Enhanced Performance of Microfabricated Thermoelectric Energy Harvester Modules based on Ge/SiGe Superlattices

University of Glasgow

SEVENTH FRAMEWORK PROGRAMME

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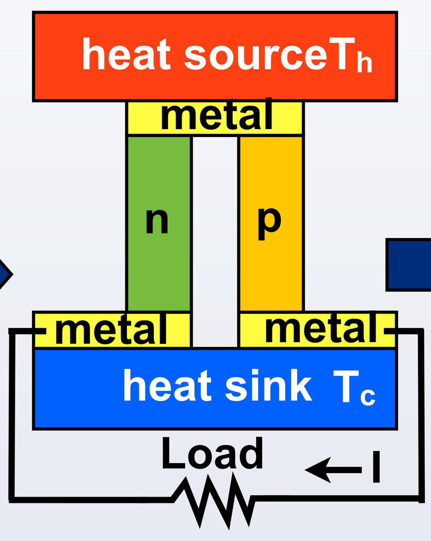
ABSTRACT: In this work we report how thick and thin quantum wells impacted on the efficiency of the material. Two n-type superlattices with periods formed by 1.5 nm thick $Si_{0.3}Ge_{0.7}$ barriers, and 3 and 9 nm thick n-Ge QW for each superlattice were studied for this purpose. The period of each heterostructure was repeated 889 and 336 times respectively to grow 4 μm thick superlattices by LEPECVD growth. The TE properties were extracted by using the micro-fabricated devices and characterisation techniques reported in [1]. As a result, thin QWs demonstrated higher Seebeck coefficients due to the higher asymmetry of the density of states around the Fermi level, and lower thermal conductivities due to the increase of phonon scattering. This increase of scattering processes reduced the value of σ by 10%, but this slight reduction was compensated by the enhancement of α, enhancing the overall value of ZT. We found that the n-type superlattices studied in this work presented higher ZTs than the p-type Ge/SiGe superlattices studied and reported in [1]. Therefore, a complete module scaling the areas of the p- and n-type legs with integrated thermometers and heaters has been developed to optimise the power output of the generator and to avoid convection currents by improving the accuracy of the characterisation.

THERMOELECTRIC:

How it works.

Two semiconductor materials connected electrically in series and thermally in parallel.
A gradient of temperature will generate a voltage that connecting it to a load will deliver a current.



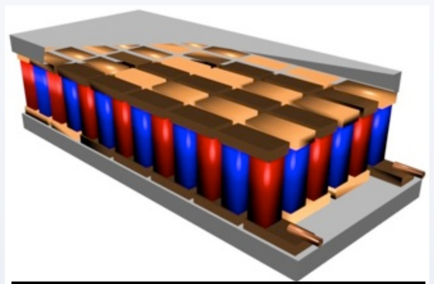


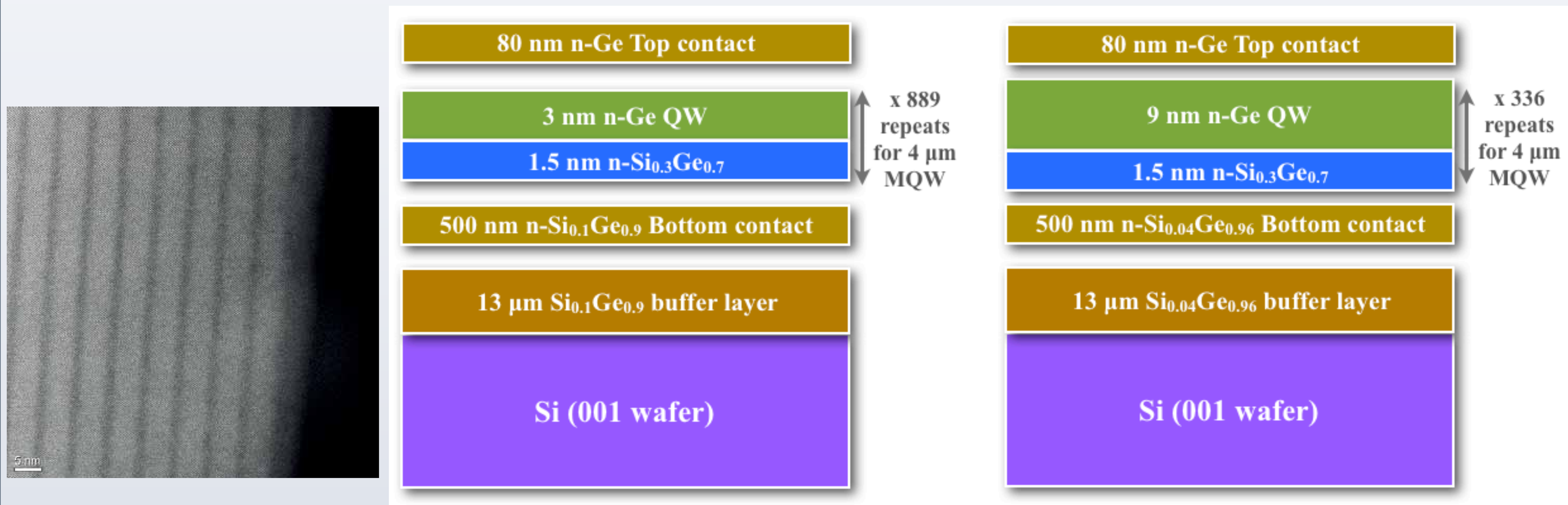
Figure of merit

$$ZT = \frac{\alpha^2\sigma}{\kappa}T$$

- Peltiers Coolers.
- Wrist watches (Seiko Thermic).
- Automobile waste heat recovery.
- Power autonomous systems, such as human bodies.
- Integrated on chip energy harvesting.

2D LATERAL SUPERLATTICES

- Material.

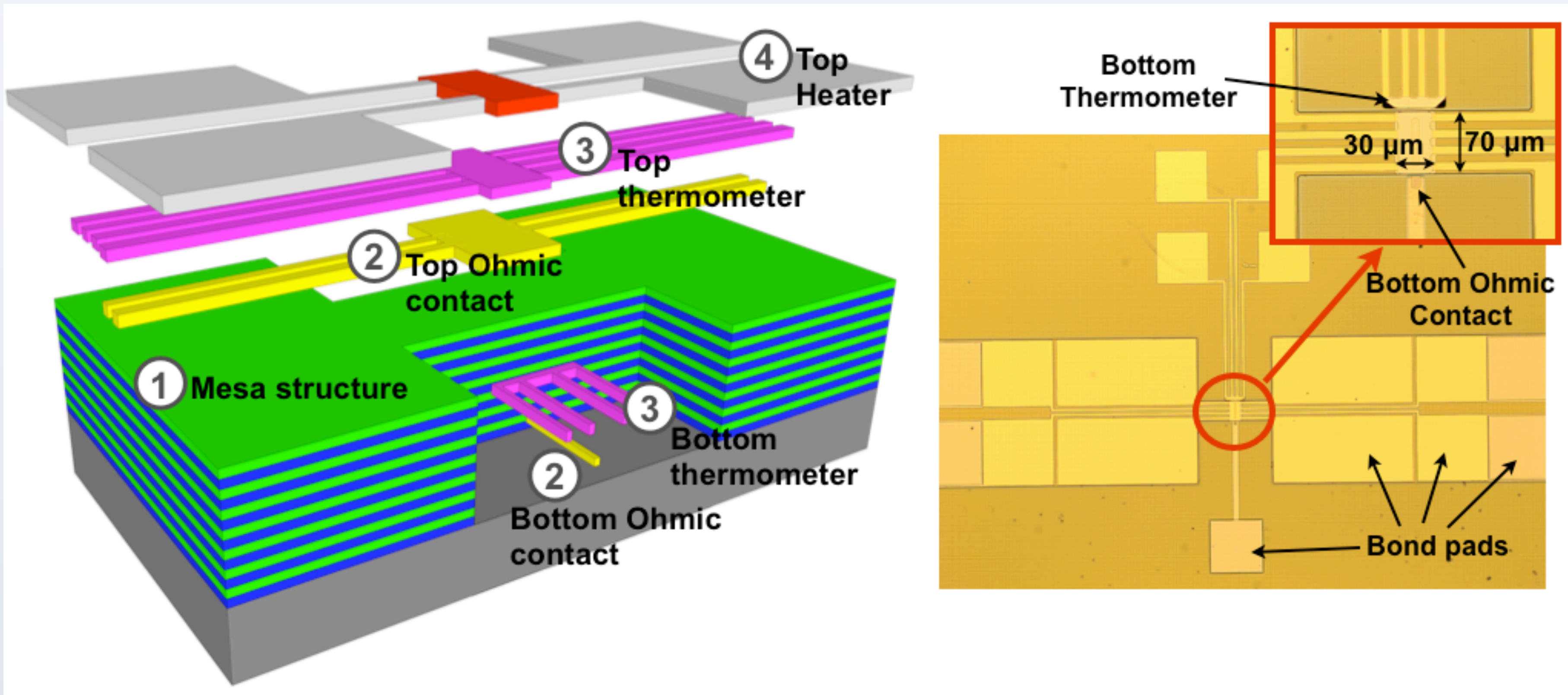


Two n-type superlattices with periods formed by 1.5 nm thick $Si_{0.3}Ge_{0.7}$ barriers, and 3 and 9 nm thick n-Ge QW for each superlattice, grown by LEPECVD [2].

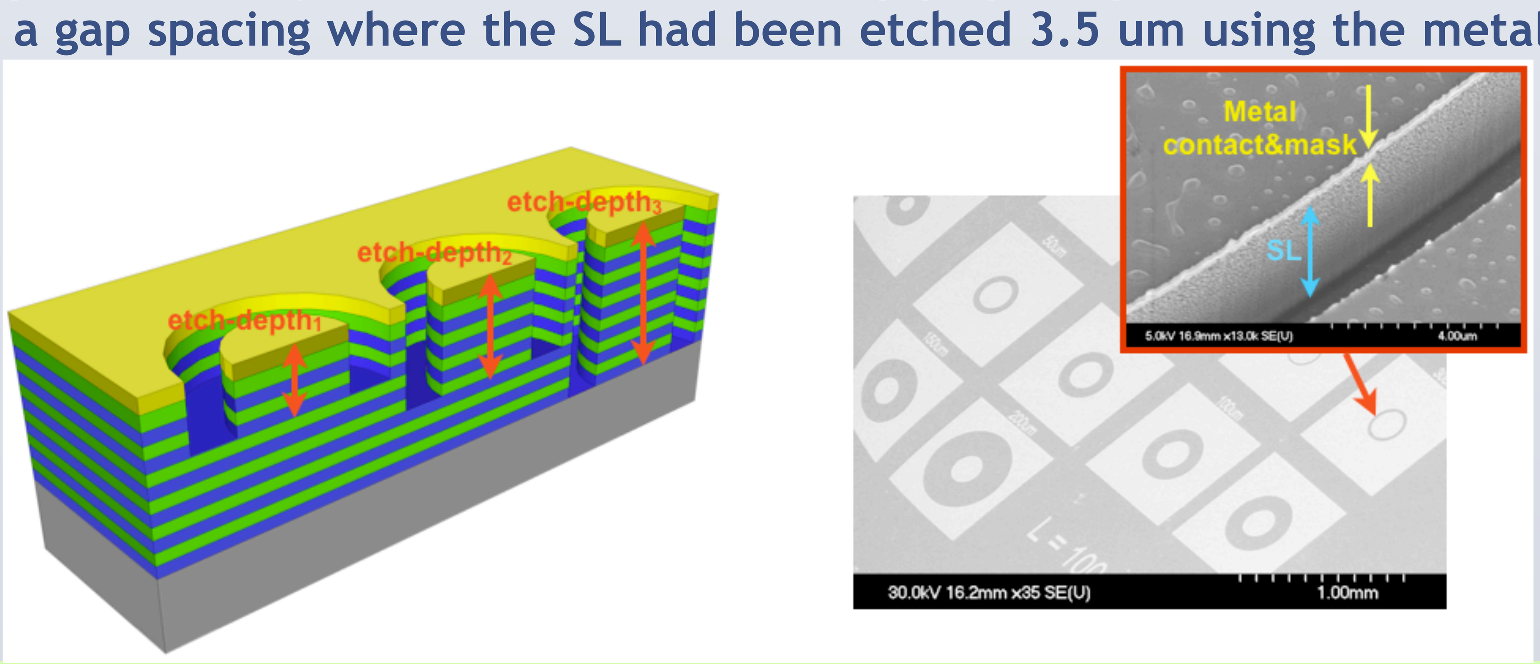
THERMOELECTRIC PROPERTIES

- Devices.

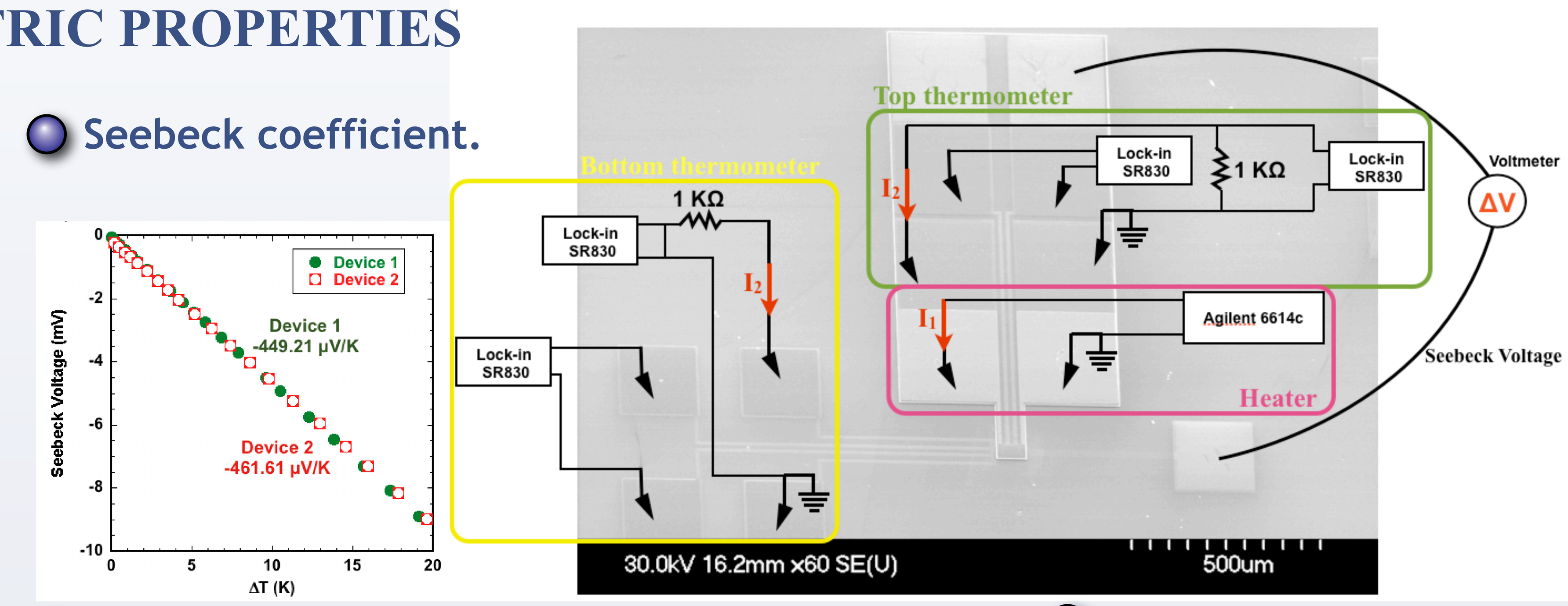
Schematic diagram of the steps followed in fabrication. The numbers indicate the order for the steps (left). Optical top view of a device. The insert shows a zoom of the central part where the device itself is placed. The larger areas at the top and at the bottom of the mesa are bond-pads to probe the different structures.



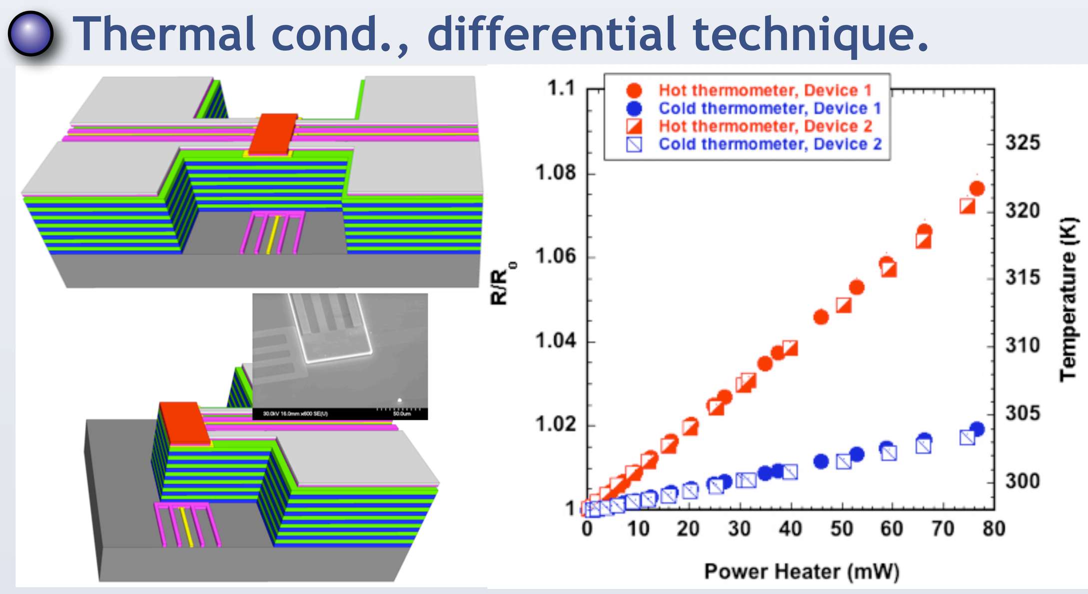
Schematic diagram of a modified CTLM where the metal is not only used as a contact but also as a mask to anisotropically etch between the metal contacts. SEM image of an array of CTLM with different gap spacings. The insert shows a zoom of a gap spacing where the SL had been etched 3.5 um using the metal as a mask.



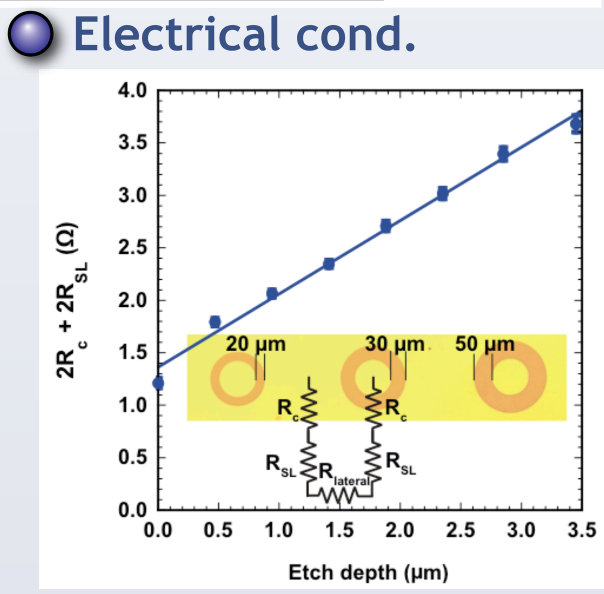
- Seebeck coefficient.



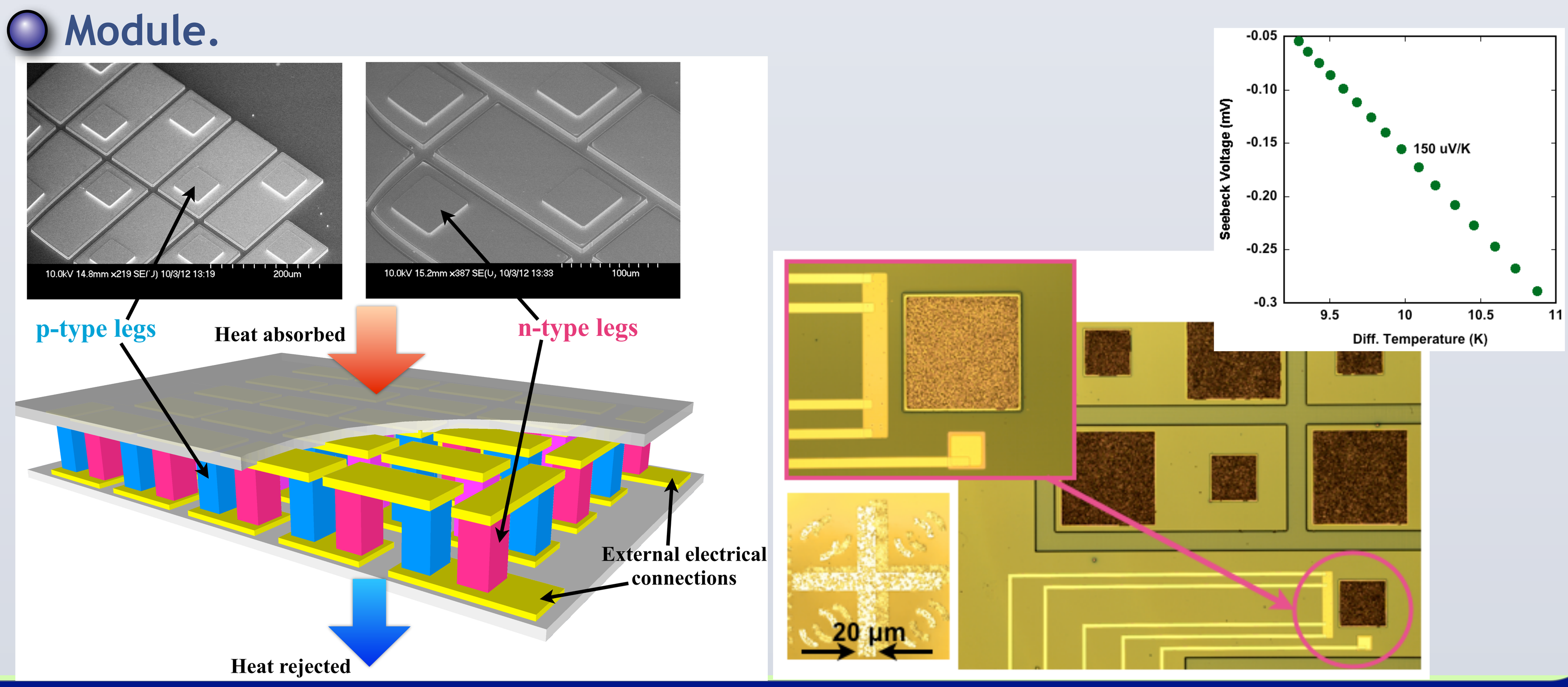
- Thermal cond., differential technique.



- Electrical cond.



- Module.



DISCUSSIONS AND CONCLUSIONS

The impact of QW thickness on the ZT and PF was investigated on n-Ge/$Si_{0.3}Ge_{0.7}$ superlattices. Best charaterization results studied in this work and in [1] for p-type SL, have lead the study of optimised generators that could work as an energy harvesters at RT. First measurements showed a low Seebeck voltage suggesting the existence of a high impedance mismatch between the legs and bumps created by flip-chip-bonding.

ACKNOWLEDGMENTS

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[1] L. Ferre Llin et al., Applied Physics Letters 103, 143507 (2013).

[2]. S. Cecchi et al., Journal of Material Science 48, 2829-2835 (2013).