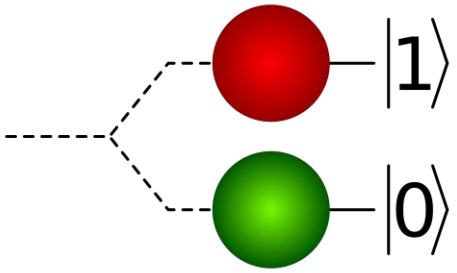


What is a qubit?

Qubit = basic unit of quantum information

What do we need to make a qubit?

A system with separate energy levels that behave quantum mechanically



Qubits need to be

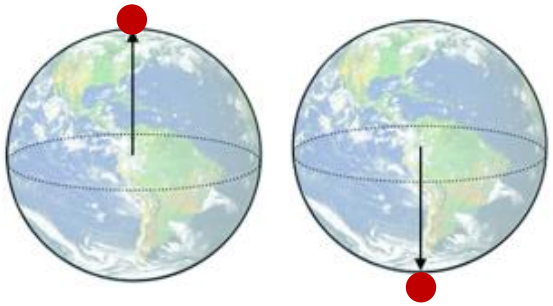
- *coupled* to external control perform quantum computation
- *decoupled* from external influences

} conflicting requirements

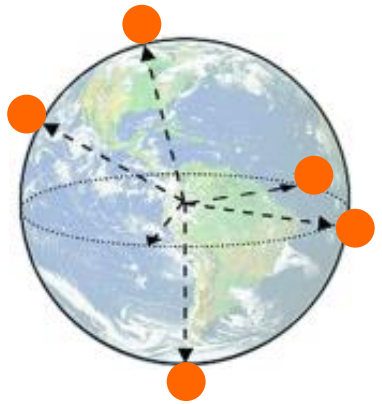
Classical bit *versus* Quantum bit (Qubit)

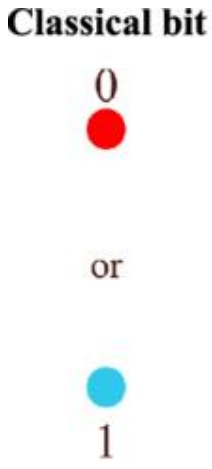
Qubit = basic unit for quantum computing

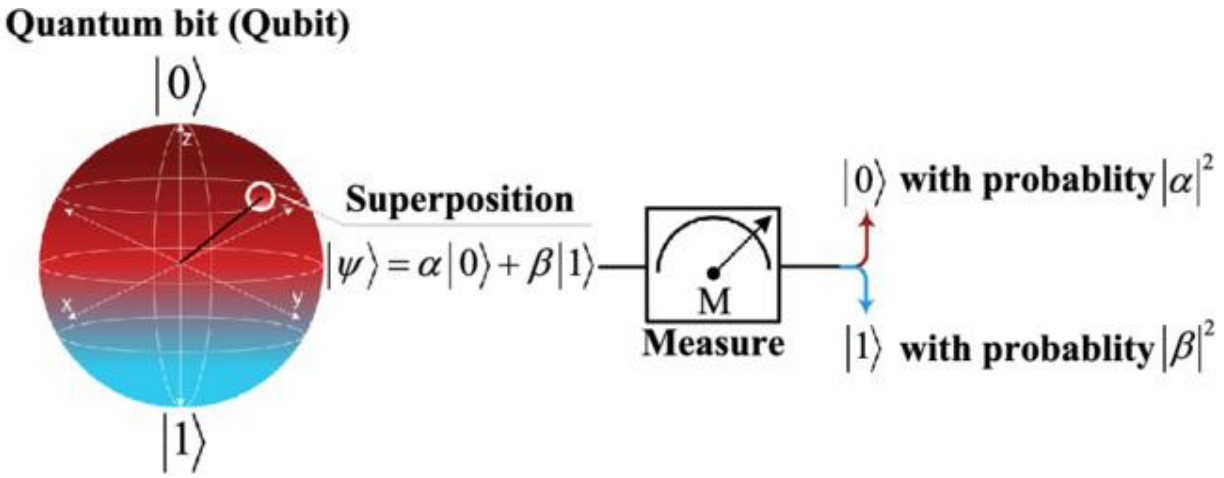
With a classical bit is like if we can be only at the North pole or at the South pole



With a quantum bit (qubit) we can stand in any spot on the globe



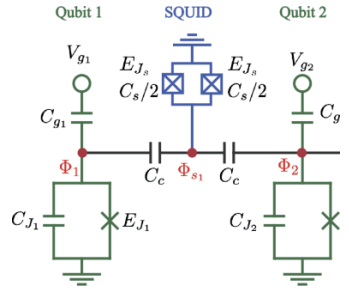




Superconducting qubits

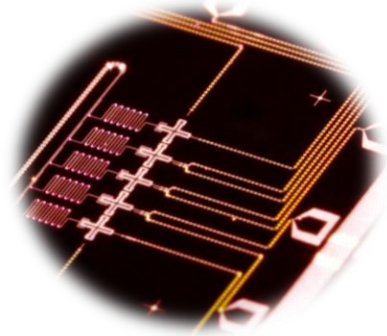
Why superconducting circuits?

Tune macroscopic ***classical*** circuit elements (*L*, *C*, …) to control the circuit ***quantum*** behaviour



How superconducting qubits are made?

Planar devices microfabricated on silicon (or sapphire) wafers using superconducting metals



How superconducting qubits are operated?

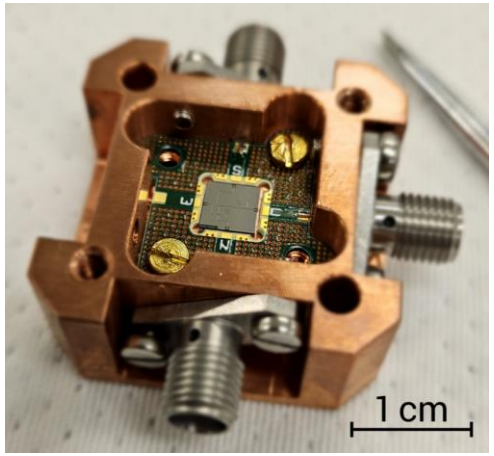
Cryogenic setups, $T \approx 10$ mK
Control and read-out with **microwave electronics**, $f \approx 10$ GHz

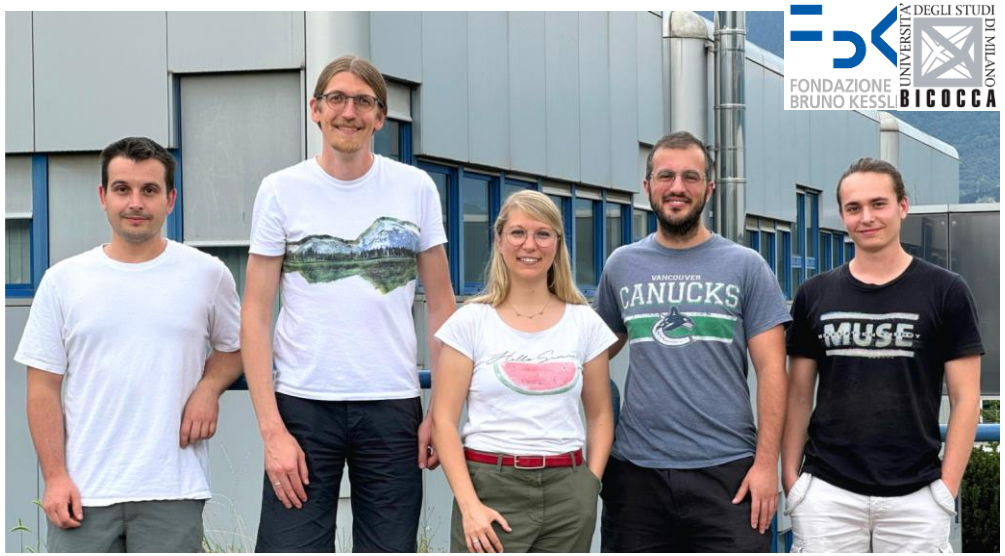
Google

At FBK the first superconducting qubit made in Italy

Press release 7 August 2024: magazine.fbk.eu/en/news

At the Fondazione Bruno Kessler in Trento, the first superconducting quantum bit (qubit) built entirely in Italy was born.





Initial measurements on the device, conducted in the **cryogenic laboratory in Trento**, have proved the quantum nature of the circuit, [...], with quantised energy levels

The challenge was to learn how to manufacture the [...] *Josephson junctions*. For this purpose, a specific **microfabrication process was studied and developed in FBK Clean Rooms**.

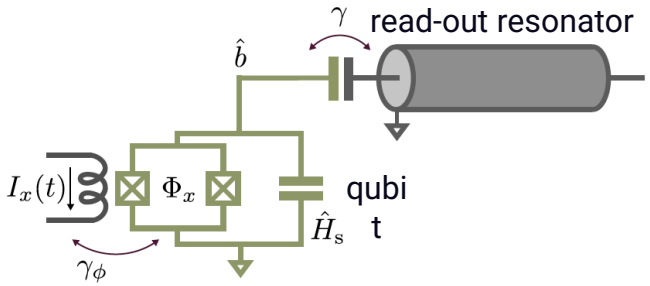
The transmon manufactured at FBK is a standard layout[2] **designed by the FBK team in collaboration with the INFN Milano-Bicocca researchers**.

Research Team

F. Ahrens (FBK researcher), M. Faggionato (FBK-UniMiB Master), N. Crescini (FBK researcher), A. Irace (FBK-UniMiB PhD), F. Mantegazzini (FBK Team Leader)

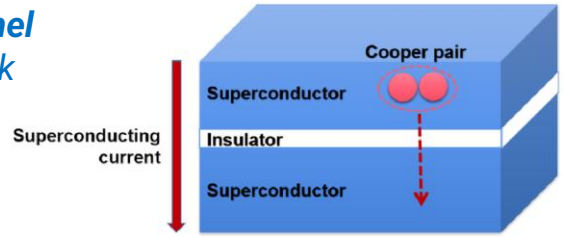
The microfabrication process

The FBK qubit (***transmon***) circuit is based on **Josephson junctions**.

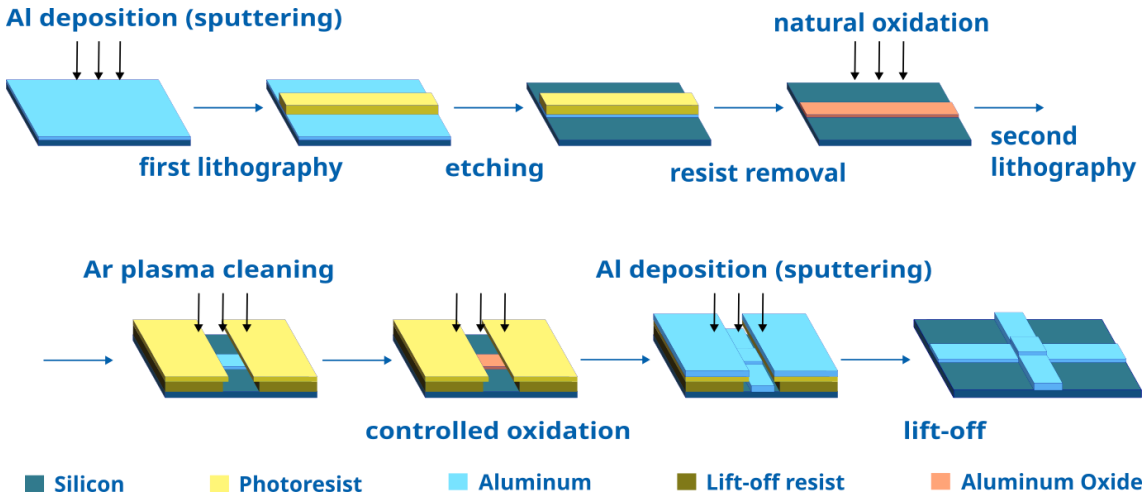


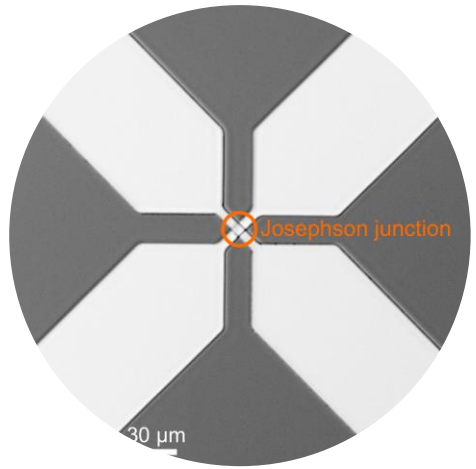
Josephson junction =
two superconducting layers separated by a weak link

*Cooper pairs can **tunnel** through the weak link*

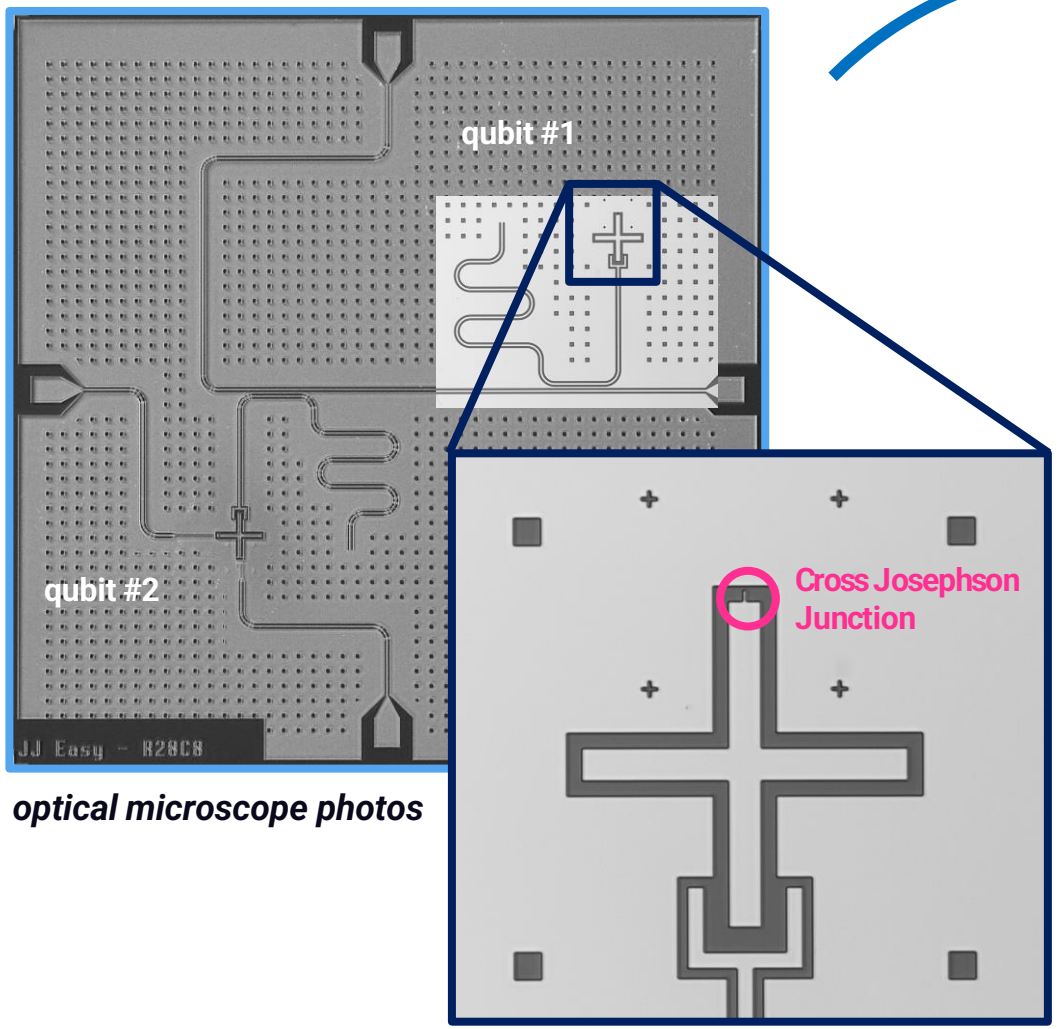


At FBK we have developed a microfab process to realise cross Josephson junctions



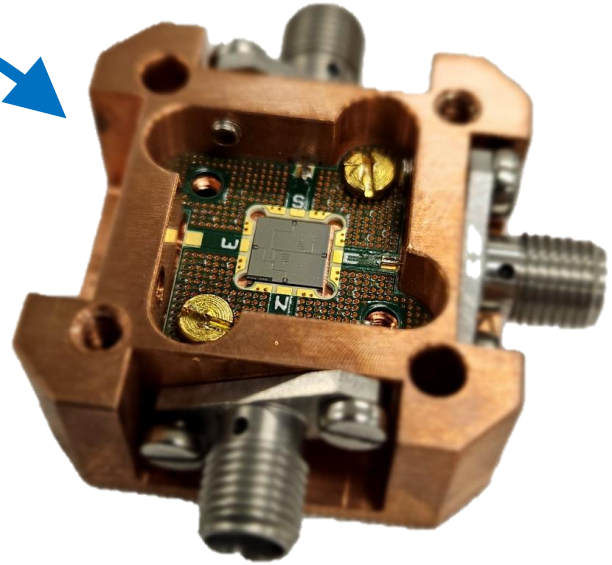


The qubit device

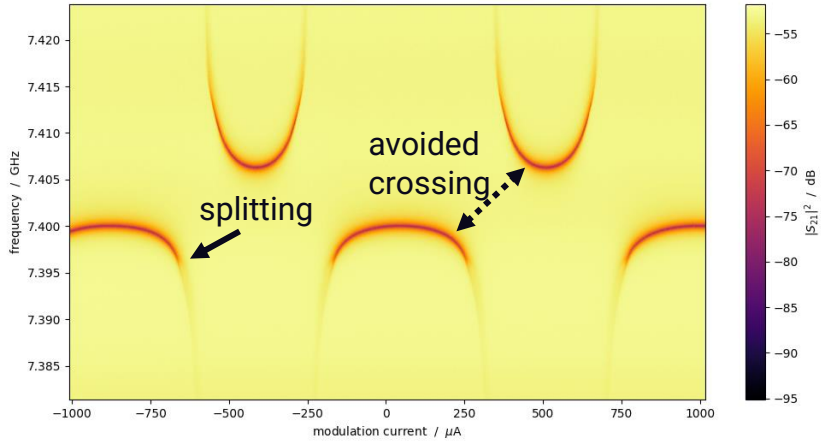


optical microscope photos

packaged in a cryogenic rf set-up



Preliminary cryogenic measurements:
We observe signature of the quantum energy levels



Impact & market of superconducting quantum computing

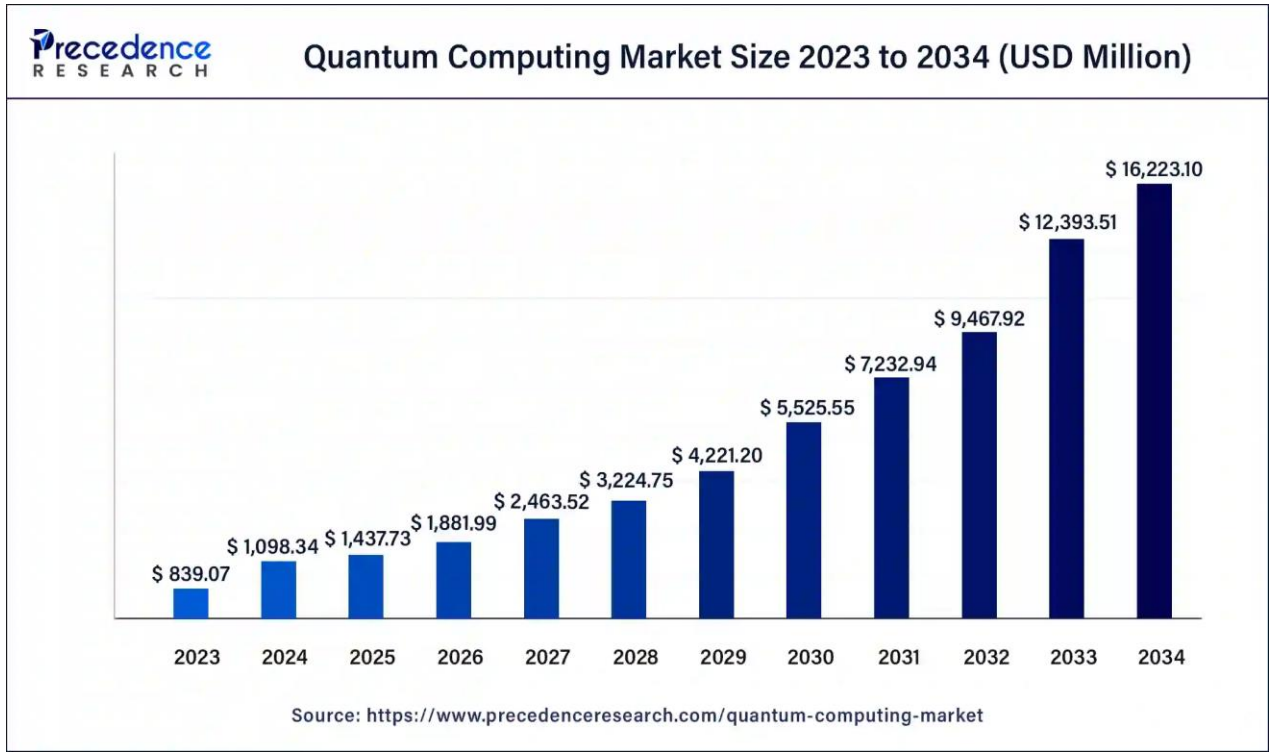
European Commission | Chips JU

Shaping Europe's digital future

The Chips Joint Undertaking (Chips JU) opened calls to support semiconductor research and innovation initiatives.

This is the first such call in quantum technologies to step up investment in frontier technologies, in particular quantum chips for computing and sensing.

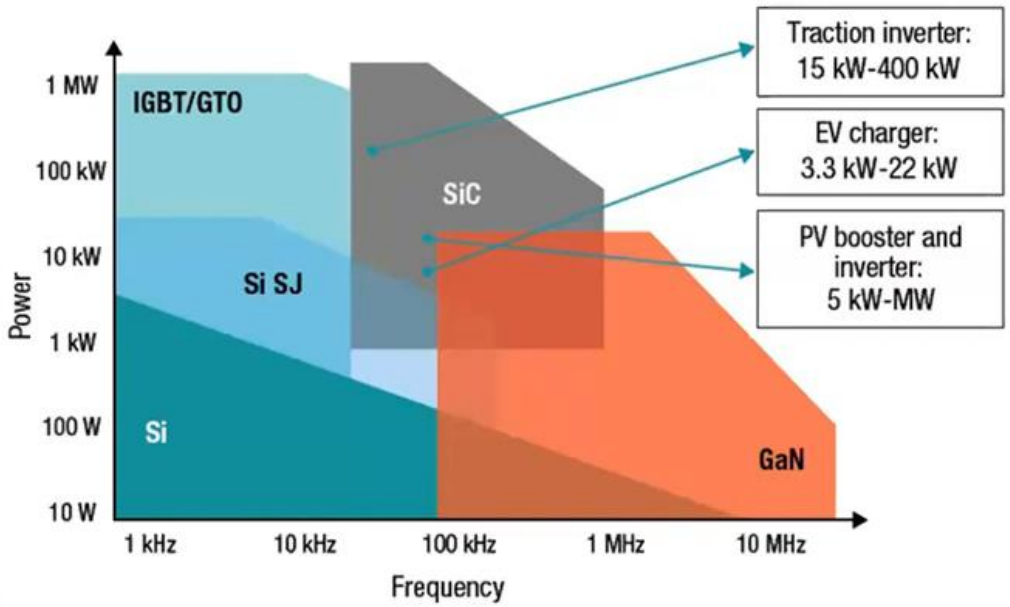
Real-world applications include solving complex optimisation problems in logistics and supply chain management, accelerating drug discovery through molecular simulations, enhancing cybersecurity with advanced encryption methods, and improving artificial intelligence and machine learning algorithms.

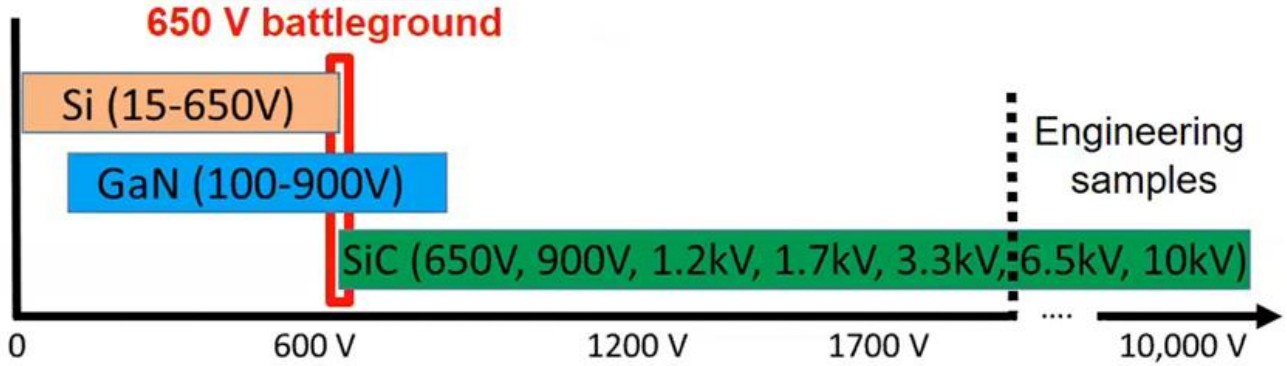


Qubits and quantum circuits are quickly spreading from research laboratories, to start-ups and to the **corporate world**.

Si vs Wide Band Gap Semiconductor

Source: Texas Instruments



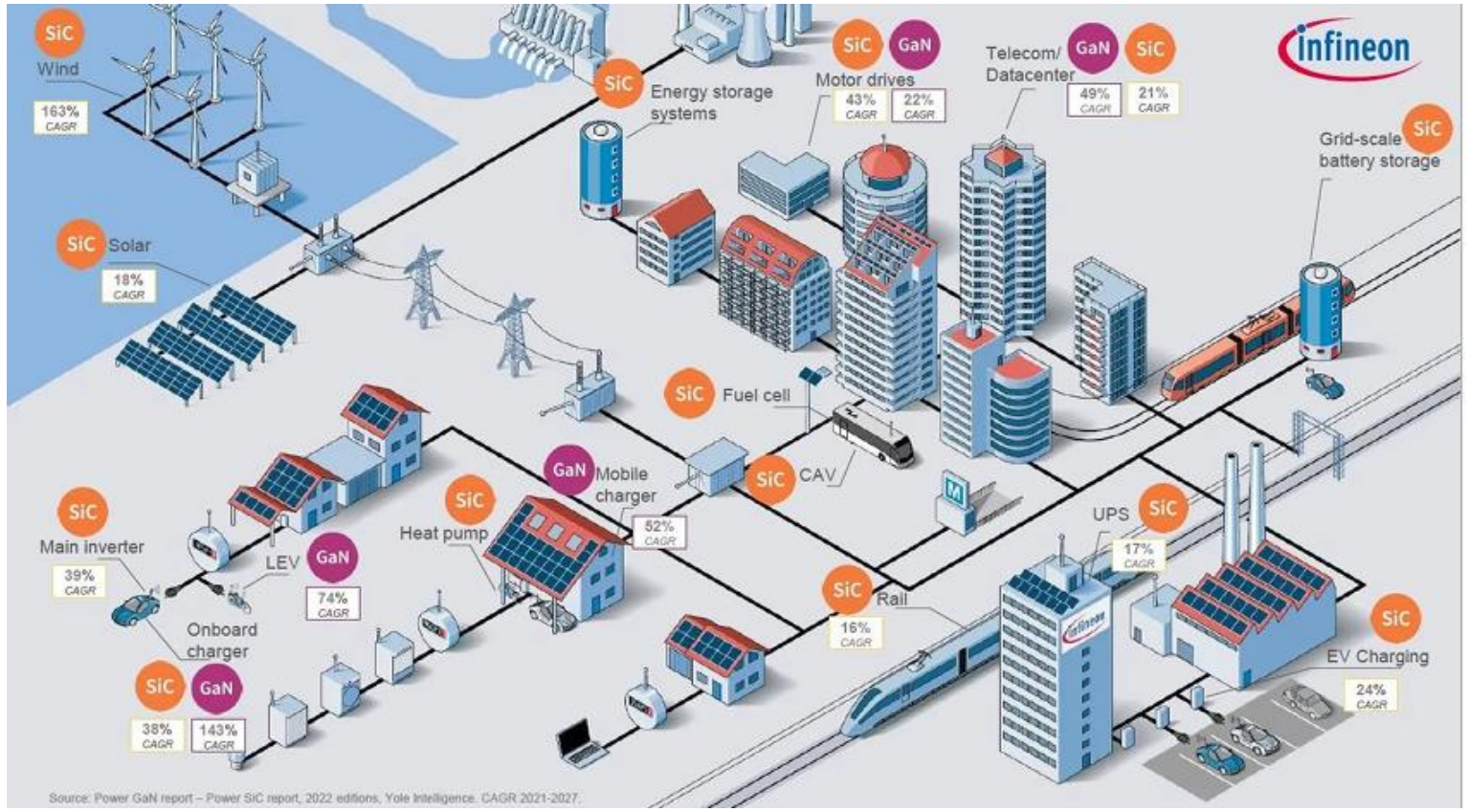


Si, GaN, and SiC all compete in the lucrative 650 V range:

- *Si* is reliable, rugged, cheap, capable of high currents, and has device/circuit design legacy
- *SiC* is efficient and operates at high currents and frequency
- *GaN* offers efficient very high frequency operation at reasonable cost

Wide Band Gap

- **Superior energy efficiency**
- **Transition to green energy**
- **Acceleration in electric vehicles (EVs)**
- **Device miniaturization**
- **Reliability and longevity**



As per TrendForce's survey, the market size of global SiC Power Devices was around USD 3.04 billion in 2023 and is expected to grow to USD 9.17 billion by 2028 at a CAGR of 25%.

Wide Band Gap

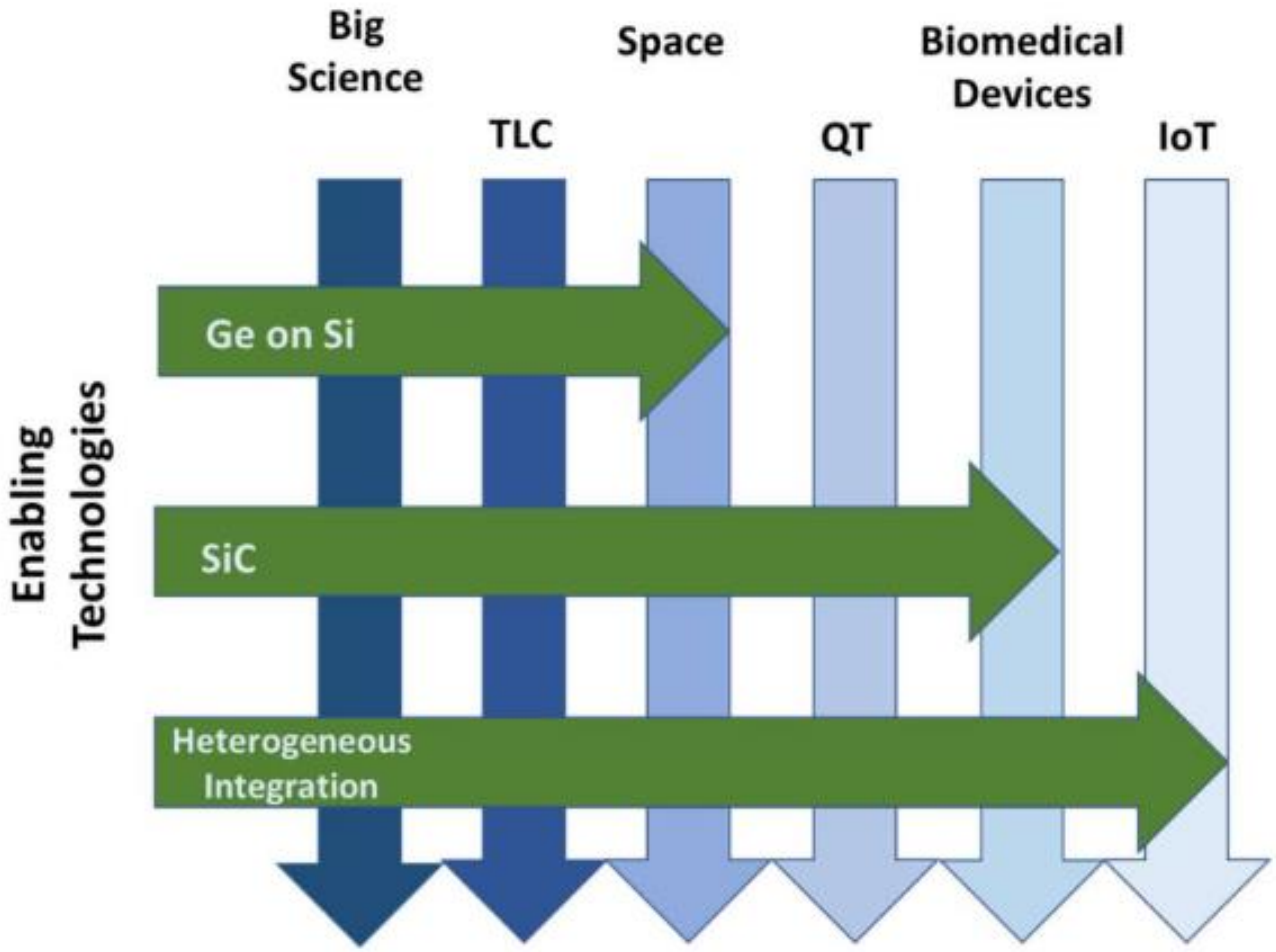
SiC represents a pillar for the energy transition and the growth of advanced technologies

- WBG power and HF devices: materials & devices processing, characterisation, modelling and reliability.
- Packaging and 3D integration
- Radiation Sensing

➢ Testing Clean Room

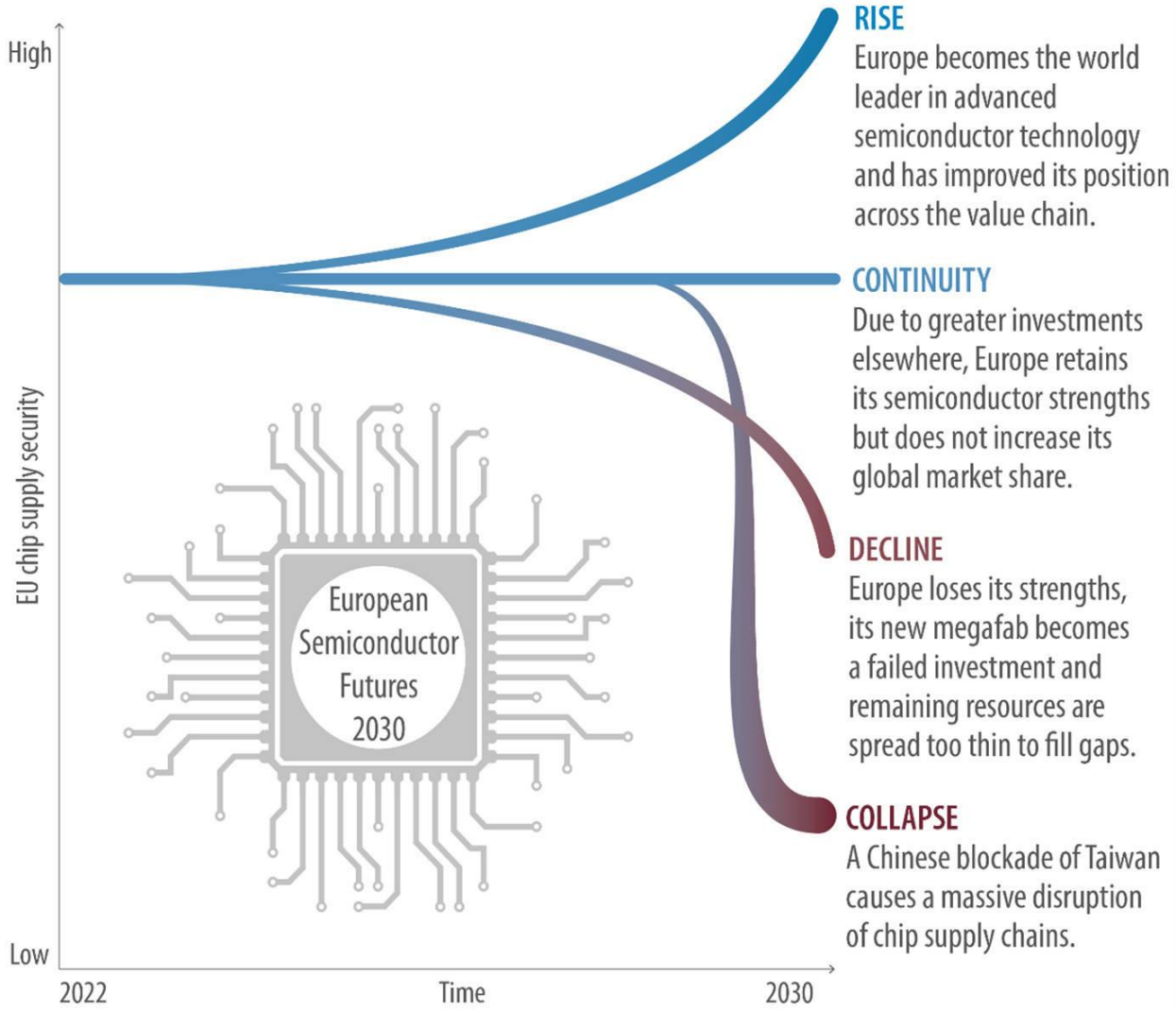
➢ Characterization facility

Wide Band Gap



Happy end?

EU prospective



Thank for you attention