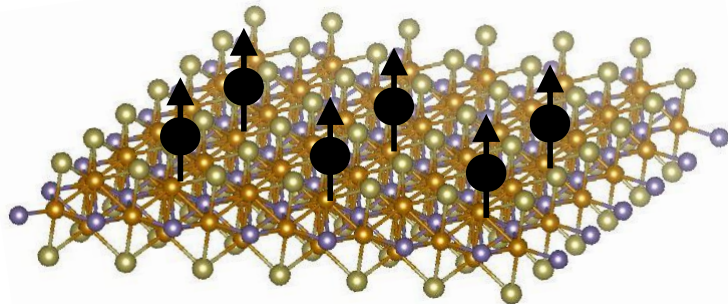
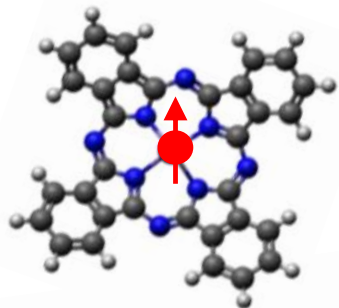




FLAG-ERA



Molecular engineering of layered magnetic materials: towards multifunctional spintronic devices

MULTISPIN

Marco Gobbi

 **CIC**
nanOGUNE

MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

FLAG-ERA Project workshop - Graphene session

21/03/2022

Outline

Introduction

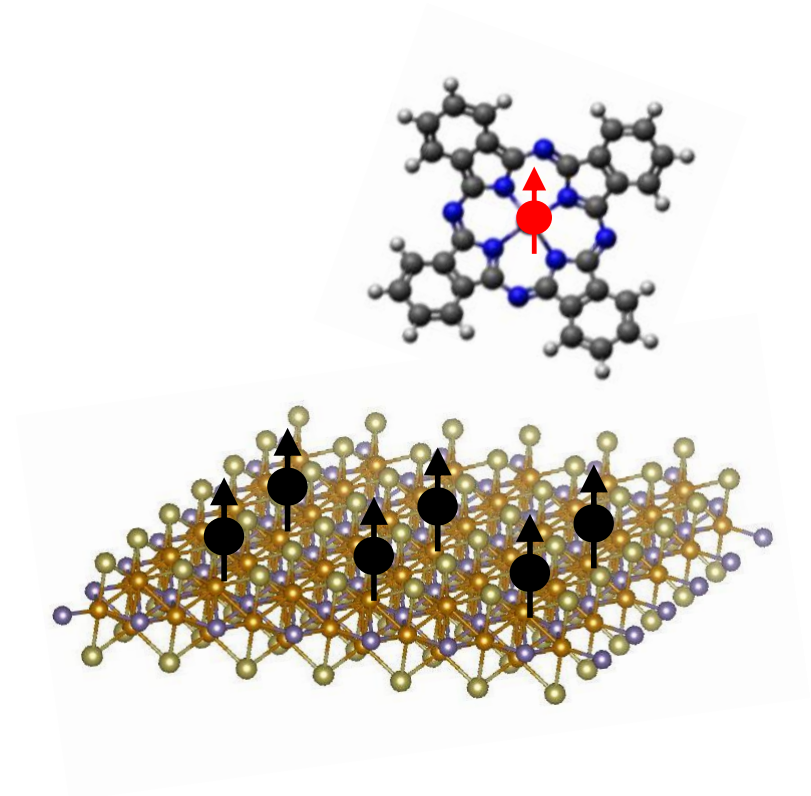
- Layered magnetic materials

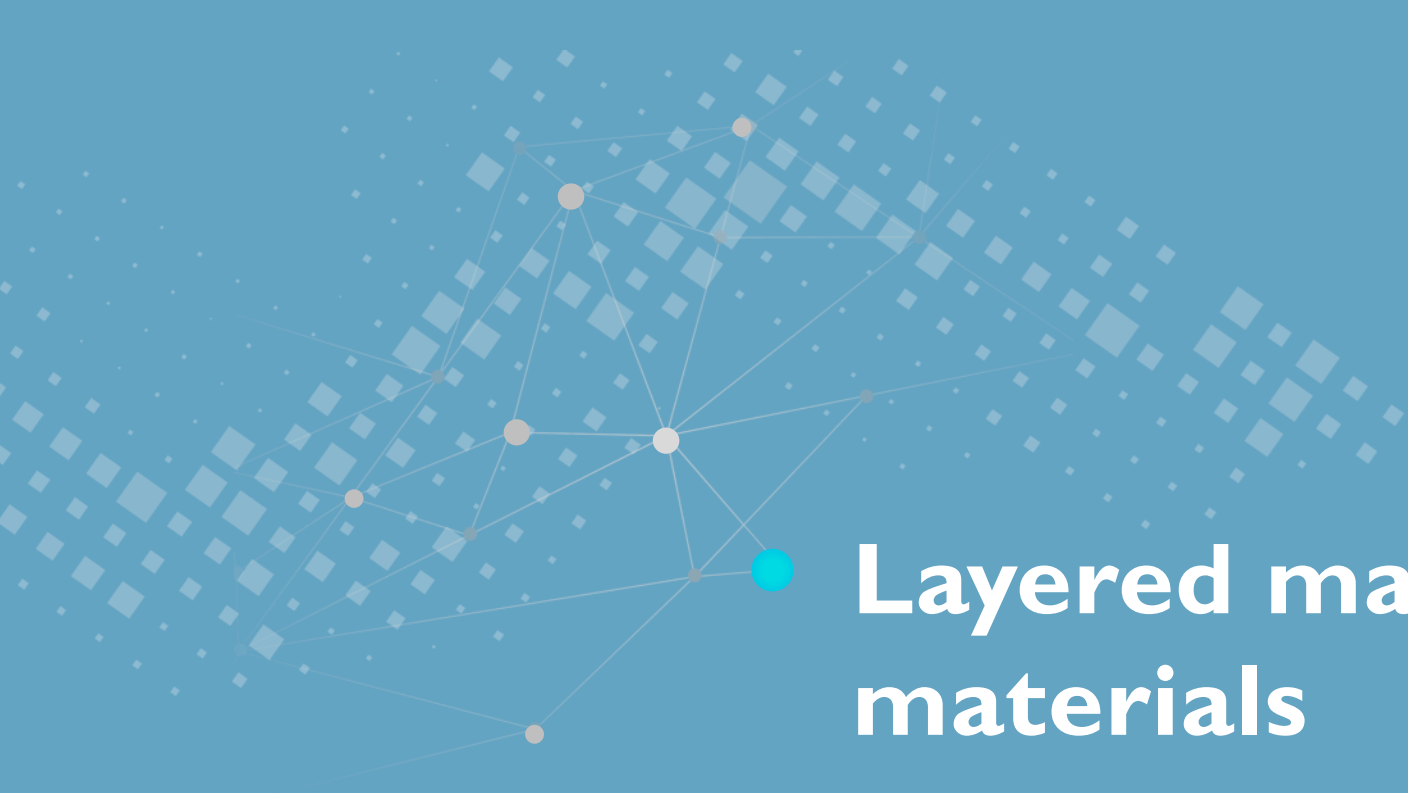
Multispin

- Layered magnetic materials and molecules
- Tailor materials properties
- Demonstrate multifunctional devices

Consortium

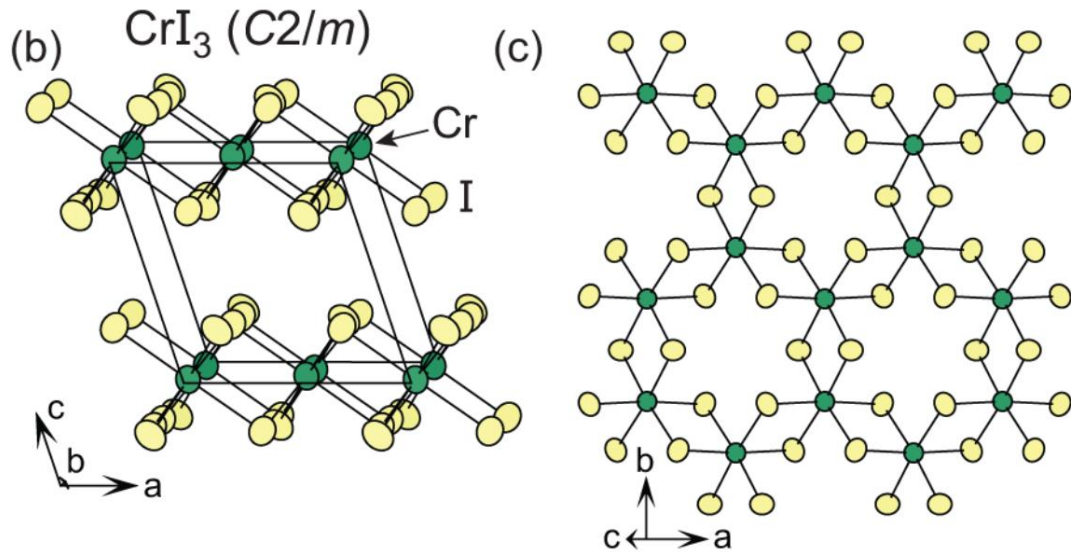
- 4 partners with different expertises



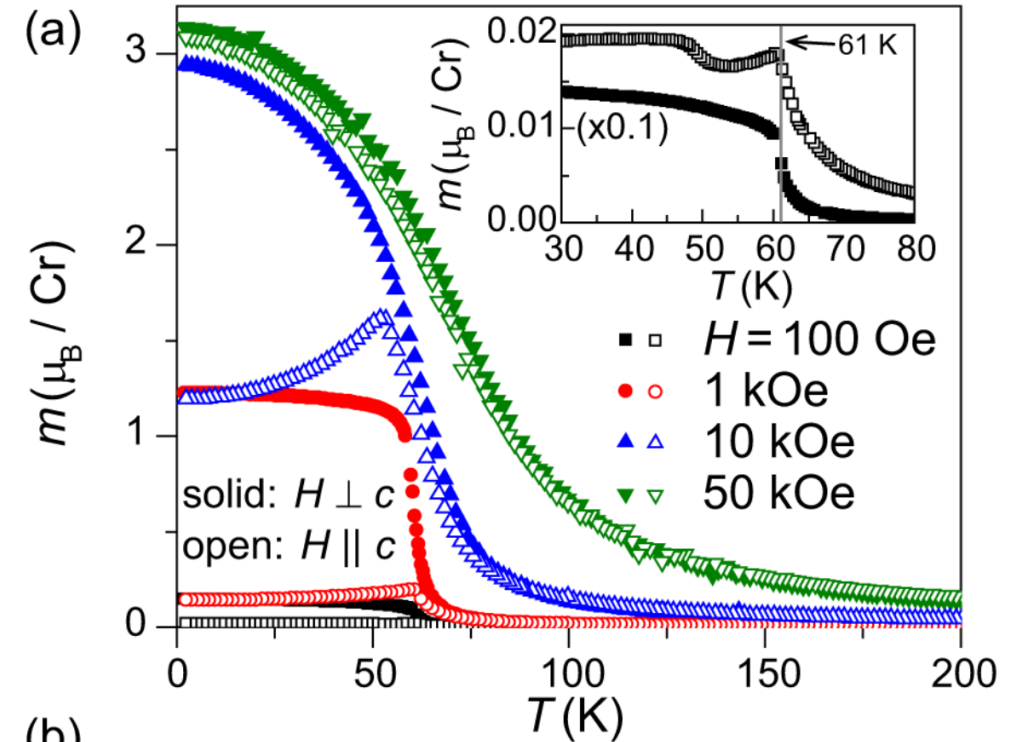


Layered magnetic materials

Layered Magnetic Materials



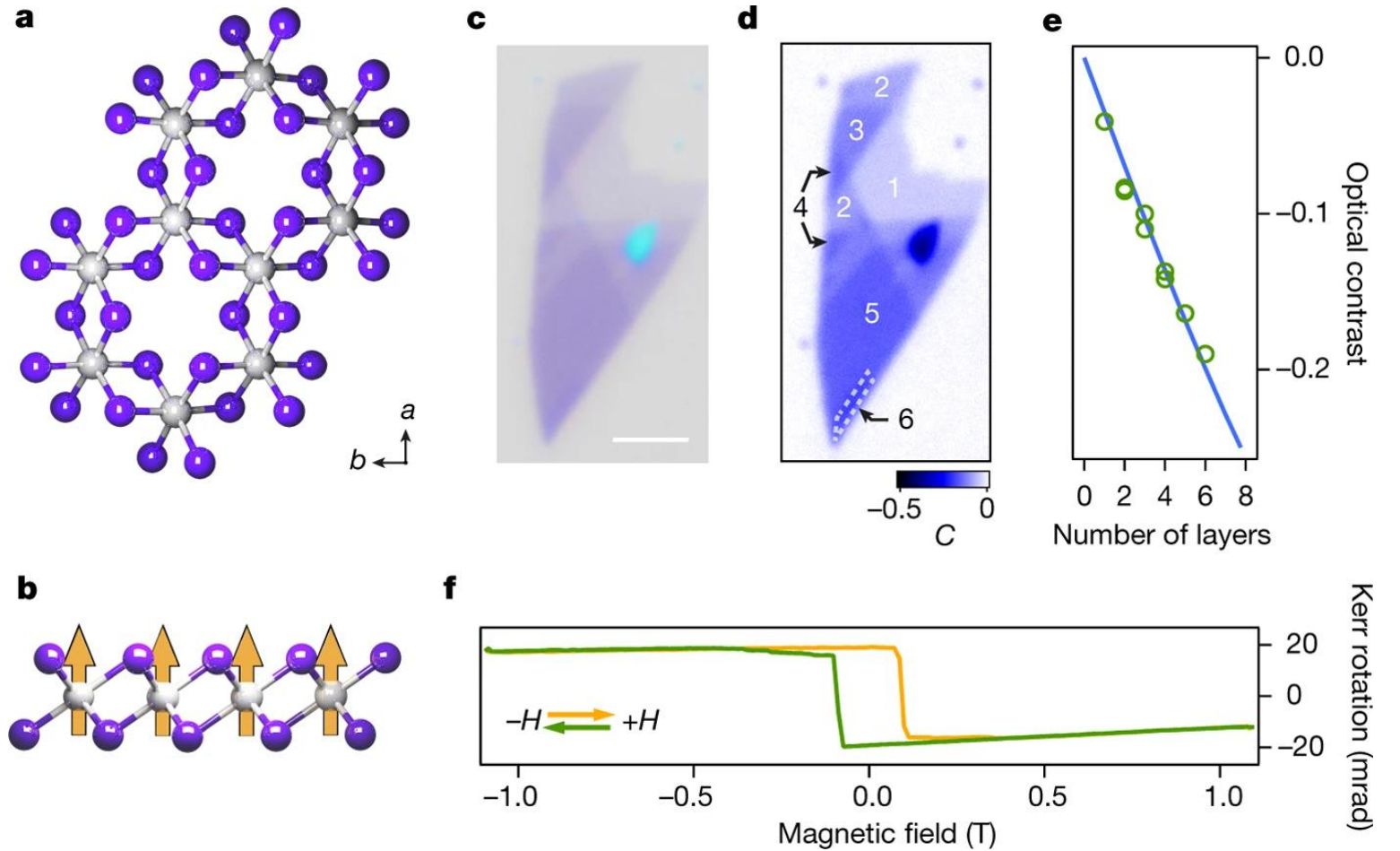
M.A. McGuire et al., **Chem. Mater.** 27, 612 (2015)
See also: J. Dillon et al., **J. Appl. Phys.** 36, 1259 (1965)



2D Magnets

B. Huang, *et al.* **Nature** 546, 270 (2017)

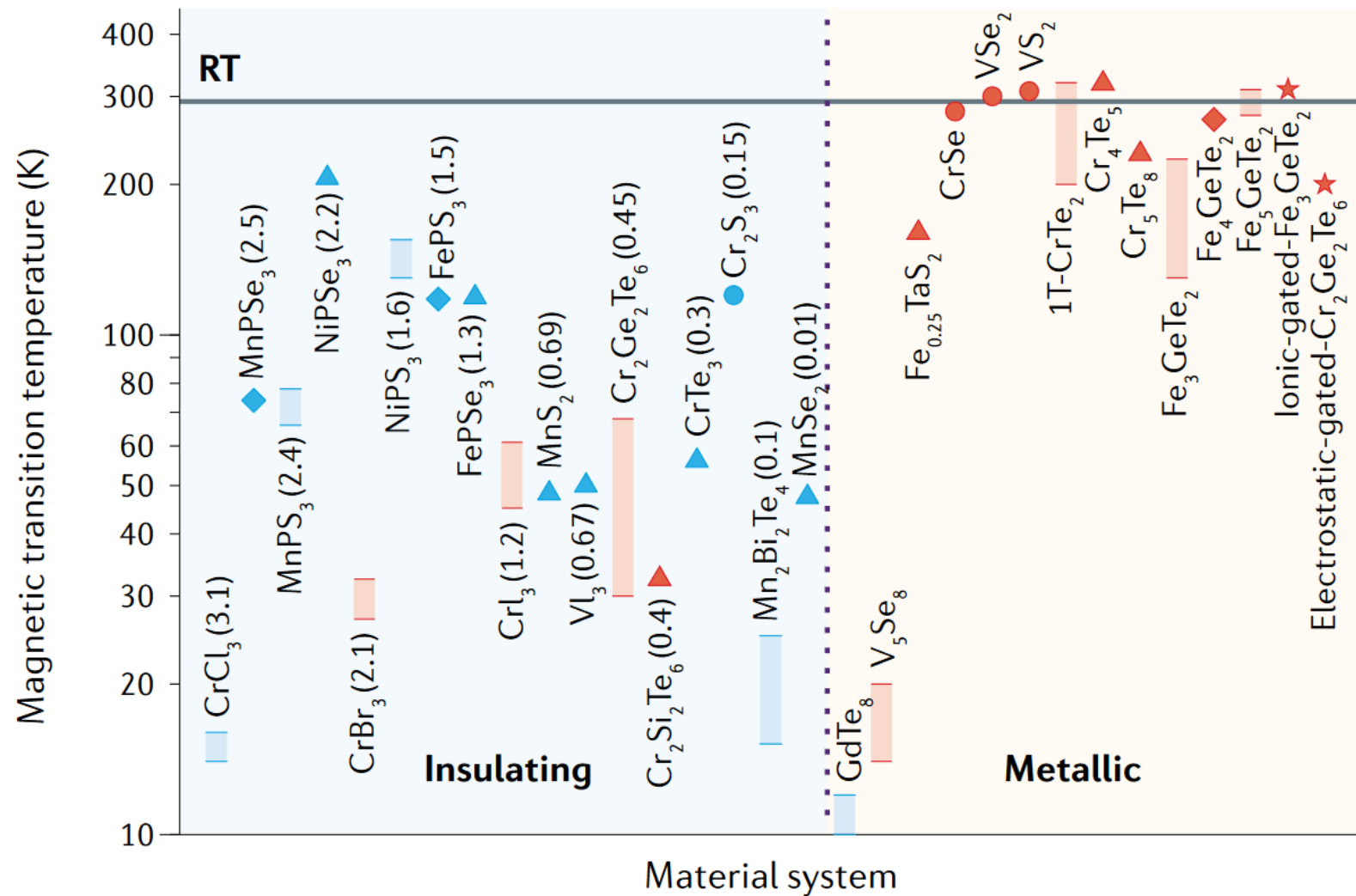
C. Gong, *et al.* **Nature** 546, 265 (2017)



FLAG-ERA

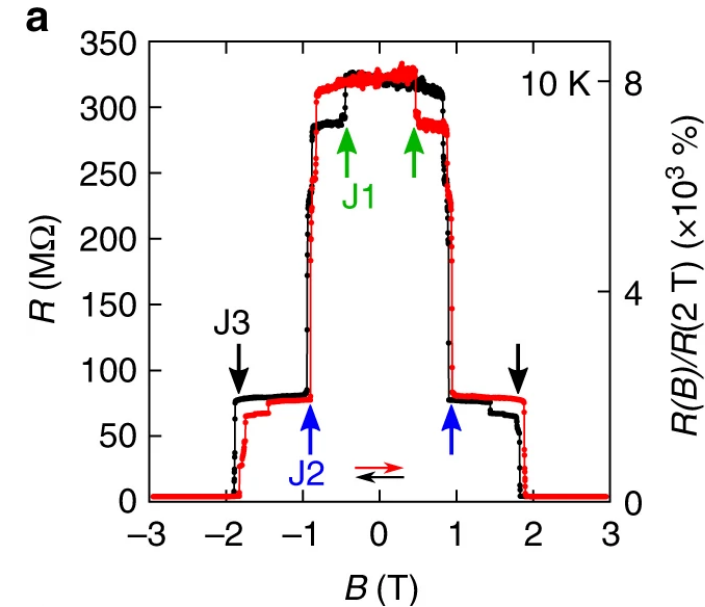
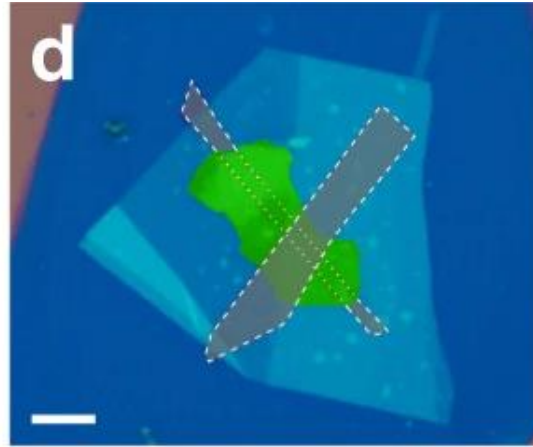
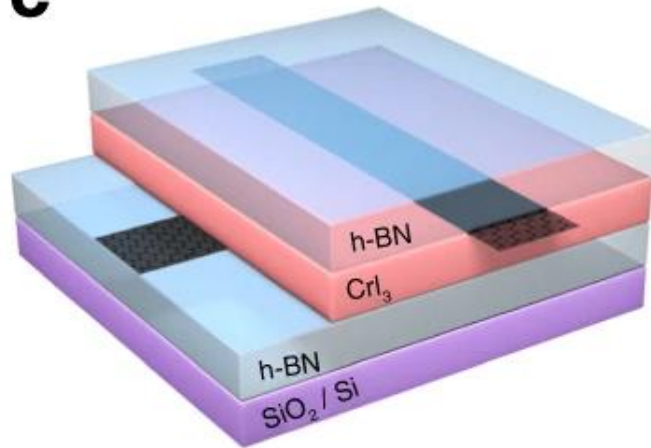


- Typically $TC < 300\text{ K}$
- Often unstable in air

H. Kurebayashi et al., **Nat. Rev. Phys.** **4**, 150 (2022)

High performance spintronic devices

c



Z.Wang et al. **Nat. Commun.**, 9, 2516 (2018)

See also

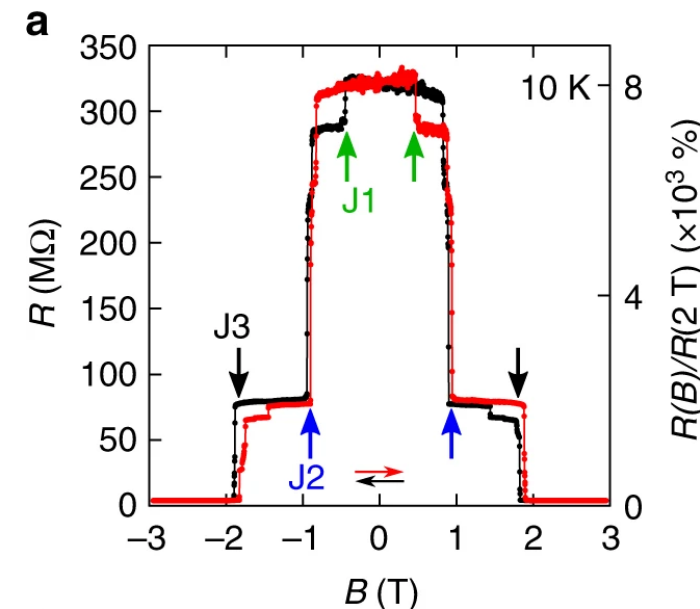
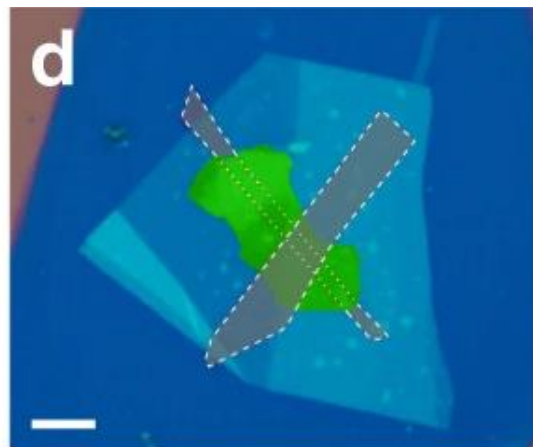
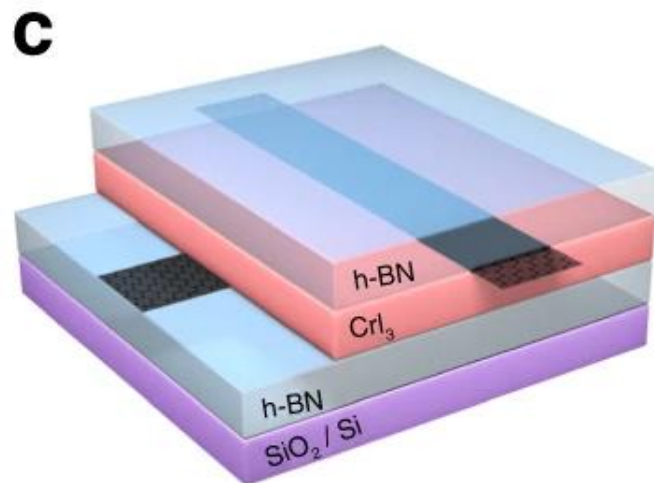
T. Song et al. **Science** 360, 2114 (2018)

D. R. Klein et al. **Science** 360, 1218 (2018)

H. H. Kim et al. **Nano Lett.** 18, 4885 (2018)

Z.Wang et al. **Nano Lett.** 18, 4303 (2018)

High performance spintronic devices



Novel
Devices

Z.Wang et al. **Nat. Commun.**, 9, 2516 (2018)

See also

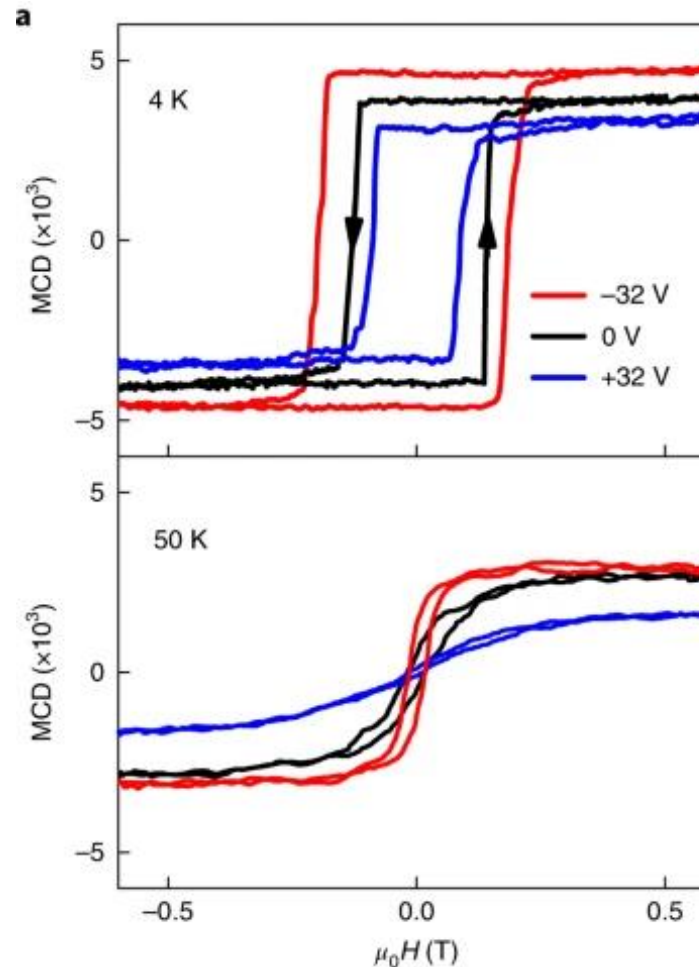
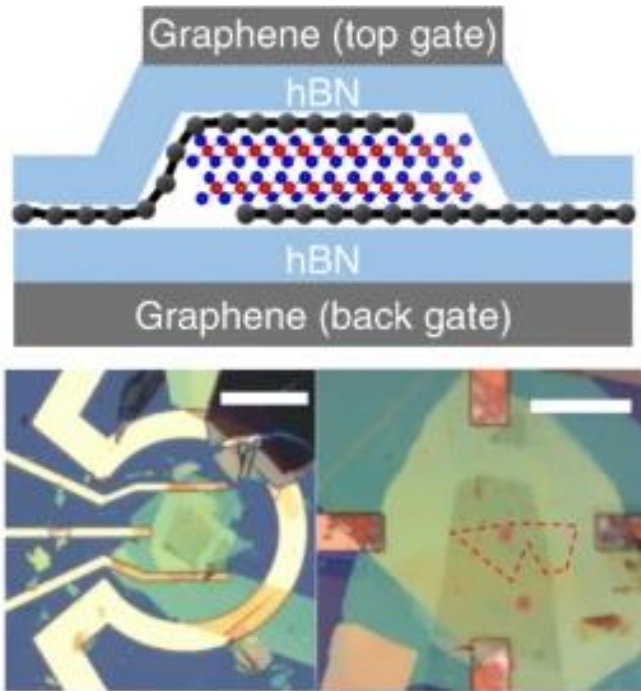
T. Song et al. **Science** 360, 2114 (2018)

D. R. Klein et al. **Science** 360, 1218 (2018)

H. H. Kim et al. **Nano Lett.** 18, 4885 (2018)

Z.Wang et al. **Nano Lett.** 18, 4303 (2018)

Tunable magnetism



Materials
Engineering

S. Jiang et al., **Nat. Nanotechnol.** 13, 549 (2018).

See also:

S. Jiang et al., **Nat. Mater.**, 17, 406.(2018)

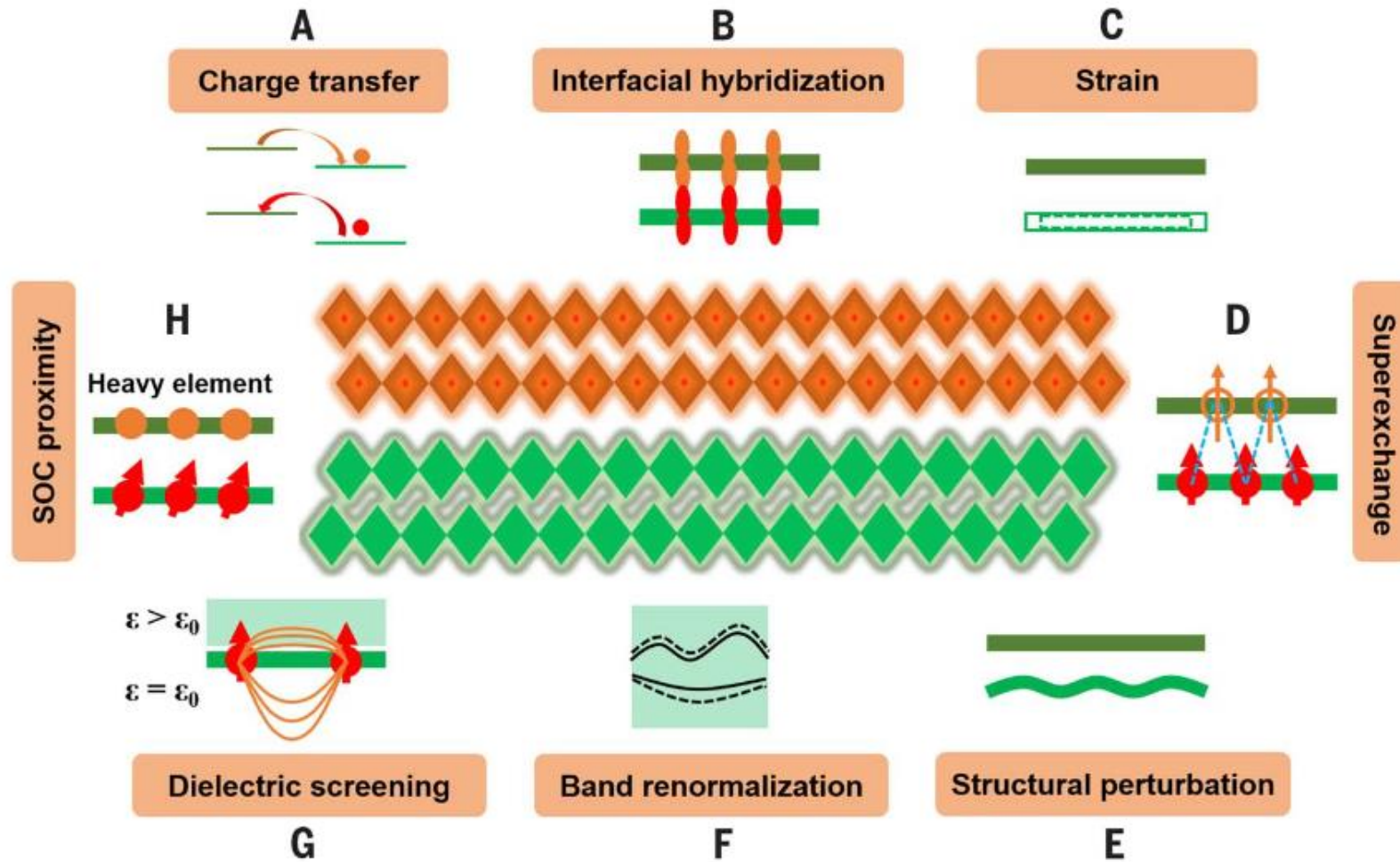
Z.Wang et al., **Nat. Nanotechnol.** 13, 554 (2018).

B. Huang et al., **Nat. Nanotechnol.**, 13, 544 (2018).

Y. Deng et al., **Nature** 563, 94 (2018).

I.A.Verzhbitskiy et al., **Nat. Electron.** 3, 460 (2020).

2D Magnets

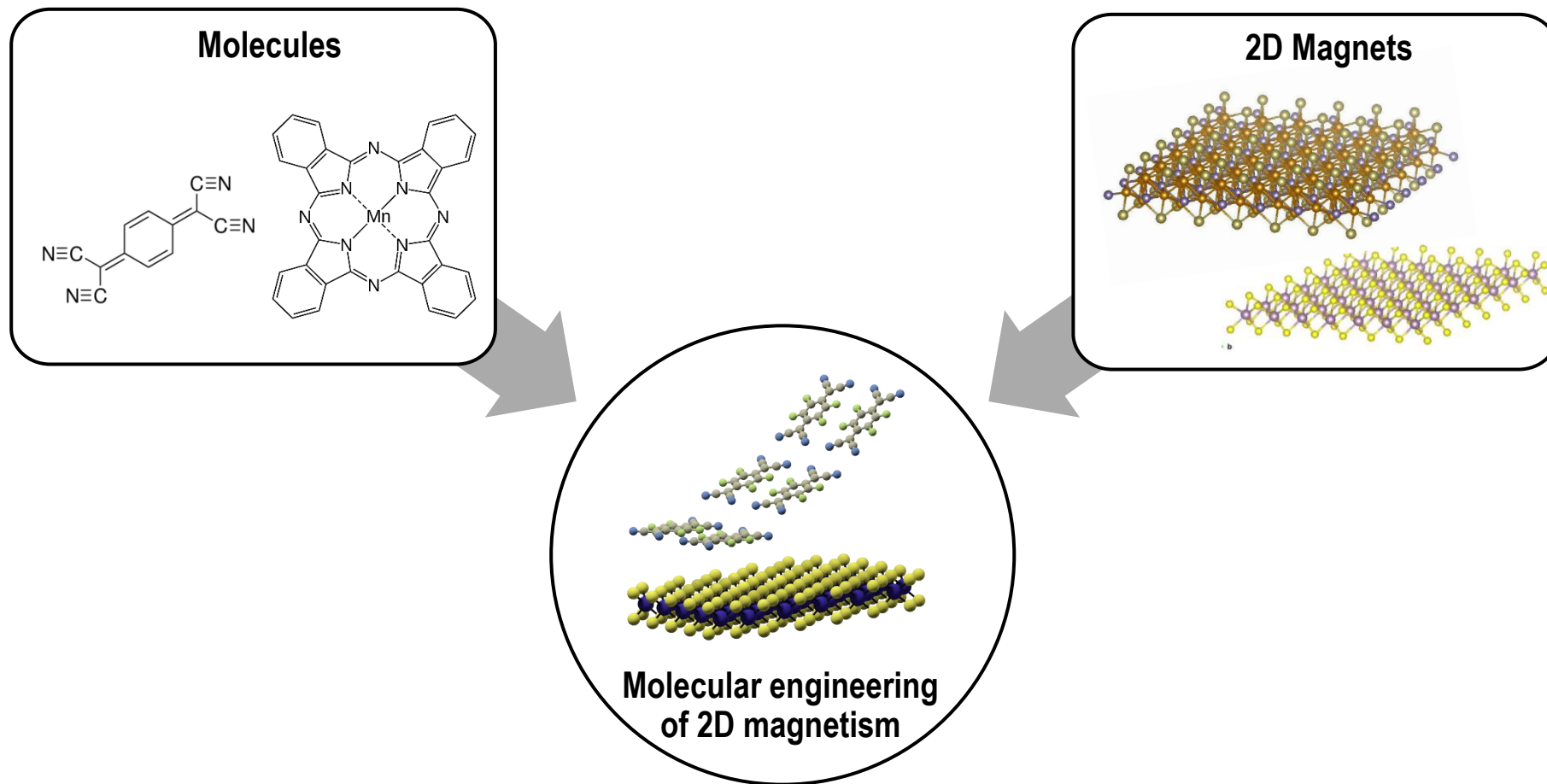


Materials
Engineering

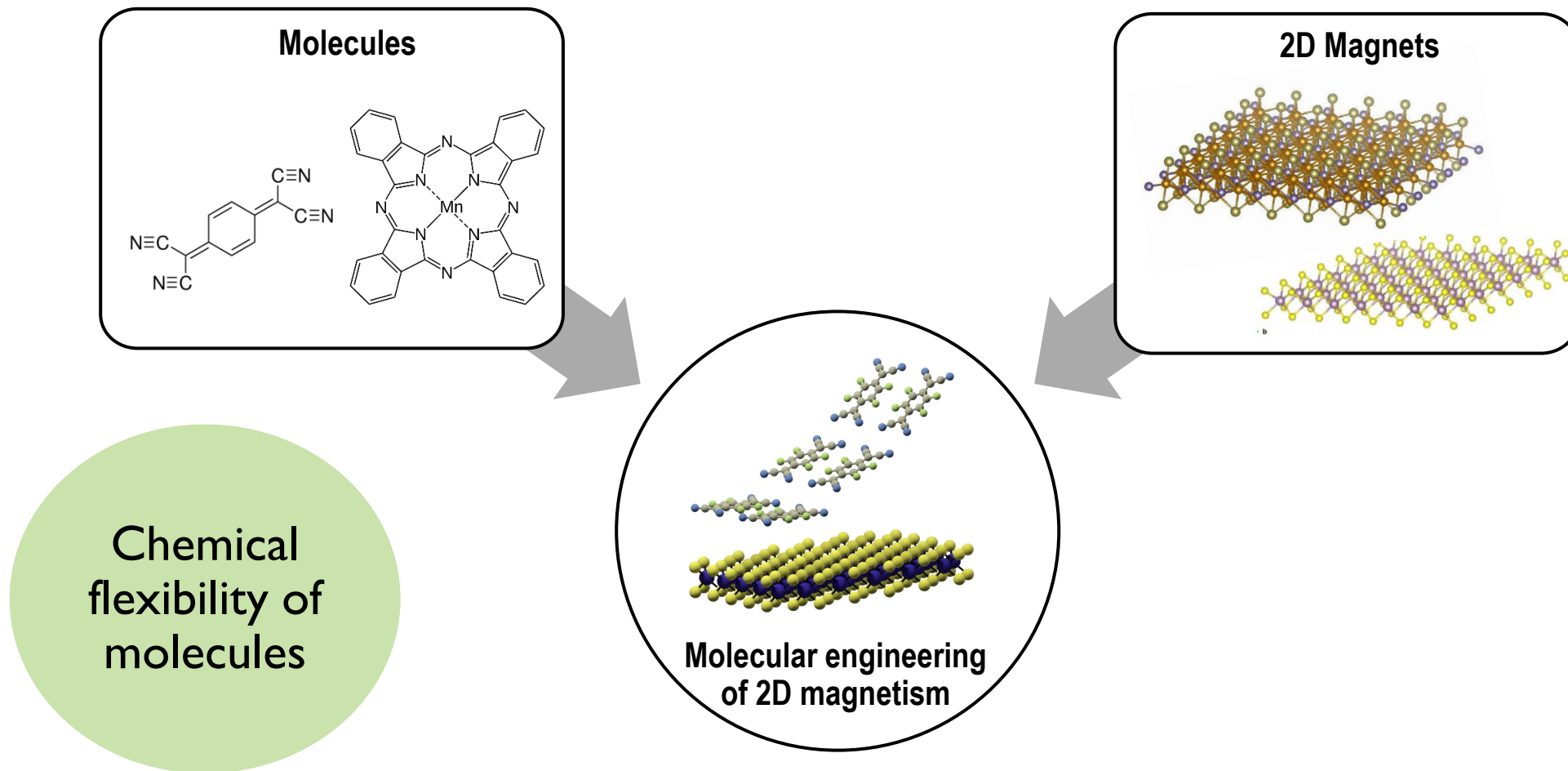


MULTISPIN

Our approach



Our approach



Overall aim

Materials
Engineering

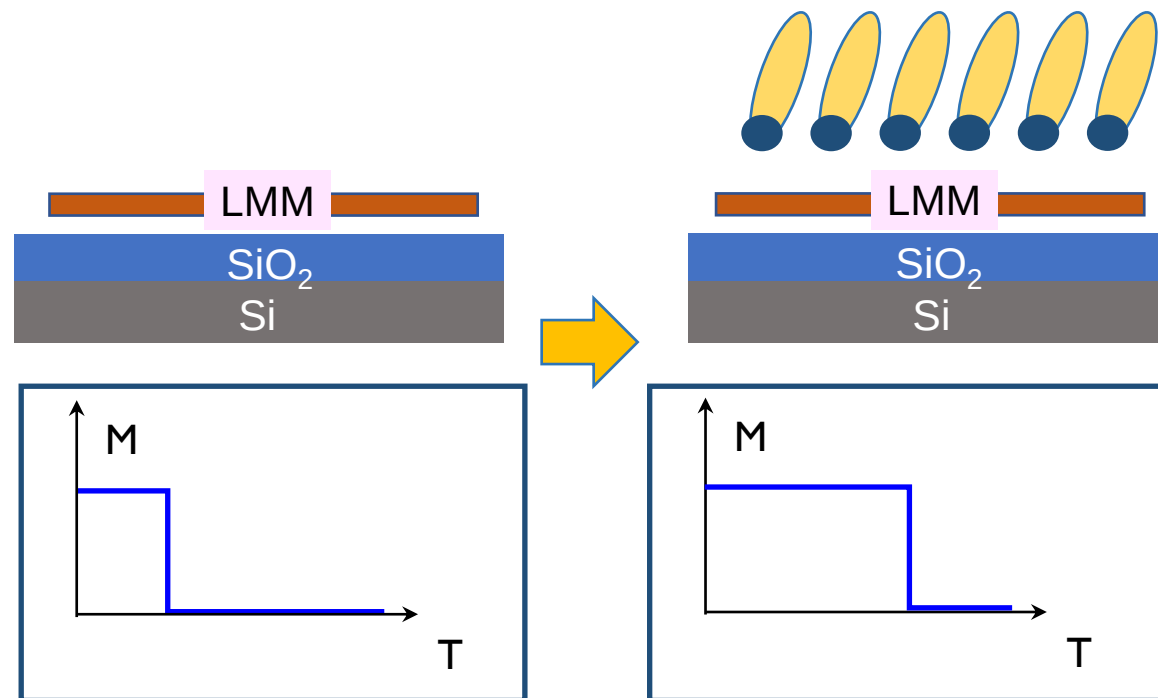
Tailor magnetic properties of LMM using molecules

Novel
Devices

Integrate LMM and molecules into multifunctional spintronic devices

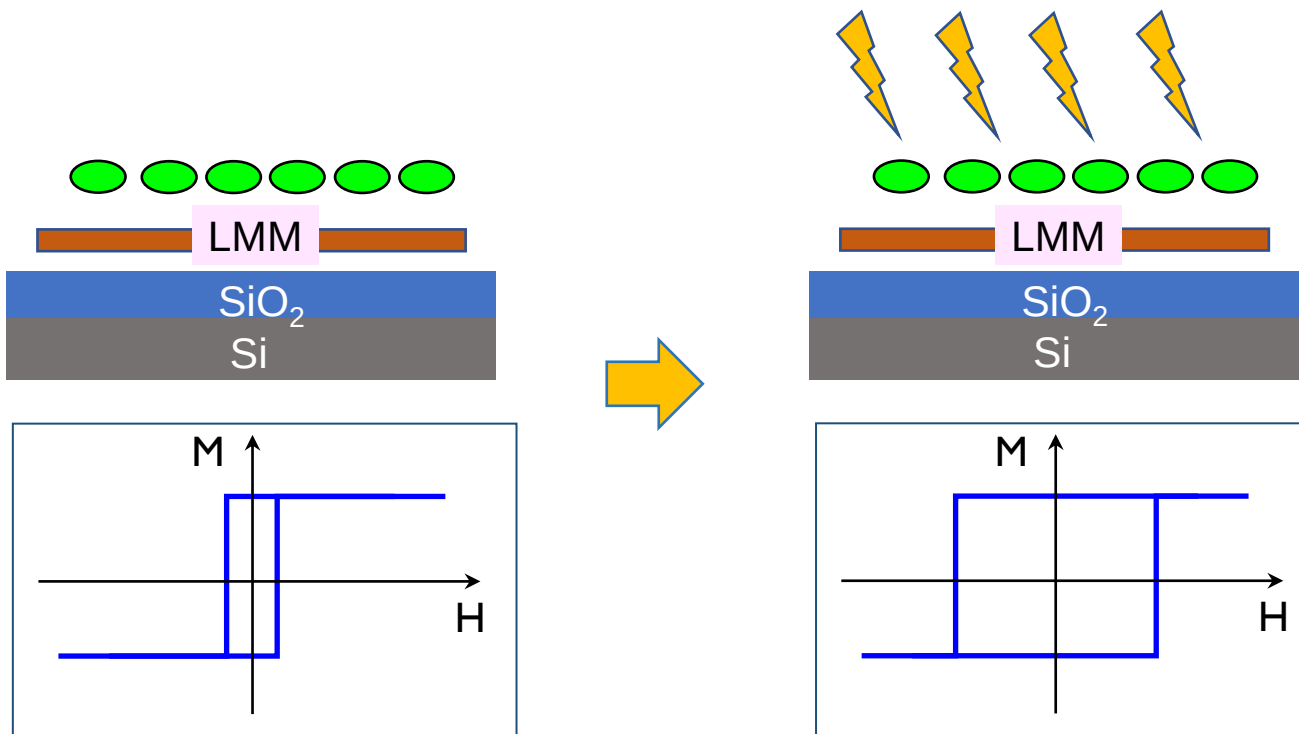
Objective I.

Molecular functionalization for improved air stability/increased T_c



Objective 2.

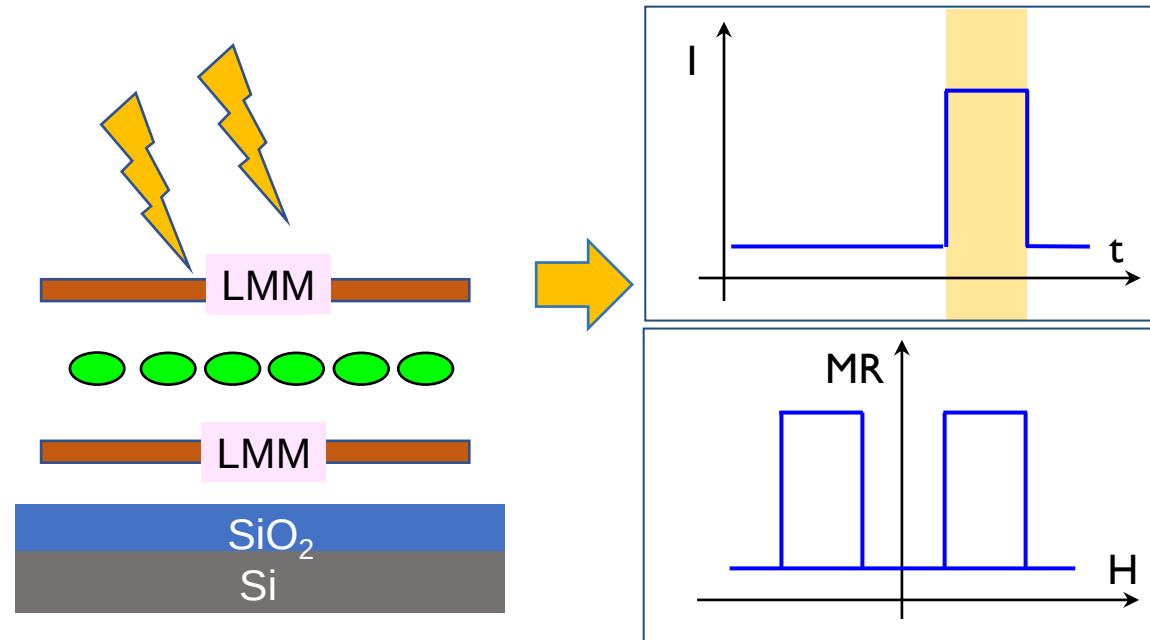
Manipulation of the magnetic properties of LMM using external stimuli



- ✓ Light irradiation
- ✓ Mechanical pressure
- ✓ Electric fields

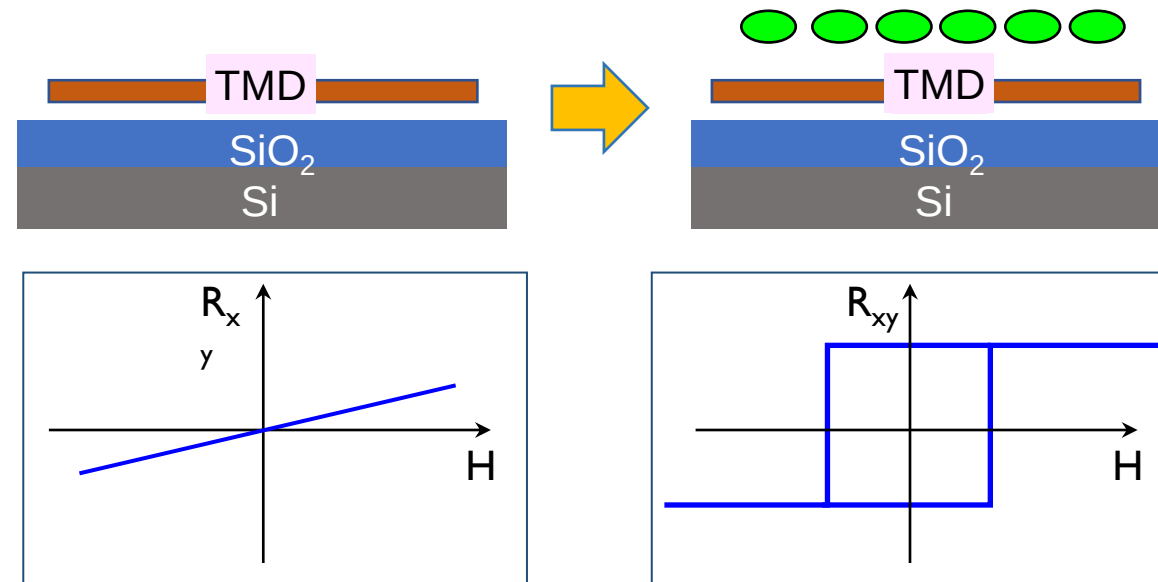
Objective 3.

Multiresponsive spintronic devices

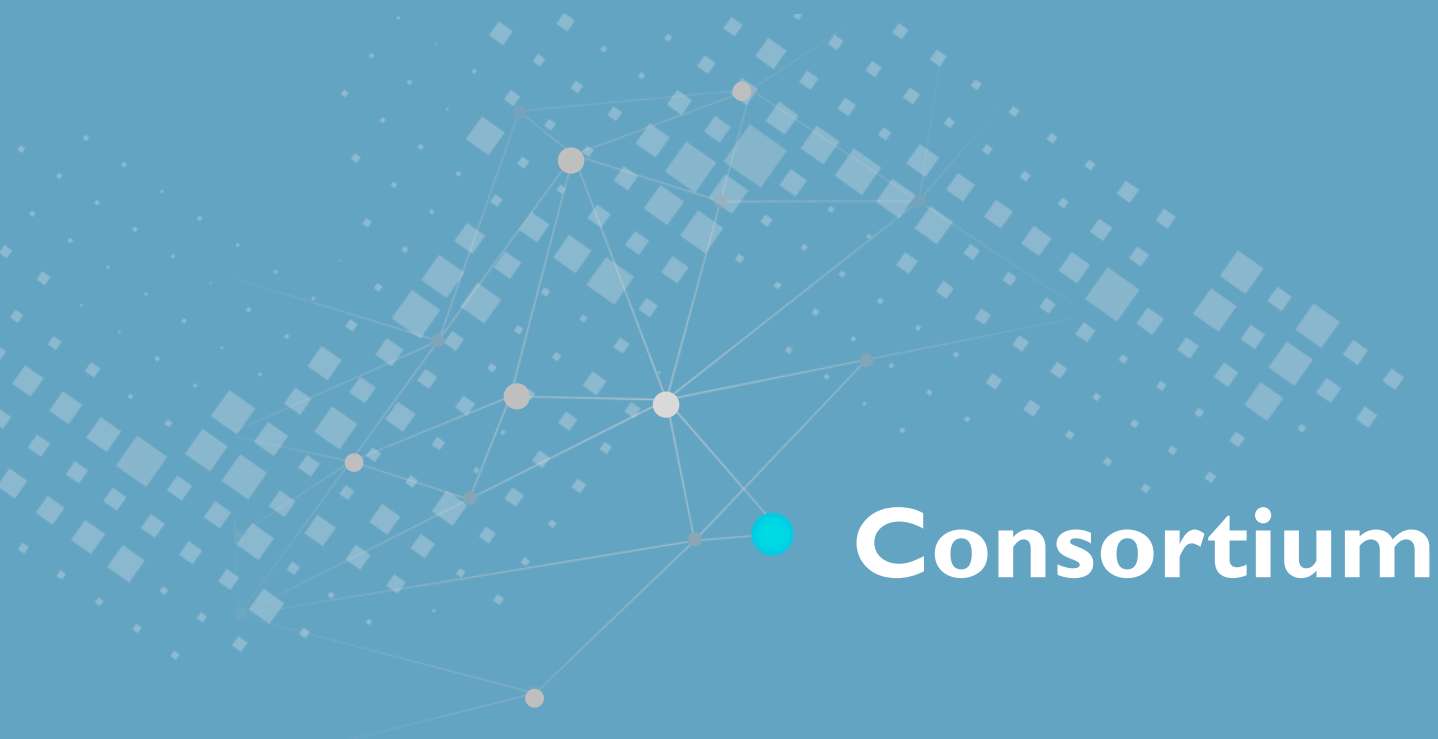


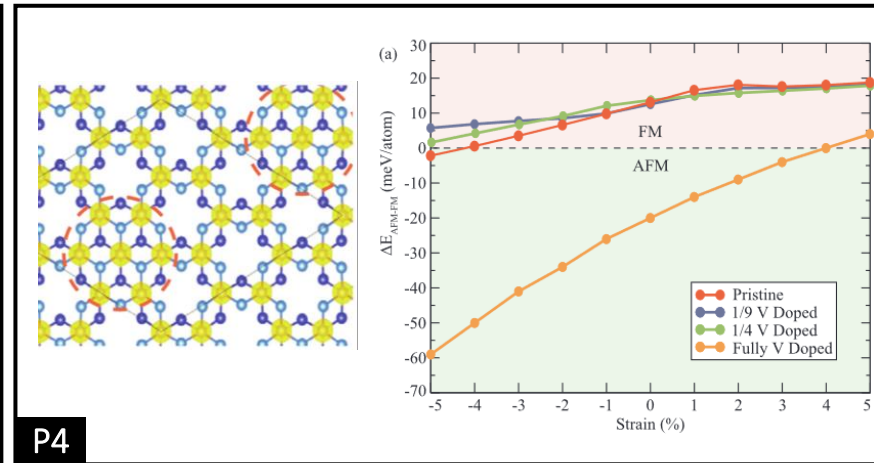
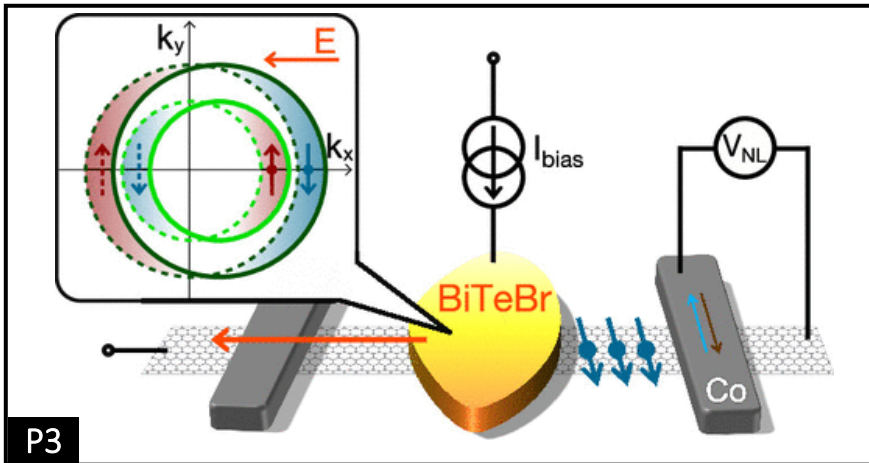
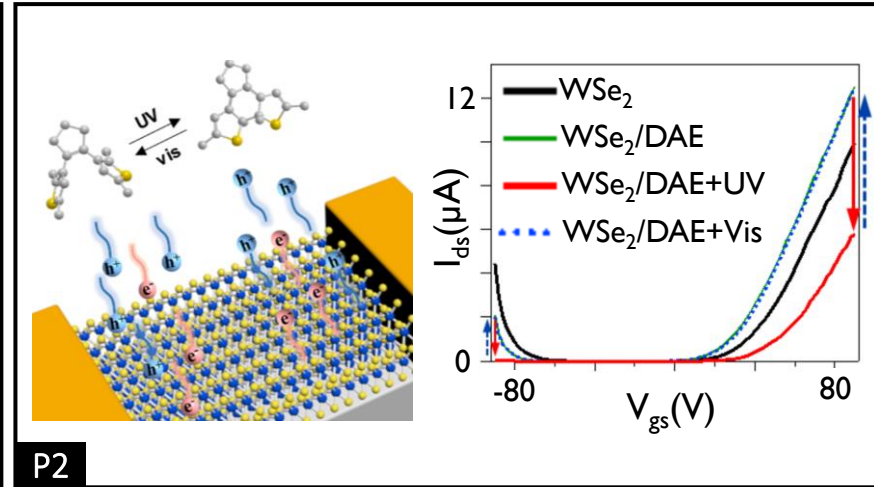
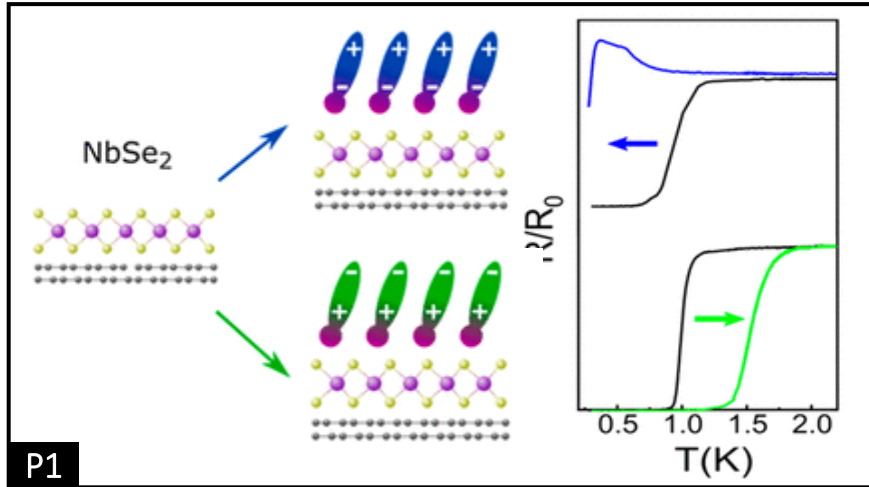
Objective 4.

Induce ferromagnetism in non-magnetic materials via molecules



Different interactions between molecules and 2D Materials





PI. CIC nanoGUNE in San Sebastian Spain



Nanodevices Group



M. Gobbi



L. Hueso

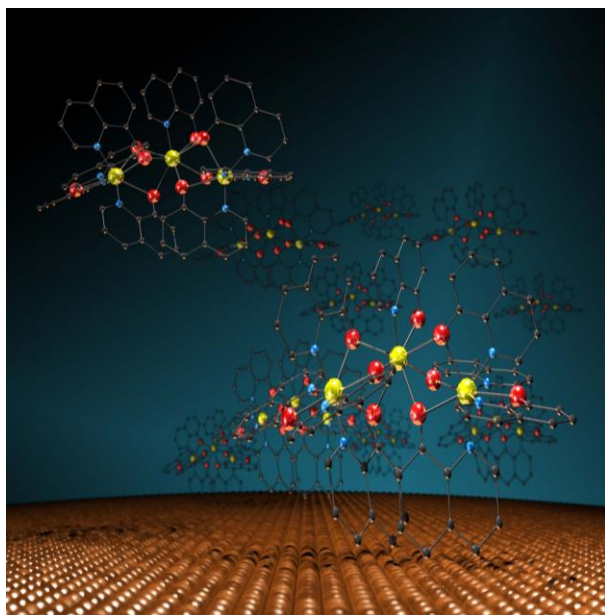


B. Martin-Garcia

PI. Nanodevices group

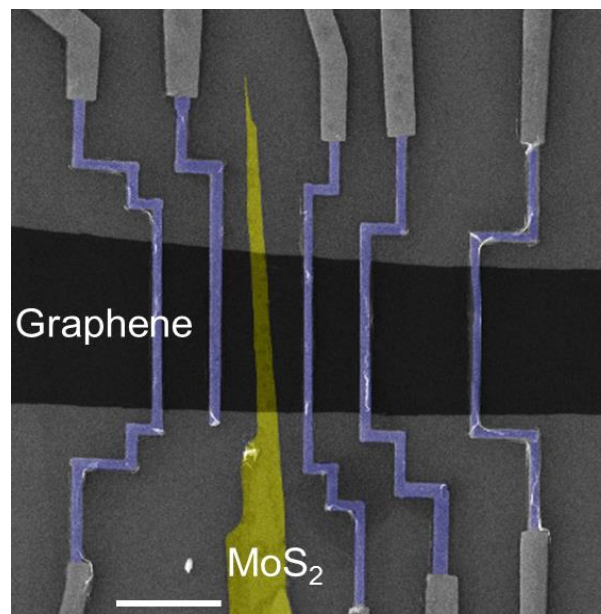
Research interests

Molecular spintronics



Advanced Materials 32, 1906908 (2020)

Van der Waals Spin Devices

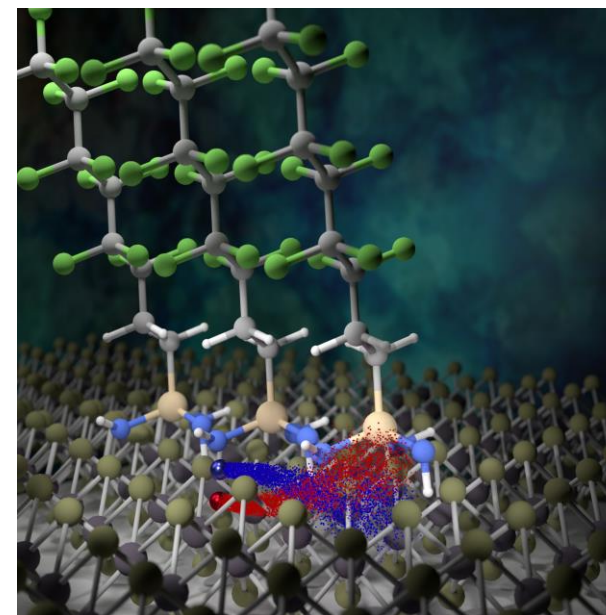


Nano Letters 19, 1074 (2019)

Nano Letters 19, 8758 (2019)

Nature Materials (2022). 10.1038/s41563-022-01211-7

Molecular Functionalization

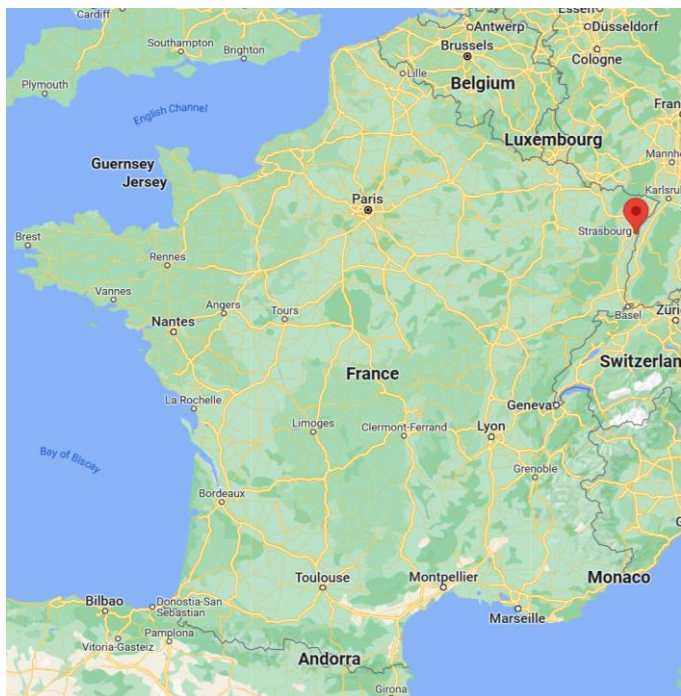


Nano Letters 21, 136 (2021)

Chemical Reviews 122, 50 (2022)

Partner 2. Institute of supramolecular science and engineering in Strasbourg

Nanochemistry Lab



Prof. P. Samorì



Dr. A.
Ciesielski

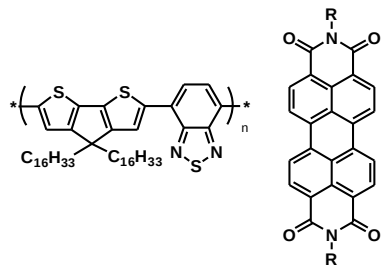


Dr. F.
Richard

Partner 2. Nanochemistry Lab

MATERIALS

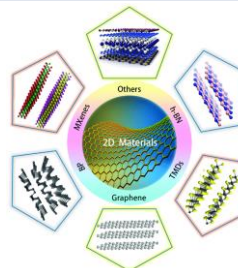
Organic/Polymeric Semiconductors



Molecular Switches



2D Materials



MULTIFUNCTIONALITY

Properties Adjustment

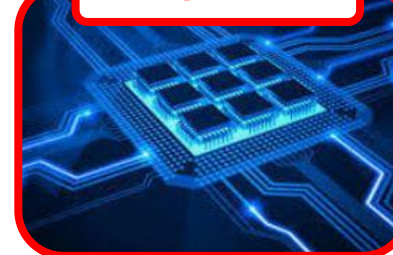
- Chemical Functionalization
- Blends
- Hybrids
- Interfacing

Multiscale Characterisation

- Structure & Morphology
- Composition & Porosity
- Opto-electronical
- Electro-mechanical

APPLICATIONS

Smart opto-electronics



Energy storage and conversion



Water Purification



Chemical Sensing



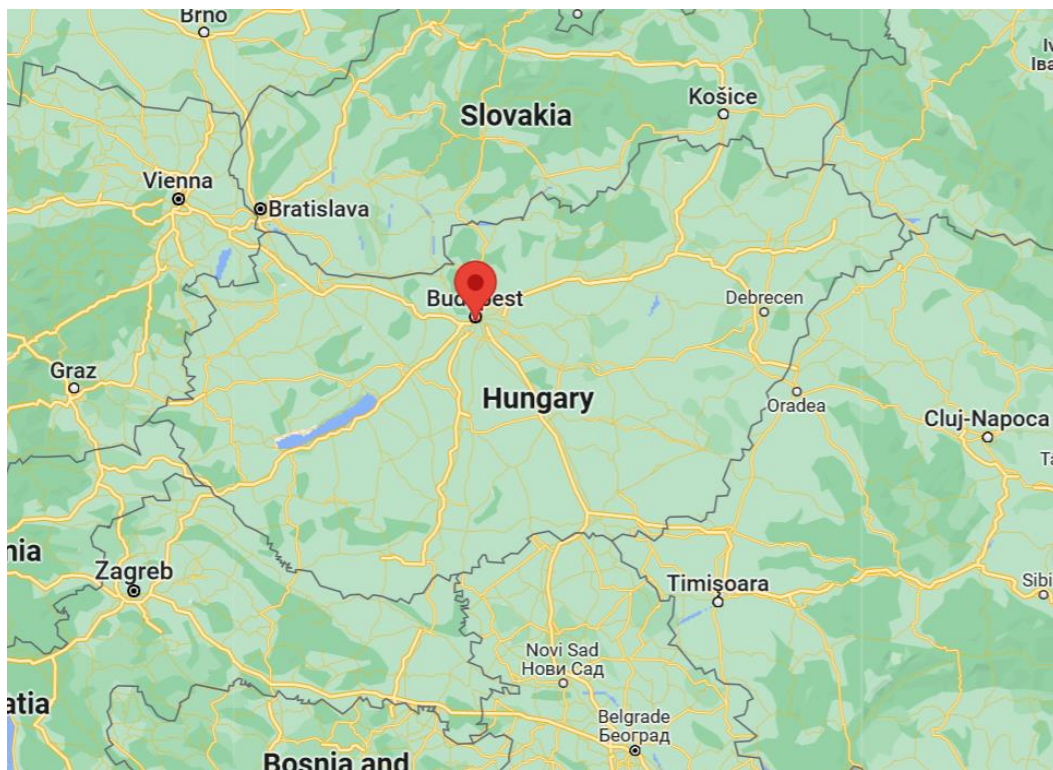
Physical Sensing



Civil Engineering



Partner 3. Budapest University of Technology and Economics (BME)



Nanoelectronics Research Lab (Quantum Electronics)



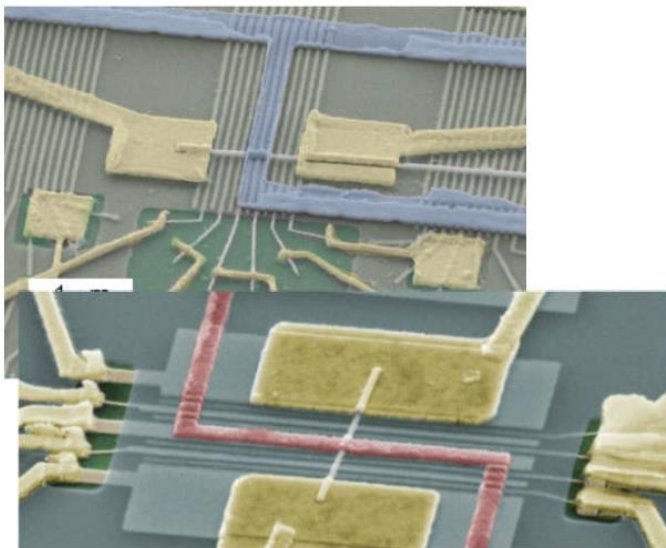
Prof. S. Csonka



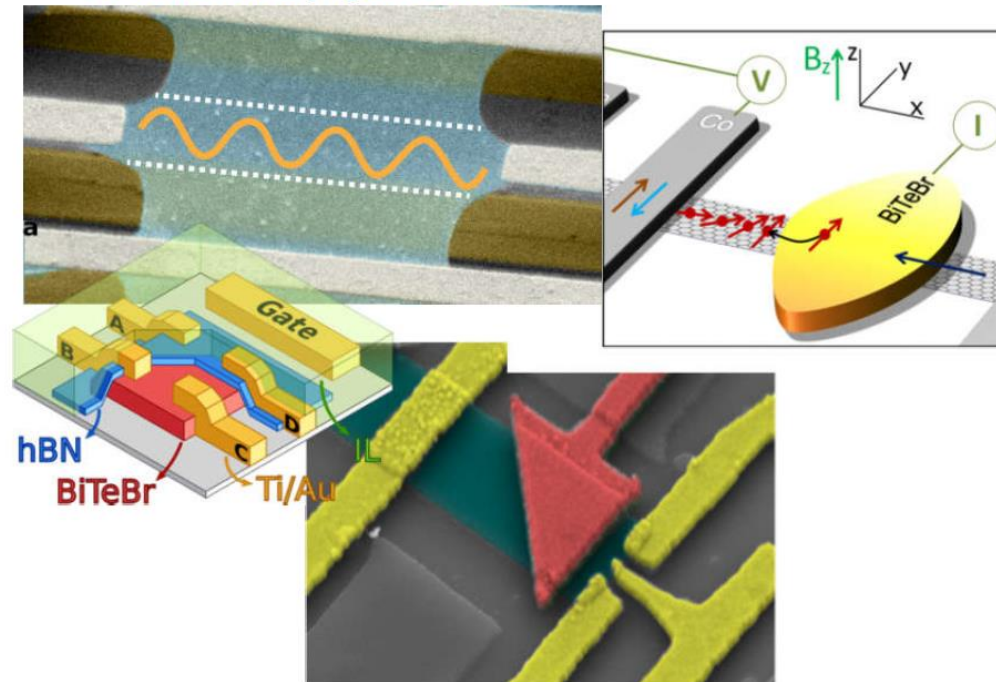
Prof. P. Makk

Partner 3. Nanoelectronics Research Lab

Quantum dots, topological superconductivity



2D materials, spintronics



Circuit QED, FMR, qubits



Partner 4. Izmir Institute of Technology



**Computational & Experimental
NanoTechnology (CENT)**

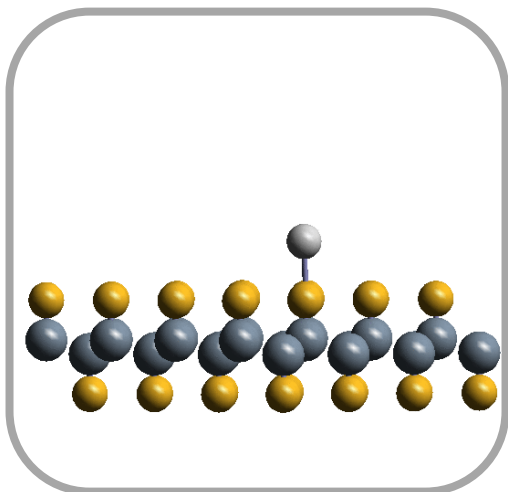


Prof. H. Sahin

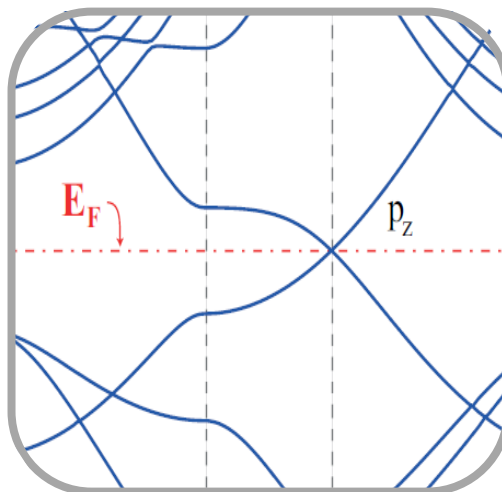


Partner 4. CENT

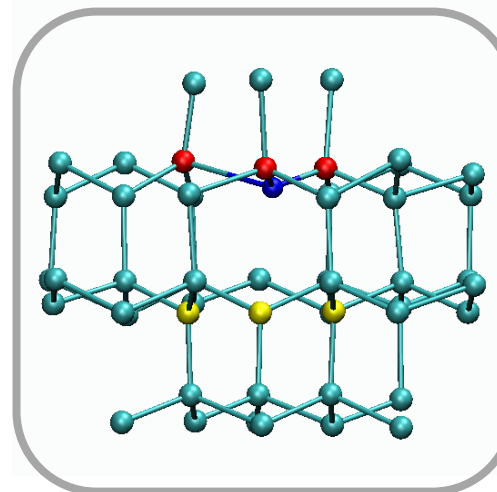
Optimization



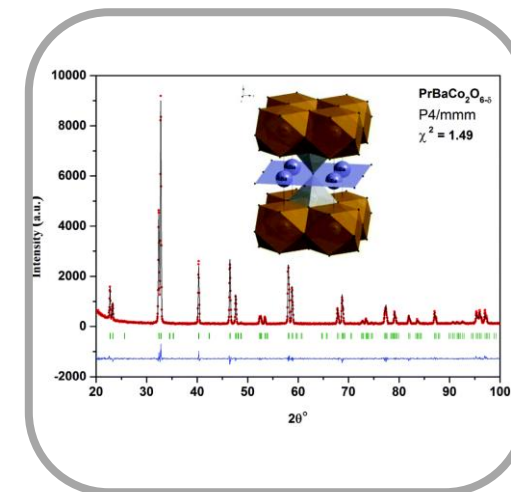
Electronic Structure



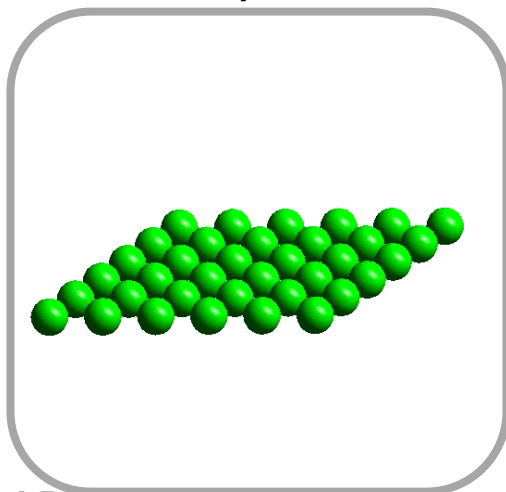
Phonons



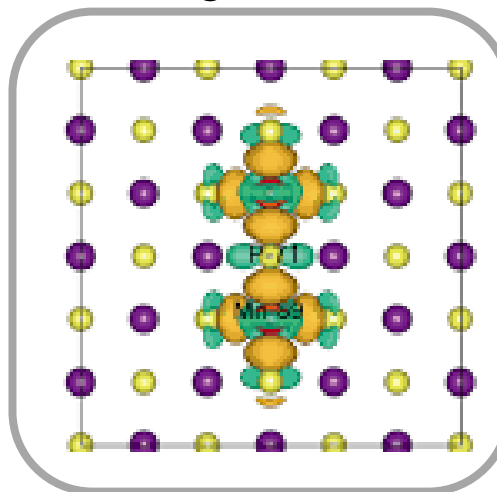
XRD



Stability Tests



Magnetism



Optical Response



Acknowledgements

