Masters's Project

3D Integration of Semiconductor Based Spin-Qubits

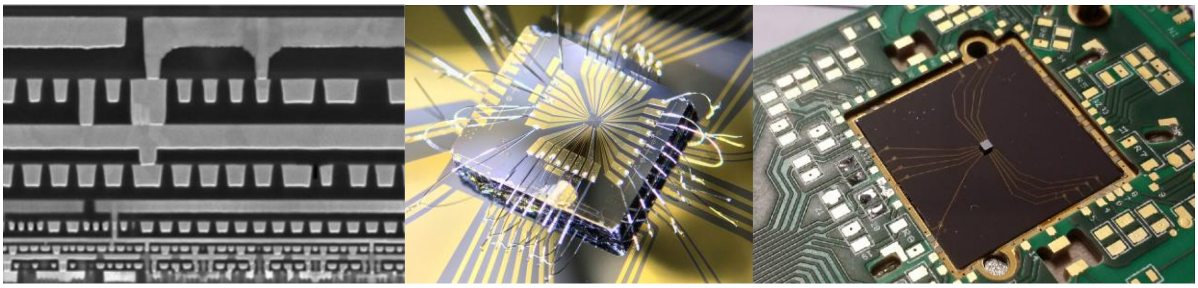

Fig. 1 (Left) *Example of 3D integration in a current generation Intel CMOS Chip*[1]***. (Middle)*** *This image shows a quantum chip connected to its interposer using aluminium bond wires. Each of the wires is placed manually in order to connect the qubit.* ***(Right)*** *This picture shows a dummy quantum chip in the center. It is flip-chipped onto an interposer, which is in turn placed on a printed circuit board (PCB, green). This PCB can then be connected using an ordinary 40-pin connector and is placed in a dilution refrigerator at cryogenic temperatures.*

[1]https://www.intel.com/content/www/us/en/architecture-and-technology/bohr-14nm-idf-2014- brief.html

Background

As semiconductor-based spin-qubits move from samples with small qubit numbers to larger scale devices, scalable control and packaging will become increasingly important in the quest for quantum computation. While current generation spin qubits usually require an entire rack of control electronics to operate them, current proposals aim for a direct integration of quantum and classical counterparts on the same chip using 3D integration. While these techniques are well established in the semiconductor industry and have been used for superconducting qubits, they are a novelty in the field of semiconductor spin qubits.

Your Task

Your Task will be the development of a flip chip bonding process with high contact density for GaAs spin qubits. In the future, this process can easily be adapted to other material systems such as SiMOS or SiGe spin qubits. In order to achieve qubit numbers exceeding 40 double quantum dots on a single chip, both, the design of the quantum chip as well as the interposer have to be optimised. This task will include fabrication of qubit chips as well as corresponding interposers as a first step. Additionally, the flip chip process has to be developed in order to achieve a reliable assembly with high contact (bump) numbers and small contact size. In the last step, control electronics will be placed next to the qubit chips using flip chip technology as well and be used to control the qubits.

This project will allow you to extend your knowledge of these topics, among other things:

- Theory of electron spin qubits and quantum computation
- Qubit fabrication and assembly processes
- Architecture considerations for electron spin qubits
- First characterization of high-density quantum chips

Furthermore, you will participate in group seminars and Journal Clubs to discuss cutting-edge developments in this area of research.

References

https://www.nature.com/articles/s41534-017-0038-y,

https://www.nature.com/articles/s41467-017-01905-6,

https://www.nature.com/articles/s41534-017-0044-0,

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