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# SiC for Sensing in Harsh Environment



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## Motivations

- Growing needs for sensors for use under high temperatures, radiative atmospheres, high gas velocities: aerospace, automotive, nuclear...
- Multiple approaches for the design of sensors : junctions, resonating or fixed micro / nano structures (MEMS, NEMS) ...
- Specific issues for harsh environments : chemical or physical approach ? which material ?

○ **RESISTE project : French national consortium to develop SiC based sensors, from epitaxy to demonstrators. (ANR funding ANR-22-PEEL-0002)**

## SiC for Sensing ?

- Large band gap semiconductor (2,3 – 3,2eV for 3C- and 4H- poltype)
- High thermal conductivity
- Large Temperature Coefficient of Resistivity (TCR)
- High Young Modulus (> 400 GPa)
- Existing know-how for processing (etching, metalization...)

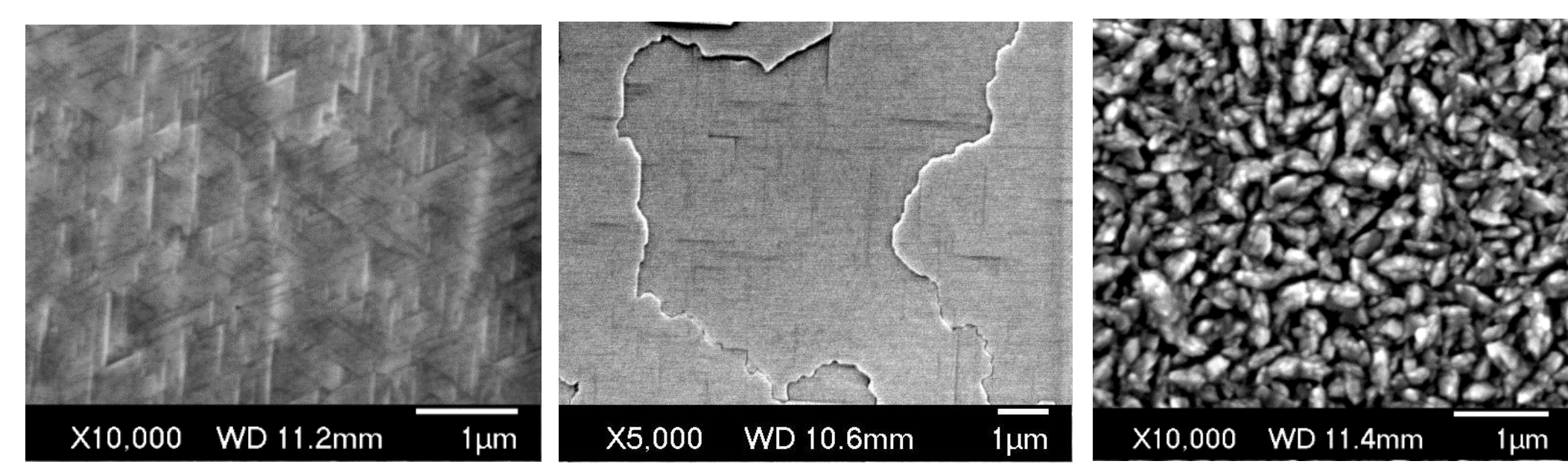
M. Mehregany, C. A. Zorman *Thin Solid Films* 355 (1999) 518-524

P.M. Sarro, *Sensors and Actuators* 82 (2000) 210

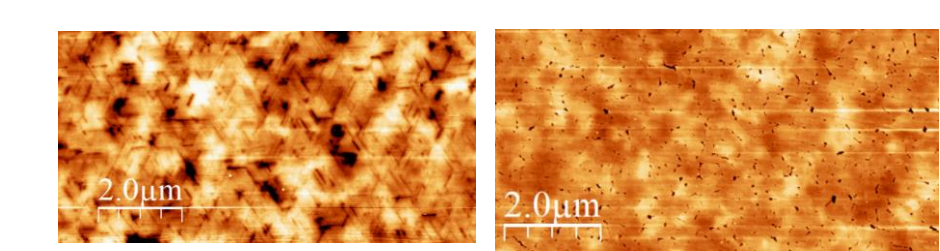
## 3C-SiC / Si Epitaxy

- 3C-SiC grown on Si for benefiting from surface micromachining (@CRHEA).

- CVD process using  $\text{SiH}_4 - \text{C}_3\text{H}_8 - \text{HCl}$  chemistry.
- Monocrystalline and textured 3C-SiC films deposited on semi insulating silicon wafers,



SEM on as grown 3C-SiC/Si(111), 3C-SiC/Si(100) and textured 3C-SiC/Si(100)

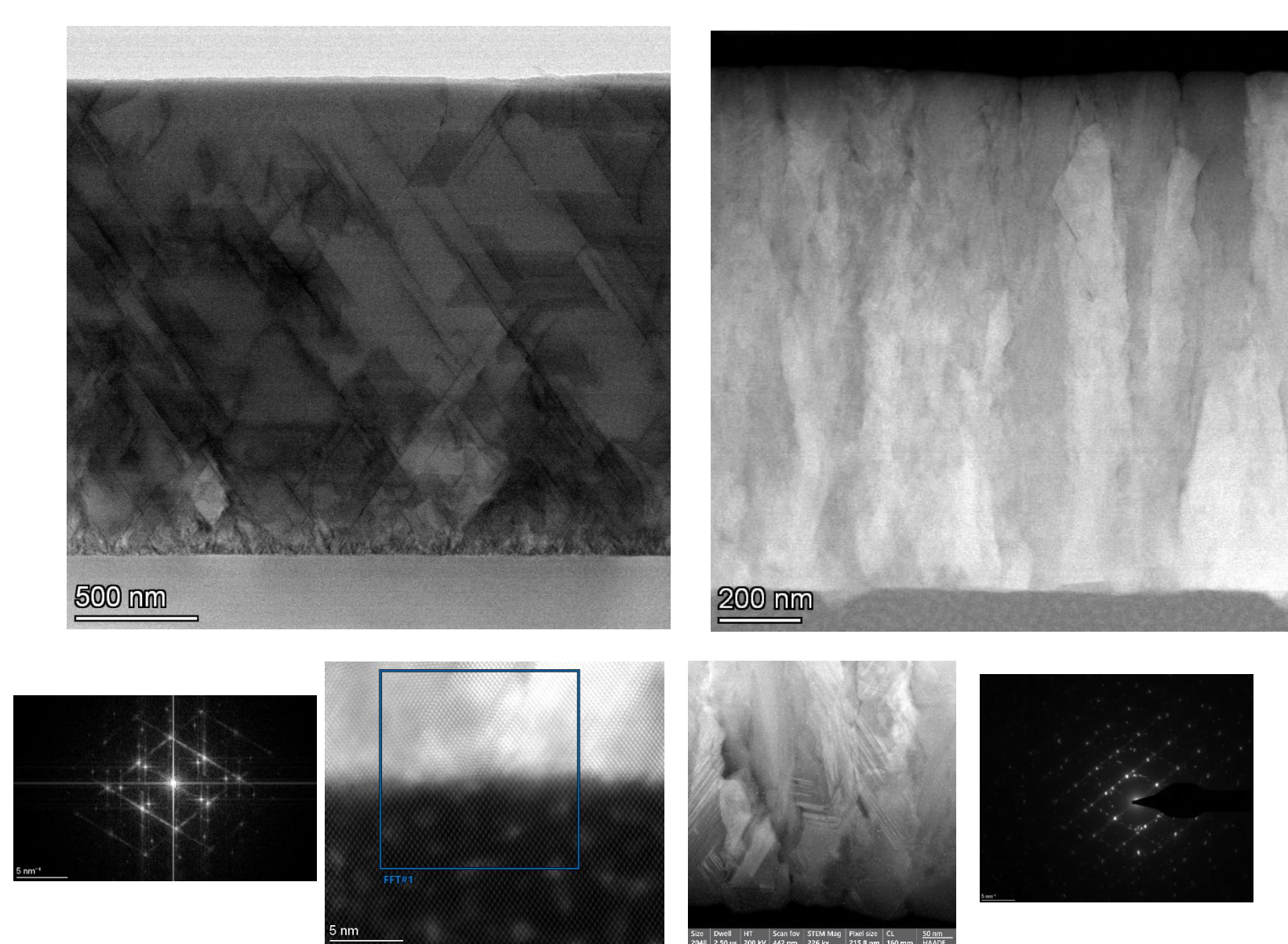


- Post epitaxy : CMP process (@NOVASiC s.a)
- $R_q < 0.3\text{nm}$  after CMP

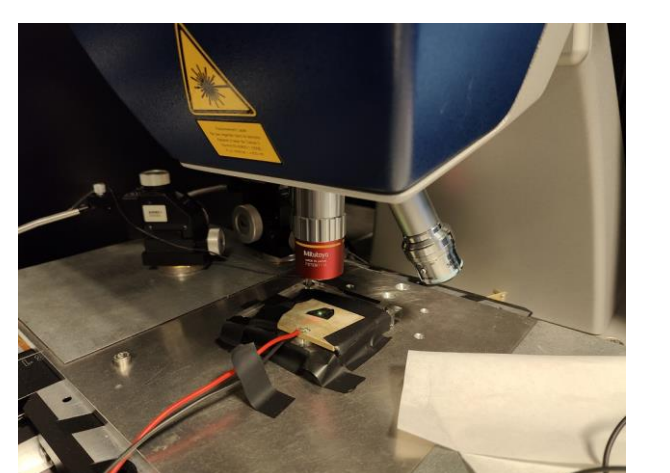
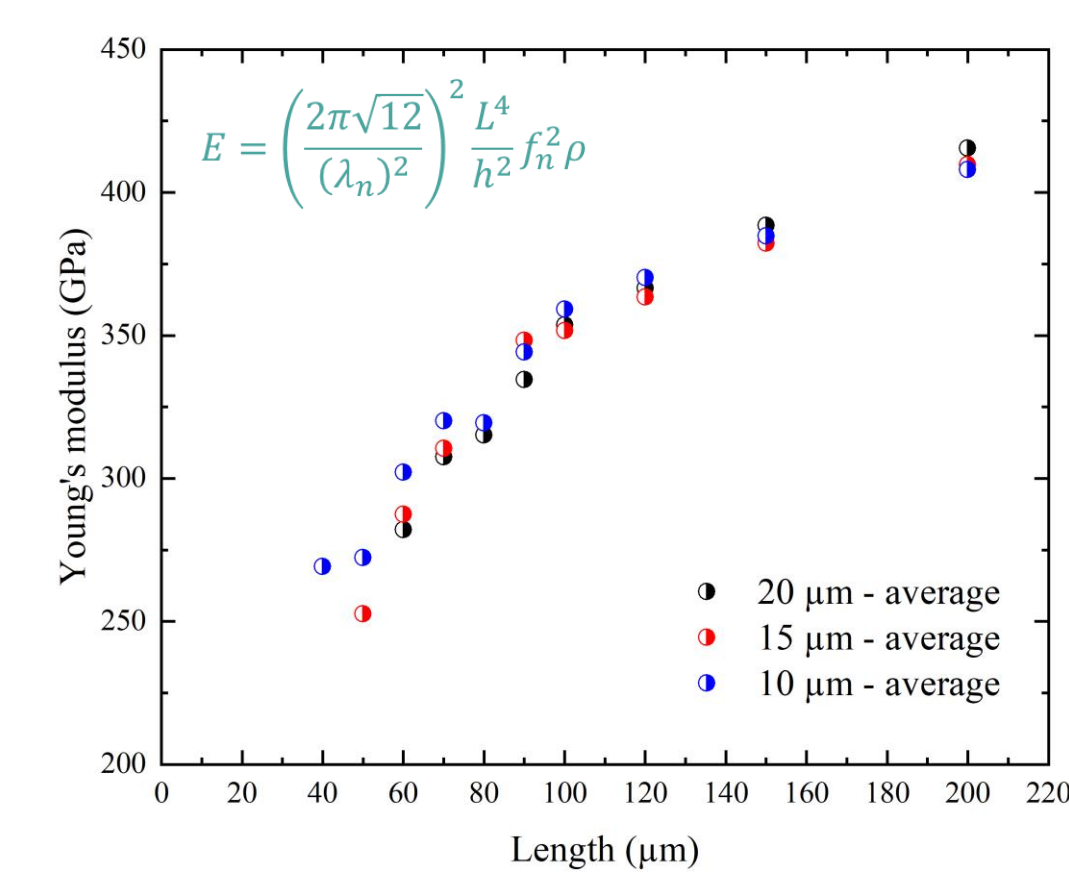
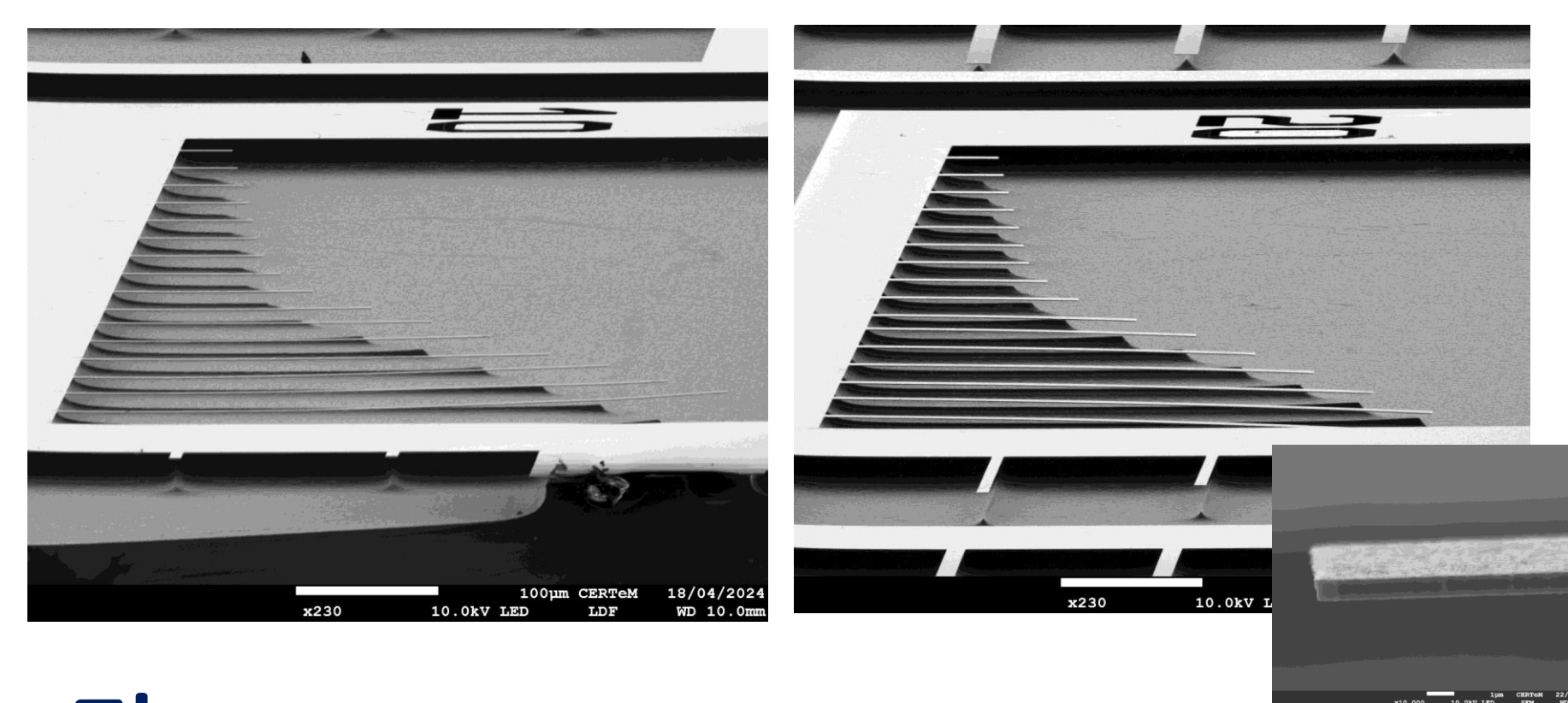
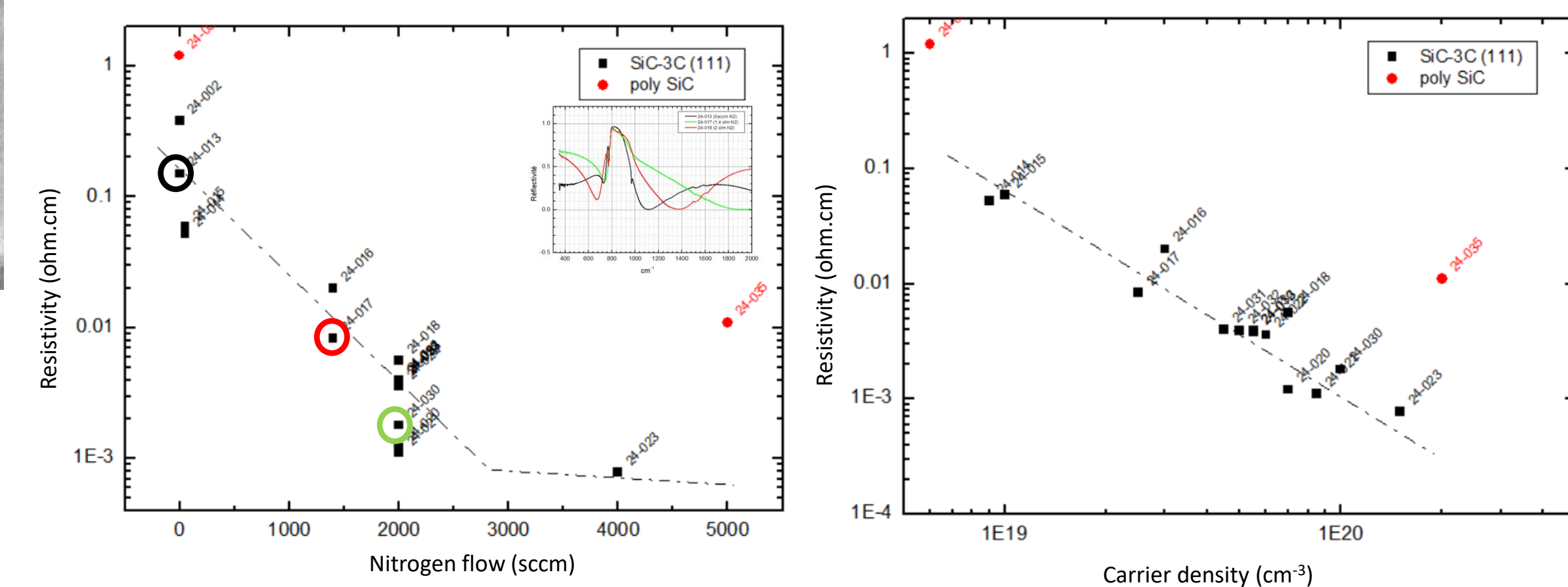
- Mechanical properties of epilayers assessed by fabrication of cantilevers (@GREMAN).

- Cantilever processing : Lithography (Ni mask) + ICP etching ( $\text{SF}_6/\text{O}_2$ ).
- Laser Doppler characterization (@GREMAN).
- Good mechanical properties of textured 3C-SiC ( $E = 420\text{GPa}$ ).

STEM cross section views of monocrystalline 3C-SiC(100) film (left) and textured 3C-SiC film (right)



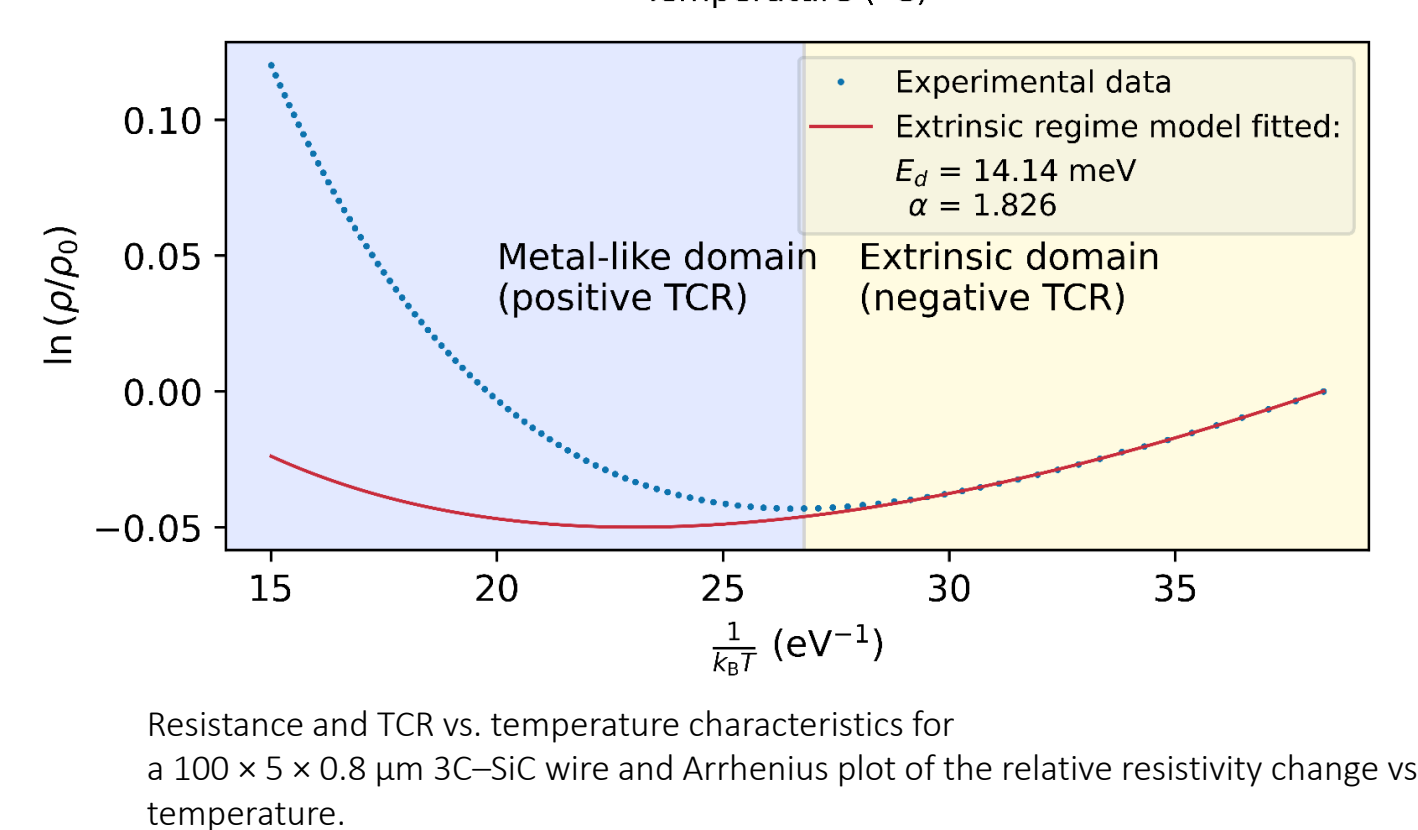
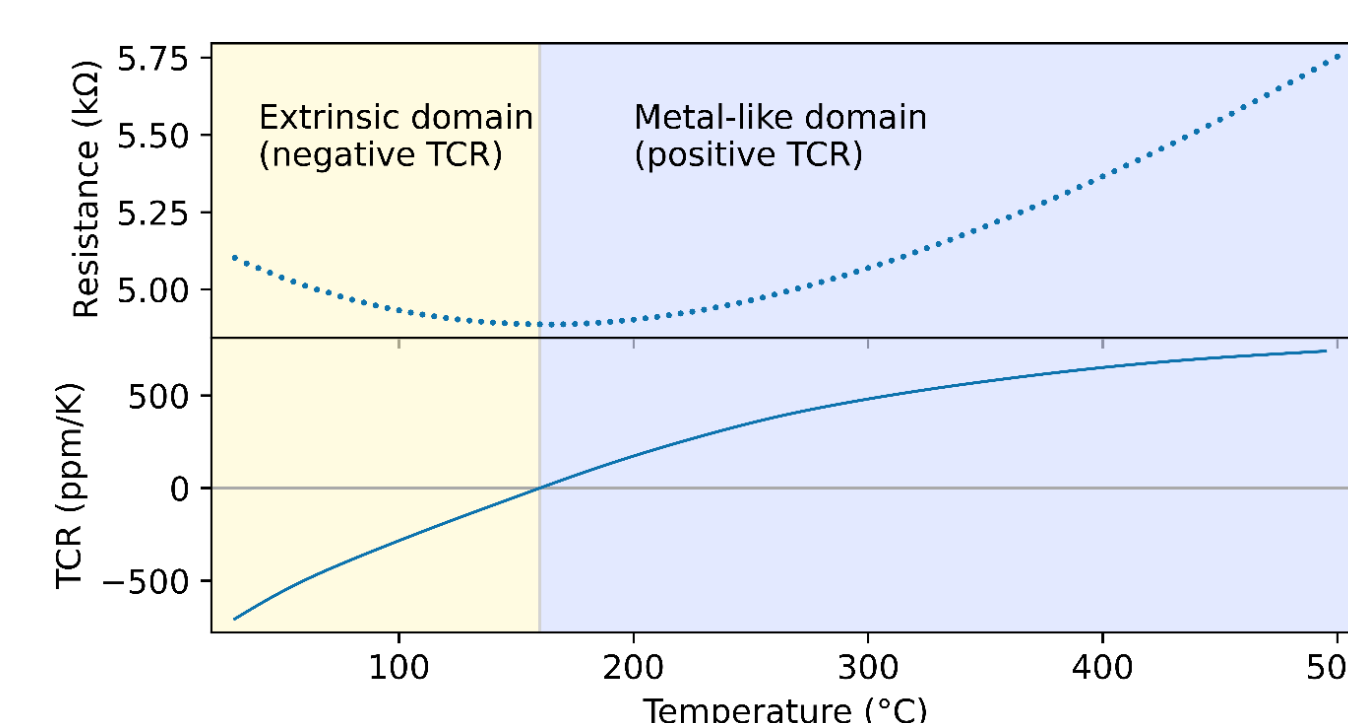
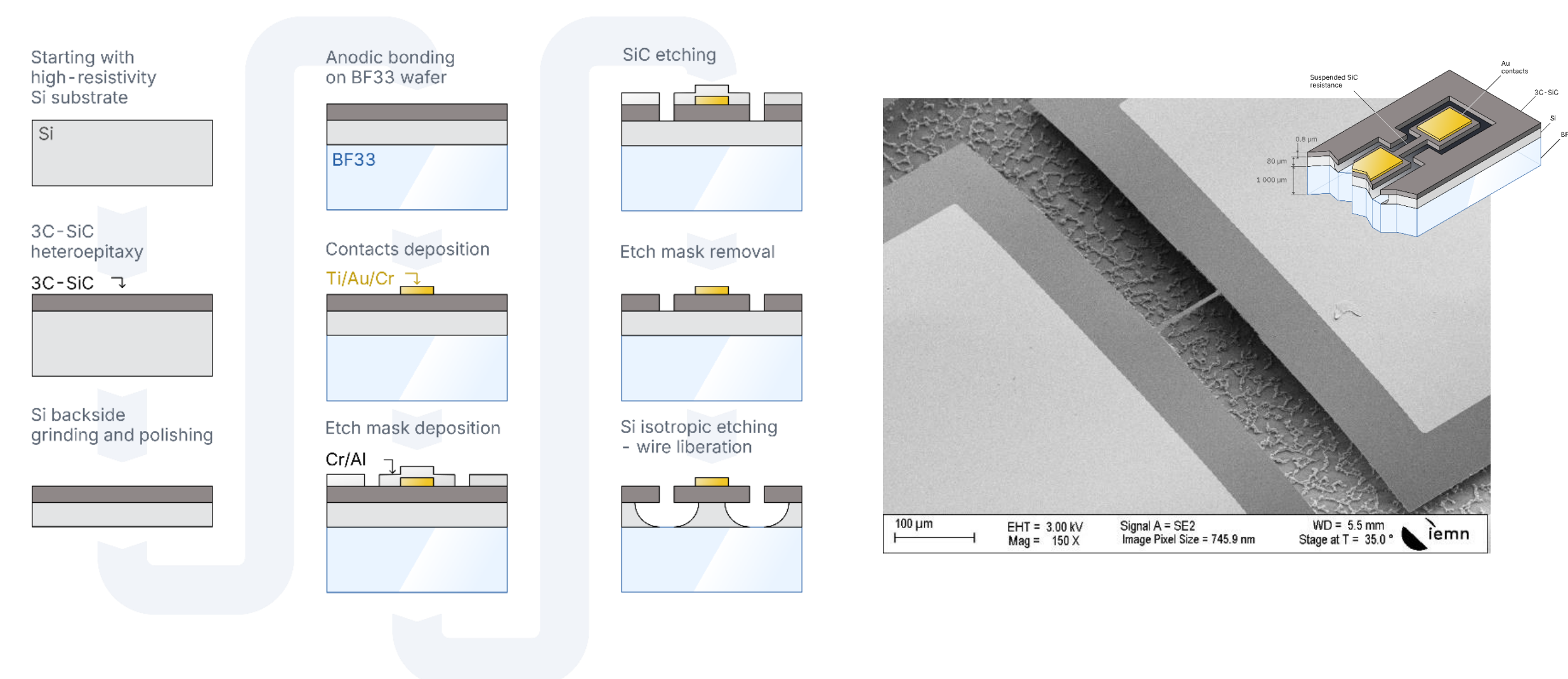
- Low resistivity required for hot wire fabrication : nitrogen doped growth process.
- Variation of the resistivity over two orders of magnitude.
- Lower doping levels for textured 3C-SiC epilayers.



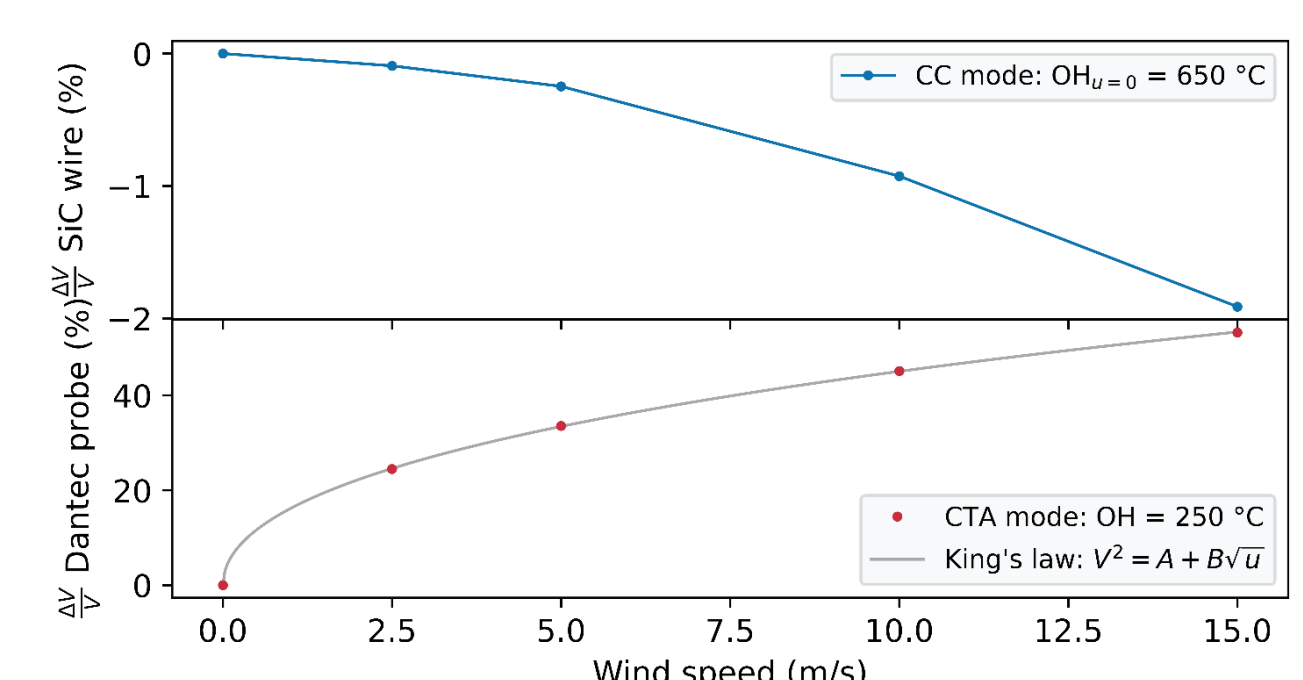
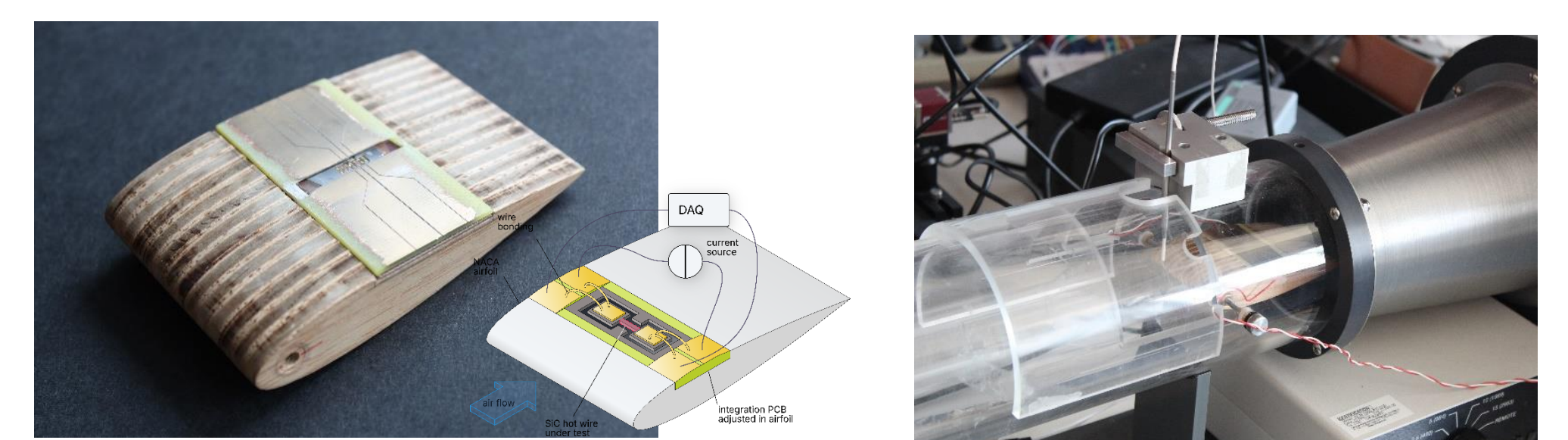
## Thermal Measurements of Gas Flow

- Realisation of SiC suspended hot wires for measurement of turbulent air flow (@IEMN).

- Design based on a bonding approach of SiC/Si on glass to suppress the leakage of Si substrate.
- SiC etching : ICP-RIE  $\text{CHF}_3 / \text{O}_2 / \text{Ar}$  mixture. Si release with  $\text{XeF}_2$ .
- (IV) characterizations on a temperature controlled probing station.



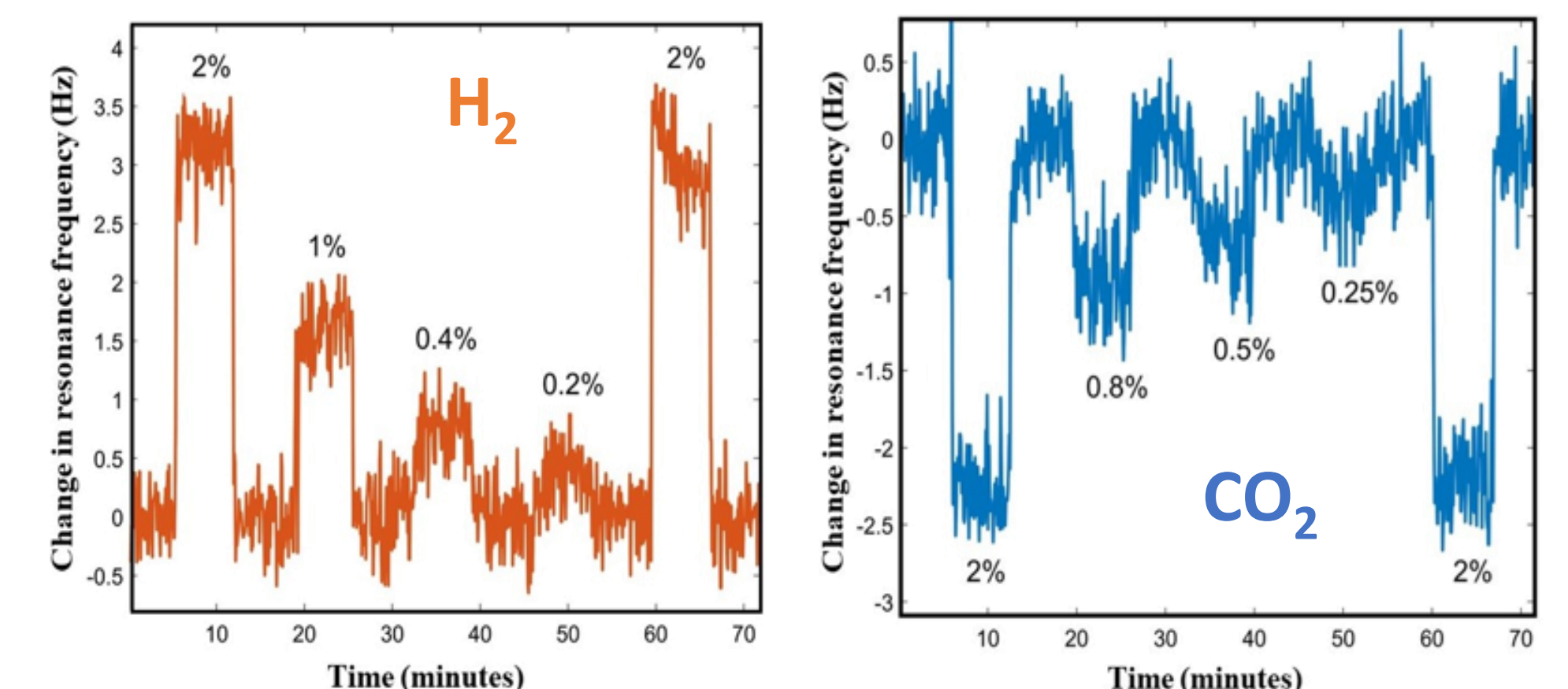
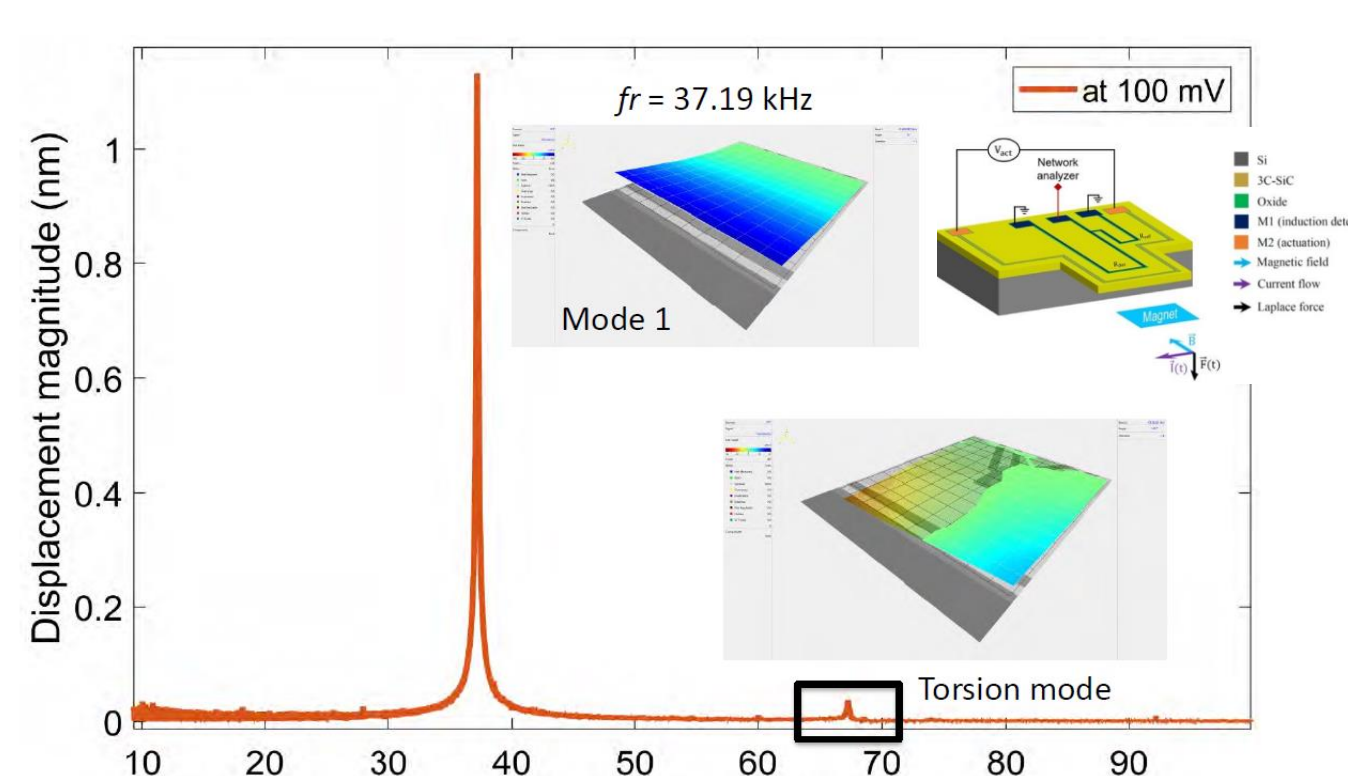
- Integration of chip on PCB and adjustment on a NACA008 airfoil.
- Characterization in a tabletop wind tunnel in air.
- Response of SiC chip up to 15m/sec.



## Hydrogen Detection

- Fabrication of SiC-based gas sensor without functionalized layer (@GREMAN / IMS)

- Resonating millimeter sized cantilevers.
- Targetting a discriminating method : both frequency and damping monitoring.



- Proof of concept for low detection limit of  $\text{H}_2$  in atmosphere.
- Discrimination between gases demonstrated.

Change in resonance frequency of 3C-SiC cantilevers, as a function of the surrounding gas concentration, for  $\text{H}_2$  in  $\text{N}_2$  (left) and  $\text{CO}_2$  in  $\text{N}_2$  (right). Detections as low as 0.2% for  $\text{H}_2$  and 0.25% for  $\text{CO}_2$ , in nitrogen, have been achieved

