



Chips***
jü

WEECS 2024
GHENT BELGIUM
5-6 December

Challenges in Superconducting Chip Fabrication

Pekka Pursula

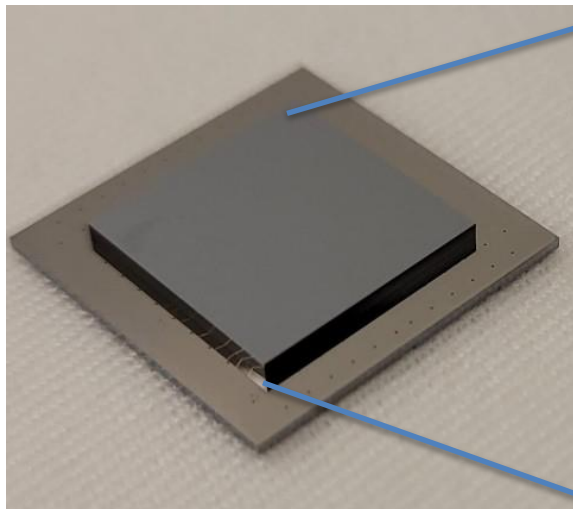
VTT

Technical Research Centre of Finland

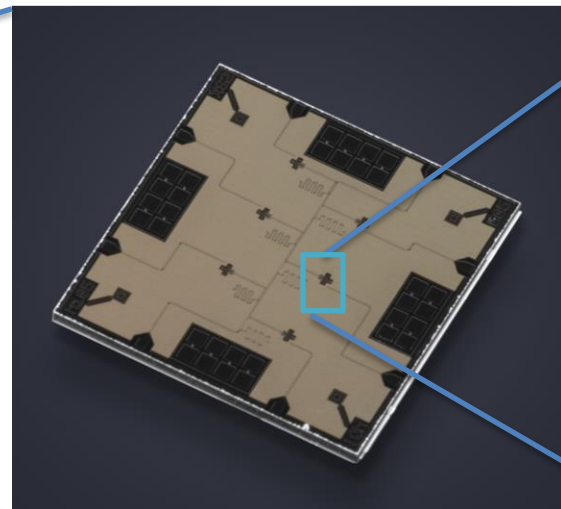
Superconducting Quantum Technology Platform

Superconducting technology is one of the most mature quantum technology platforms:

- Based on mature semiconducting fabrication techniques
- Large scale, high-quality QPUs and quantum computers exist



3D-integrated
QPU module

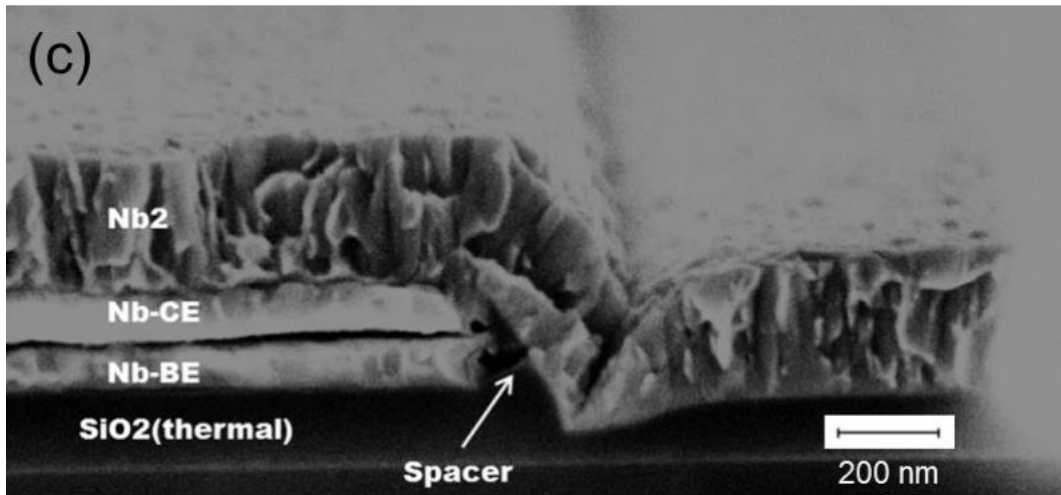


Qubit chip



Qubit

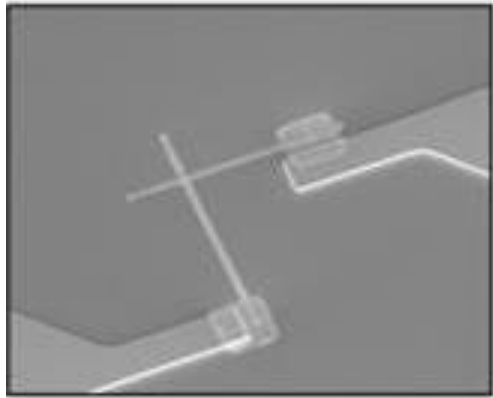
Josephson Junction



Josephson junction stack

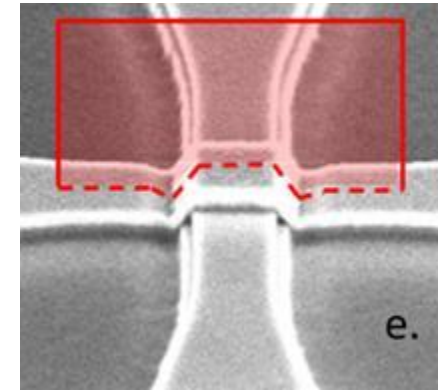
- Tunnel junction, typical stack Al/AlO_x/Al, with oxide thickness ~1nm
- Size 100nm – several um
- Superconducting material stacks include materials not typically used in semiconductor industry: Aluminium, Niobium, Tantalum, Indium, Nitrides: TiN, NbN...
- Q-values 10^7 @ GHz range
- Two junction process types: angle evaporation and trilayer junctions

Fabrication and Scaling Challenges: Josephson Junctions



Angle evaporation

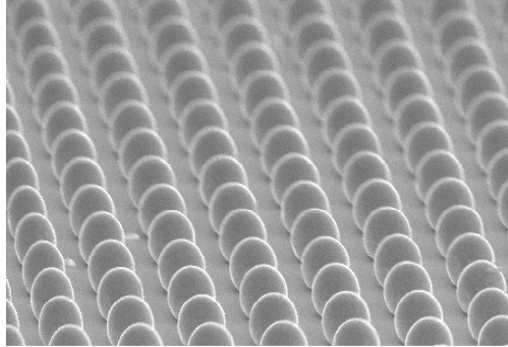
- Excellent quantum coherence
- Proces not widely used in semiconductor industry
- Small wafer sizes: 100-200mm
- Lower repeatability and yield, does not enable complex circuits with large number of junctions



Trilayer junctions

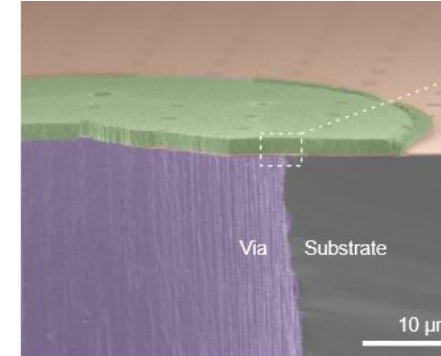
- Lower quantum coherence
- Standard sputtering and/or evaporation process
- Larger wafer sizes up to 300mm
- Higher repeatability and yield, enables complex circuits with large number of junctions

Fabrication and Scaling Challenges: 3D Integration



Bumping and Flip chip

- Superconducting bumps, typically Indium
- Density not as important as losses and quantum coherence
- Typically chip level flip-chip

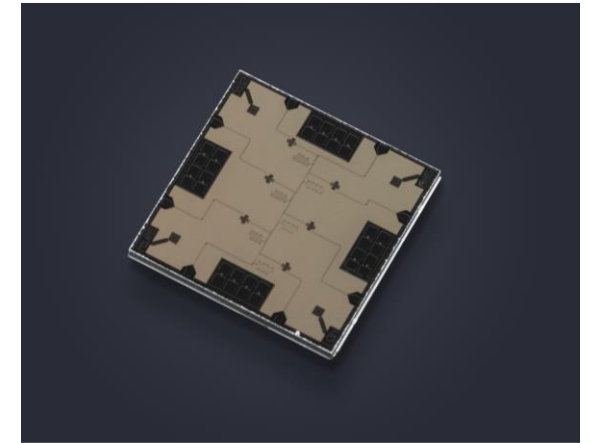


Superconducting TSVs

- Superconducting TSVs
- ALD superconductors, e.g. TiN
- Thick substrates >500 μm
- Density not as important as losses and quantum coherence

The Superconducting Pilot Line

- Superconducting processes rely on mature processing techniques used in semiconducting industry, but require non-typical material stacks
- Market currently exists for QPUs and TWPAs, and certain sensor components
- The superconducting pilot line will develop stable and scalable high-quality quantum processes for superconducting devices
- The processes will be available for external users through PDKs and scheduled fabrication runs



Qubits



TWPA