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## Projet ciblé EMCOM: Emerging Memories for COMputing

Thomas Buttiens, Maxime Culot, Théo Frottier, Salvatore Teresi, Anouk Goossens, Fernando Gallego, Williams Savero Torres, Aurélie Kandazoglou, Paolo Sgarro, Laurent Vila, et al.

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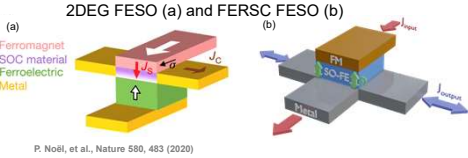
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<sup>3</sup>CNRS/UPS, C2N, Palaiseau  
<sup>4</sup>CEA, LETI, Grenoble

### Abstract

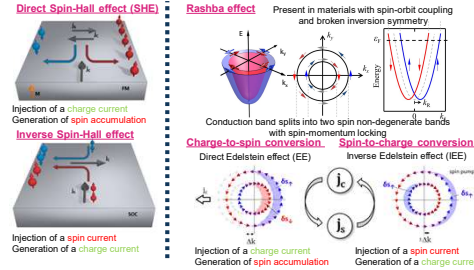
- The Ferroelectric Spin Orbit (**FESO**) device is based on the **ferroelectric** control of spin charge interconversion, for **logic in memory** applications
- Ultra low energy **aJ switching** and **non volatility** are achievable thanks to **ferroelectricity**
- We aim to demonstrate **room temperature** operation of a **nanopatterned FESO** device
- We developed two strategies based on two material family, **oxides** (Lab Albert-Fert, C2N) and ferroelectric Rashba semiconductors, **GeTe** (Spintec, LETI)

### Motivation

- The FESO is a magnetoelectric-free alternative to the MESO device proposed by INTEL. (Manipatruni, S. *et al. Nature* **565**, 35–42 (2019)).
- These **non volatile ultra low energy aJ** switching devices have a potential for in memory computing applications (majority gate)

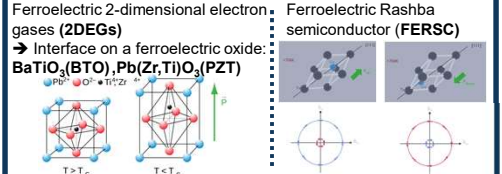


### Spin charge interconversion

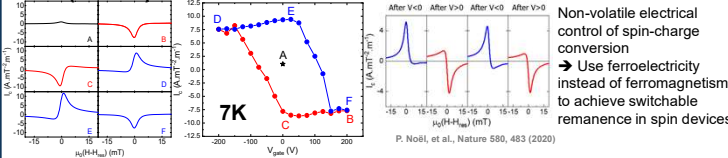


### Material challenges

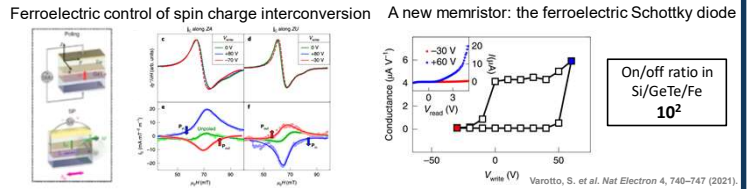
- #### Device requirements
- Demonstrate **non volatile control** of spin charge conversion in nano patterned FESO devices < 200 nm at **room temperature**
  - High interconversion output  $V_{out} > 10$  mV
  - High endurance  $N > 10^7$  cycles



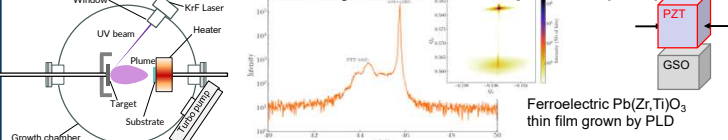
### Ferroelectric control of spin-charge conversion in SrTiO3 2D Electron Gas (2DEGs)



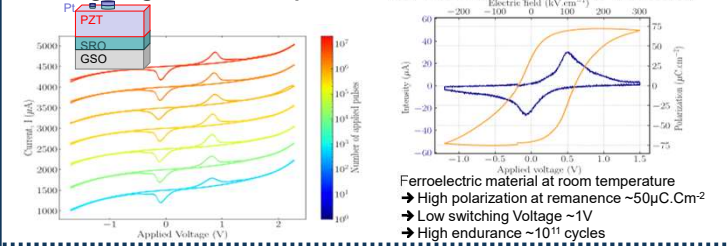
### Room temperature spin charge interconversion in ferroelectric GeTe



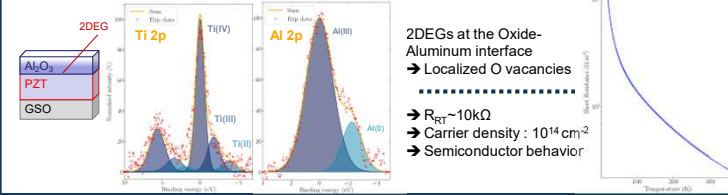
### Growth of Ferroelectric Oxide by Pulsed laser deposition (PLD)



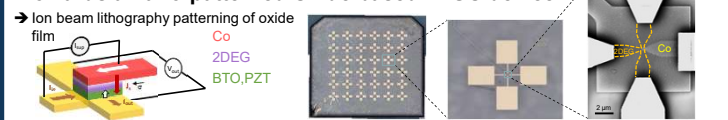
### Investigating the room temperature ferroelectricity in PZT thin film



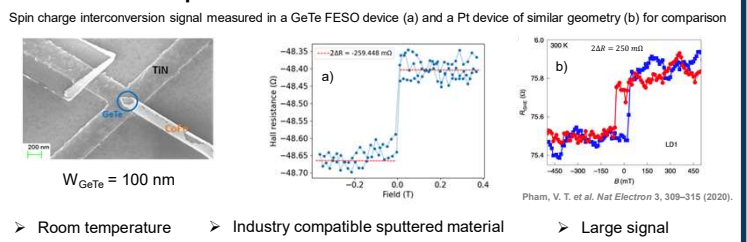
### A 2DEGs in Ferroelectric PZT thin film



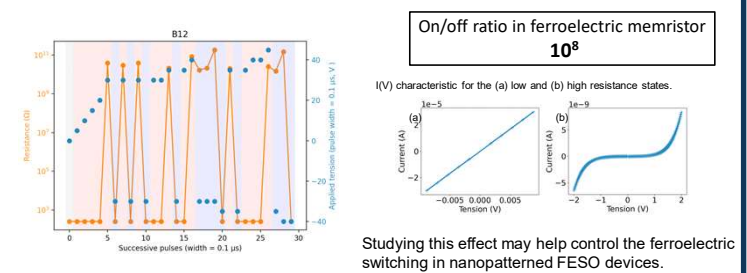
### Towards a nano-patterned Oxide based FESO device



### Towards a nano-patterned GeTe FESO device

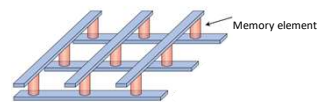


### Ferroelectric resistance switching effect



### Integration of the memristor in a crossbar array

- Benefits of the ferroelectric memristor
- High on/off ratio :  $10^8$
  - Low sensibility to variability
- Expected benefits :
- High endurance of ferroelectric switching :  $10^{12}$
  - Low variability
  - Self-rectifying behaviour



### Conclusion

- High-quality thin films of PZT, with characterized ferroelectric properties, have been fabricated
- 2DEG on PZT has been obtained at Room temperature
- Oxide based FESO transistors has been patterned

### Perspective

- ❖ Investigating spin-to-charge conversion in PZT 2DEG at room temperature is necessary
- ❖ The FESO devices need to be studied

- Spin to charge conversion in a nano patterned room temperature FESO device with sputtered GeTe has been demonstrated
- The spin charge interconversion material GeTe has shown potential as a ferroelectric memristor with a giant  $10^8$  on/off ratio

- ❖ Ferroelectricity in GeTe needs to be optimized, potentially through doping
- ❖ The memristors could be integrated in a crossbar array

