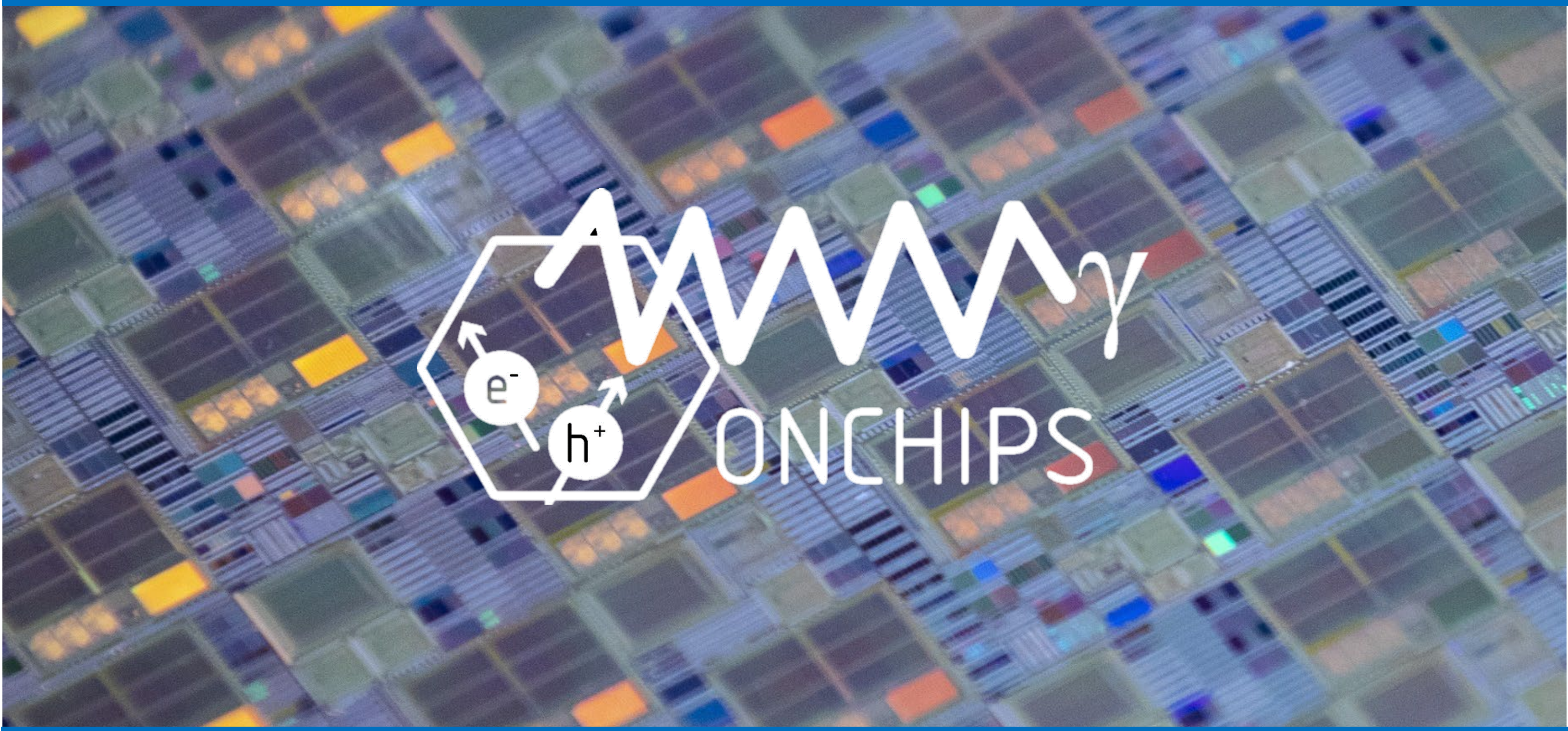

ONCHIPS bulletin - 2nd issue

February 2025

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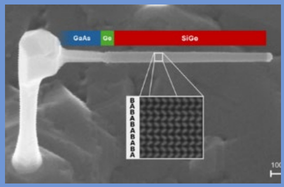

The ONCHIPS project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101080022

New chip to solve quantum computing roadblocks -

Quantum Flagship – press release

The ONCHIPS project is making a significant impact in the quantum computing world, attracting widespread attention from science and technology media across the EU, UK, and US. Following the Quantum Flagship press release, the project has already garnered over 30 pieces of media coverage. Notable mentions include leading Netherlands outlets like Computable, Silicon Canals, and Bits & Chips, as well as coverage in MSN News and Mobeez, a French publication with 3.6 million monthly visitors. This press buzz highlights the innovative work of the ONCHIPS consortium and underscores the exciting potential of our technology.

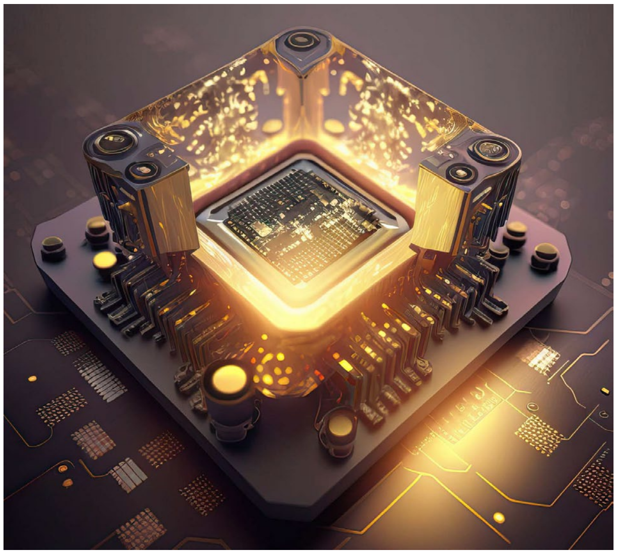

Figure 1 Artistic reporesentation of a light emitting chip created by Jason Jung using Midjourney v4.

The European Commission is investing in a groundbreaking quantum chip that combines light and electronics for the first time, promising faster, more efficient quantum computers.

Supported by the Quantum Flagship, the ONCHIPS consortium is laying the foundations for a new type of quantum hardware with advanced materials that have never been combined before.

The team hope to make quantum computers more practical for real-world applications and enable them to solve the most challenging problems we face in the world today– unlocking new possibilities for science, industry, and everyday users.

To make this vision a reality, the ONCHIPS consortium is turning to Germanium-Silicon (GeSi) – a material whose ability to efficiently emit light was only discovered in 2020.

Quantum's Scaling Problem

Quantum computers are set to be exceptionally powerful tools for solving certain types of problems, like simulating molecules for drug discovery, optimising complex systems, or breaking encryption. However, researchers seeking to scale them up to the size face significant hurdles.

Just as the first computers of the 1950s were impractical and unsuitable for widespread adoption due to their enormous size and limited processing power, today's quantum computers have their own challenges, particularly with their fundamental building blocks, or 'qubits.'

"One major issue of scalability is that qubits are often limited in their ability to interact with one another," explains project coordinator Professor Floris Zwanenburg, full professor at the University of Twente's MESA+ Institute for Nanotechnology. "As the number of qubits increases, effective communication between them becomes more complex."

But Germanium-Silicon (GeSi) presents a viable solution to overcome these bottlenecks.

"We are combining spin qubits for computation and photonics for communication on a GeSi platform that is compatible with traditional CMOS manufacturing, which could be a total game-changer for scaling quantum computers. By combining spin qubits (electrons) with photonic communication (light), the chip bridges the gap between processing quantum information and transmitting it over long distances. This will significantly help us solve a major bottleneck in quantum scalability," Professor Zwanenburg said.

Read the entire press release on:
[New chip to solve quantum computing roadblocks | Quantum Flagship]

Highlights from the second phase of ONCHIPS

ONCHIPS' dynamic team experiences a highly productive second phase of the project, yielding significant results across all key areas.

Our partners from CNRS – Saclay and TU Eindhoven have conducted an in-depth investigation into the growth of SiGe hexagonal nano-branches on GaAs nanowires and bulk nonpolar substrates. A summary of the growth methods and results is provided on the last page of this bulletin.

High quality nanowires devices are developed at the University of Twente and their electrical transport properties are currently investigated. The progress we made towards defining tuneable quantum dots is an important prerequisite for obtaining a spin qubit.

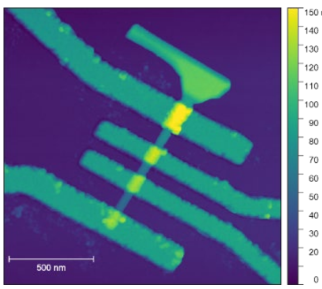

Figure 2: AFM scan of nanowire devices fabricated at the University of Twente.

The optical spectroscopy measurements on single hex-SiGe nanowires performed by our partner from TU Munich largely confirm the theoretical predictions. To experimentally determine the electron and hole g-factors and intrinsic spin relaxation dynamics in bulk hex-Ge and hex-GeSi as well as heterostructures and quantum dots, magneto-optical measurements will be carried out by TU Munich. These measurements rely on efficient and fast detection of the emitted light from hex-GeSi structures and quantum dots in the 2.3-3.4 µm range. To provide a suitable light detection solution to carry out these experiments, Single Quantum has developed, optimized, and benchmarked superconducting nanowire single-photon detectors for these wavelengths. The detectors were placed in a tailored detection system built specifically for this task that offers unprecedented single-photon detection capabilities for realizing the challenging characterization of spin dynamics in hex-GeSi nanowires and quantum dots. Joint experiments TU Munich – Single Quantum are being planned for the coming months.

Research performed by our partners from University of Konstanz and TU Budapest has yielded a theoretical description of hex-GeSi that can be applied to nanostructures based on hexagonal GeSi. The developed theory is used to model spin-dependent transport and optical properties and quantum coherence of the spin degree of freedom [1,2]. To support the realisation of spin qubits and spin-photon interfaces in hex-GeSi our theory is used to interpret experimental results and provide quantitative guidelines for optimized device design.

Conferences and outreach activities

The ONCHIPS consortium fosters collaborations with a wide range of stakeholders, including scientific partners, industry, startups, and end-users, through strategic meetings and engagements with projects within European and national quantum ecosystems. The consortium showcases its objectives and results at key conferences like the International Conference on Quantum Dots, Silicon Quantum Electronics Workshop, Nanowire week. Additionally, ONCHIPS promotes its research and the field of quantum science and technology beyond the scientific community through outreach activities such as videos, high school visits, lab tours, and training sessions.

Figure 3 12th international conference on quantum dots (QD 2024), Munich, organized by our partner TU Munich and chaired by Prof. Jonathan Finley.

Publications

[1] Y. Pulcu *et al.*, Phys. Rev. B 109, 205202 (2024).
[2] A. Sen *et al.*, Phys. Rev. B 108, 245406 (2023).

For more news and recent results, visit our website:
https://www.onchips.eu/

Hexagonal SiGe nanowire growth

The hexagonal GeSi has emerged as a revolutionary material which brings forward exciting photonic functionalities and has the promise to be compatible with CMOS technology. in ONCHIPS we grow enriched Ge quantum dots acting as light emitting diode in Si rich hex-GeSi nanowire, an important stepping stone for opening the field 'active' Si photonics.

Single branched nanowires for nanometric control over hex SiGe dimensions

To achieve light emission and pave the path for novel quantum devices, a suitable base material is needed. This is why the fabrication of hexagonal SiGe, the foundation of our future devices, must be thoroughly explored to learn how to shape nature as our own will. At University of Eindhoven, we successfully forced SiGe into a hexagonal crystal structure, critical for light emission, by growing it as single-branched nanowires (see figure below). The growth of both the GaAs trunk and of the SiGe branch has been performed in-situ in a MOVPE reactor. The precise control we achieved over the diameter and length of the nanowires, will play a crucial role in tuning the quantum properties of future devices. Furthermore, thanks to this new geometry, we began to explore dopants incorporation to create a p-i-n junction, a key component for electrical stimulation. However, the trunk-branch structure is not the only approach to growing hexagonal SiGe.

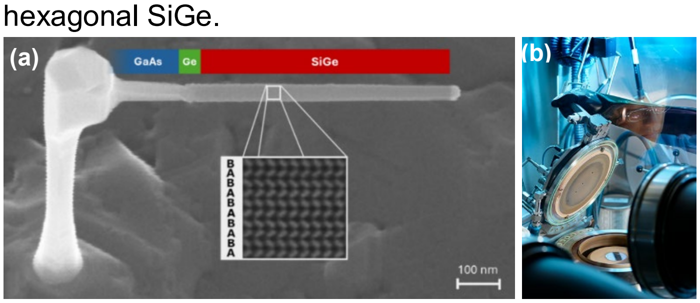

Figure 4 (a) Example of single branched nanowires grown at TU Eindhoven. The hexagonal SiGe branch has been grown by destabilizing the Au catalyst particle used to grow the GaAs trunk. (b) Reactor at TU Eindhoven where the nanowires are grown.

SixGe(1-x) nanowires on bulk non polar substrates

At CNRS Paris - Saclay we intend to grow vertical SixGe(1-x) nanowires on bulk non polar substrates to replicate the hexagonal stacking along the nanowire. The growth is performed by vapor phase epitaxy in an ultra-high-vacuum chamber using a vapor-liquid-solid process with a gold catalyst.

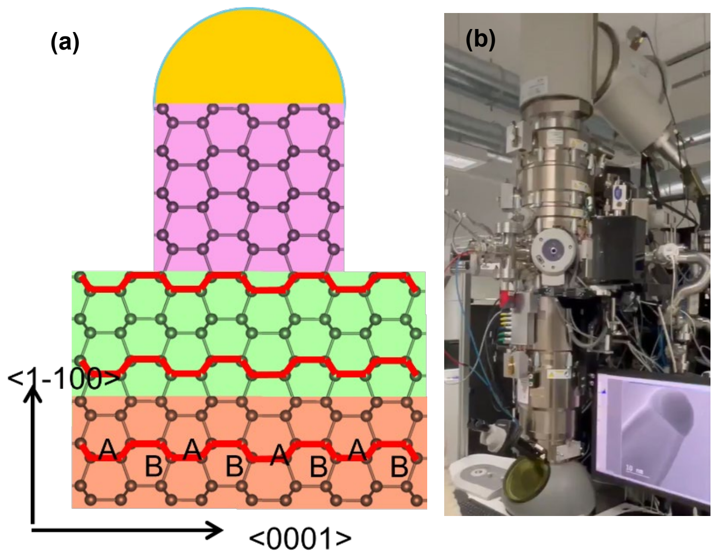

Figure 5 (a) Atomic arrangement of hex-GeSi nanowire. (b) TEM for real-time observation of crystal growth at CNRS Paris-Saclay - unique instrument installed at Ecole Polytechnique.

Watch the ONCHIPS growth video at:
https://utwente.yuja.com/v/onchips-instructionvideo-srt