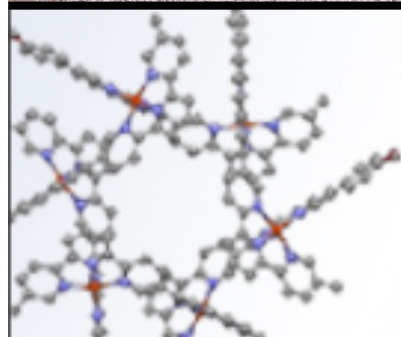


# 2D magnetic materials based on molecular/2D heterostructures

**E. Coronado**



ICMol



VNIVERSITAT  
ID VALÈNCIA

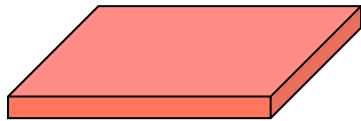
Instituto de Ciencia Molecular

# 2D Materials

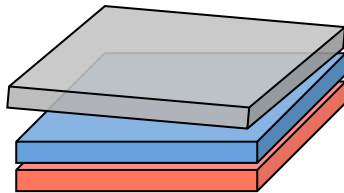
complexity



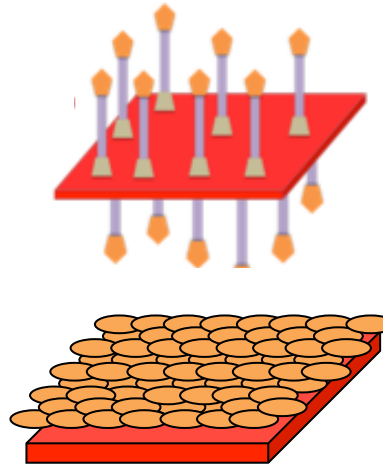
*Monolayers*



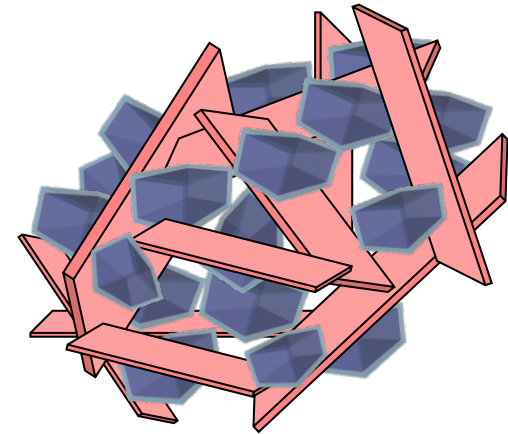
*VdW  
Heterostructures*



*Functionalized layers &  
hybrid heterostructures*



*Hybrid materials  
& composites*



quality

*2D PHYSICS*

*2D ELECTRONICS*

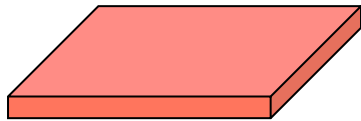
*2D CHEMISTRY*

# 2D Materials

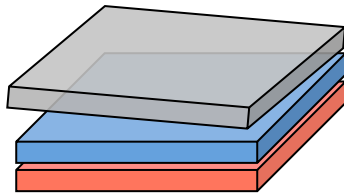
complexity



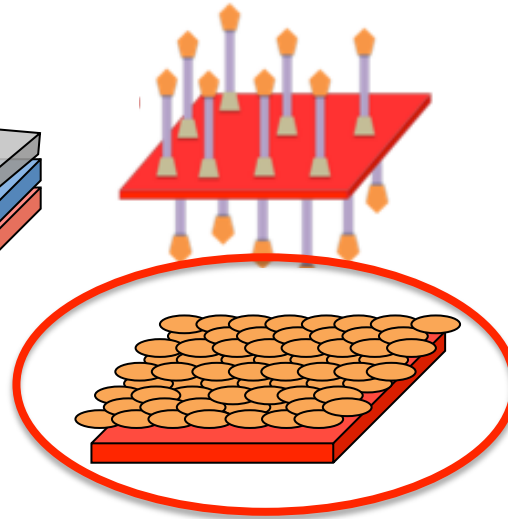
*Monolayers*



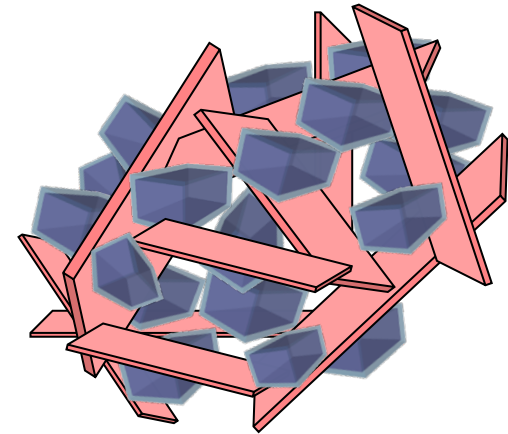
*VdW  
Heterostructures*



*Functionalized layers &  
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*Hybrid materials  
& composites*



quality

*2D PHYSICS*

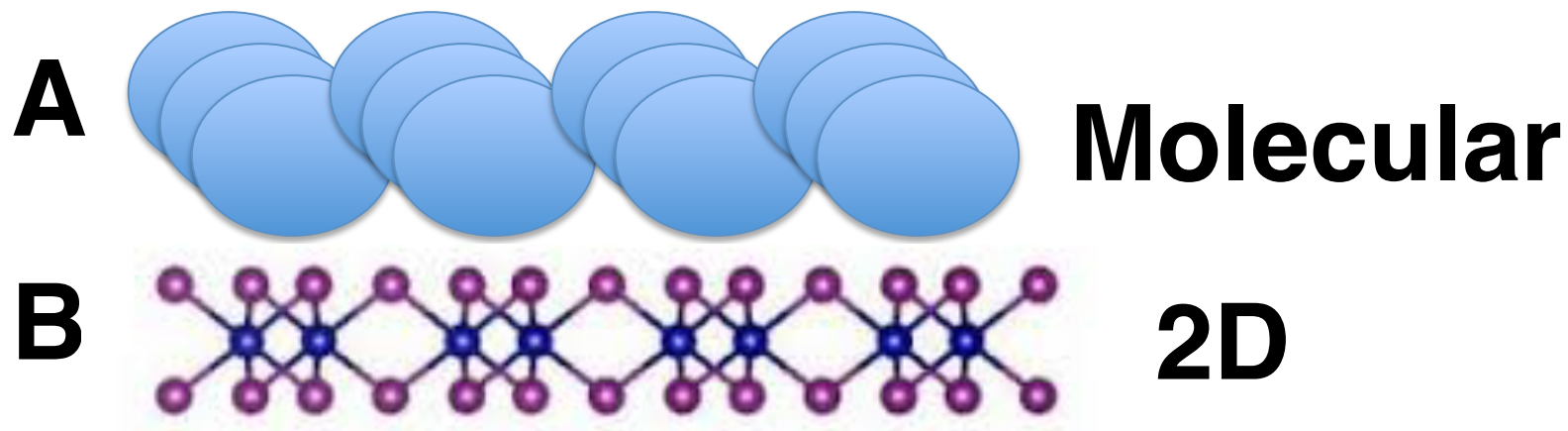
*2D ELECTRONICS*

*2D CHEMISTRY*

Molecular/2D heterostructures  
*Smart materials*

# ***MOLECULAR/2D HETEROSTRUCTURES***

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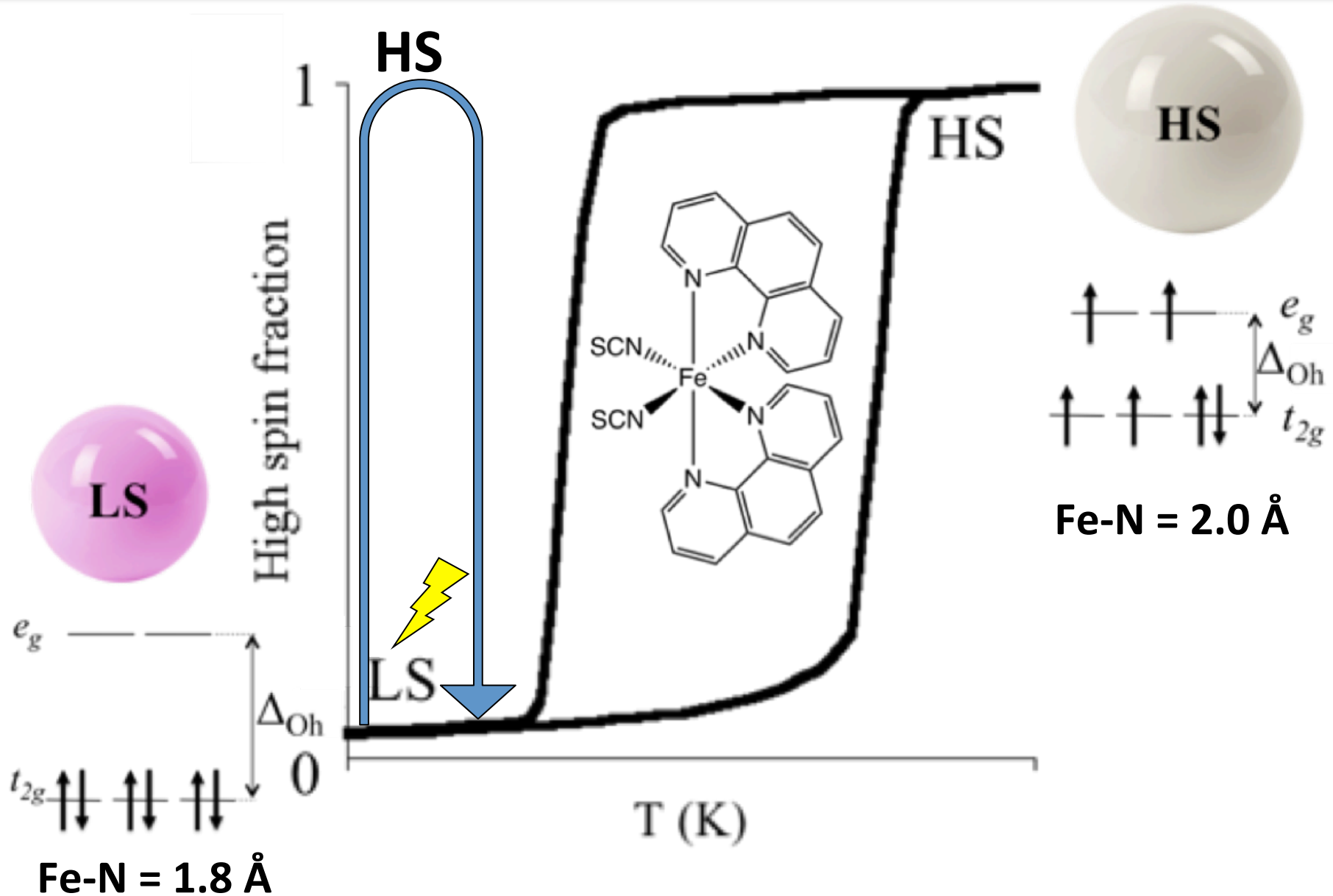


***Stimuli-responsive molecules  
+ 2D material***

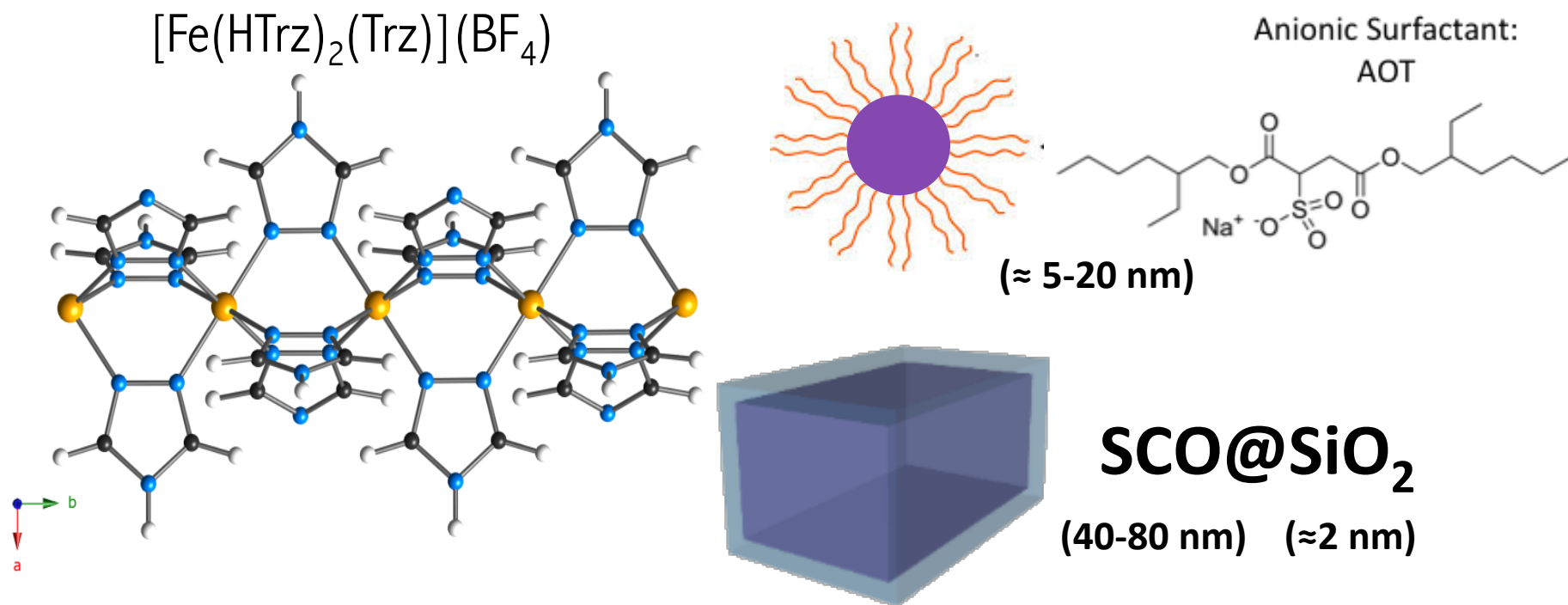
**=**

***Smart  
2D heterostructure***

# Molecular switches: Spin-crossover (SCO)



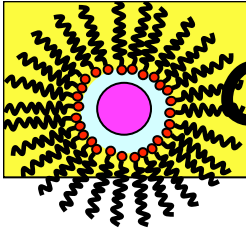
# SCO nanoparticles



*J. R. Galán, EC et al. Adv. Mater.* **2007**, *19*, 1359 and *Inorg. Chem.* **2010**, *49*, 5706

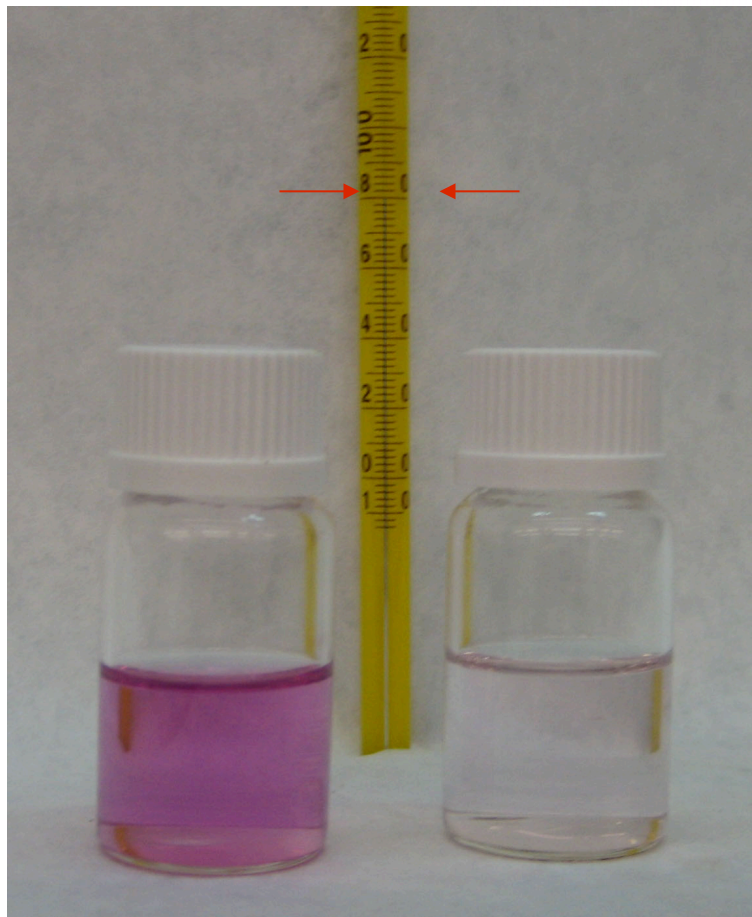
*M. Giménez-Marqués, EC et al. J. Mater. Chem. C* **2015**, *3*, 7946

*R. Torres et al. Dalton Trans.* **2019**, DOI: 10.1039/c9dt02086a

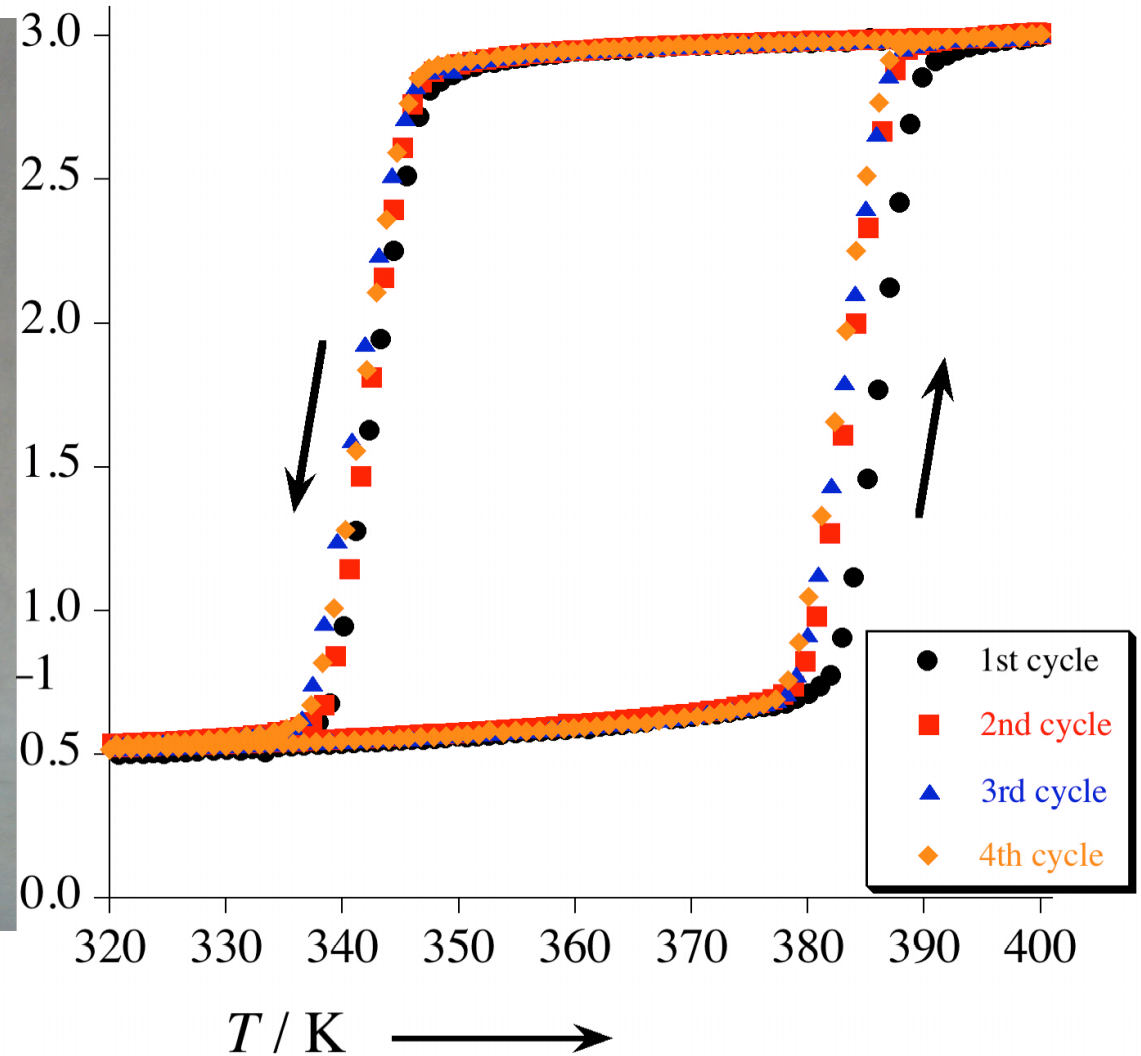


# Optical and Magnetic measurements

## MAGNETIC BISTABILITY

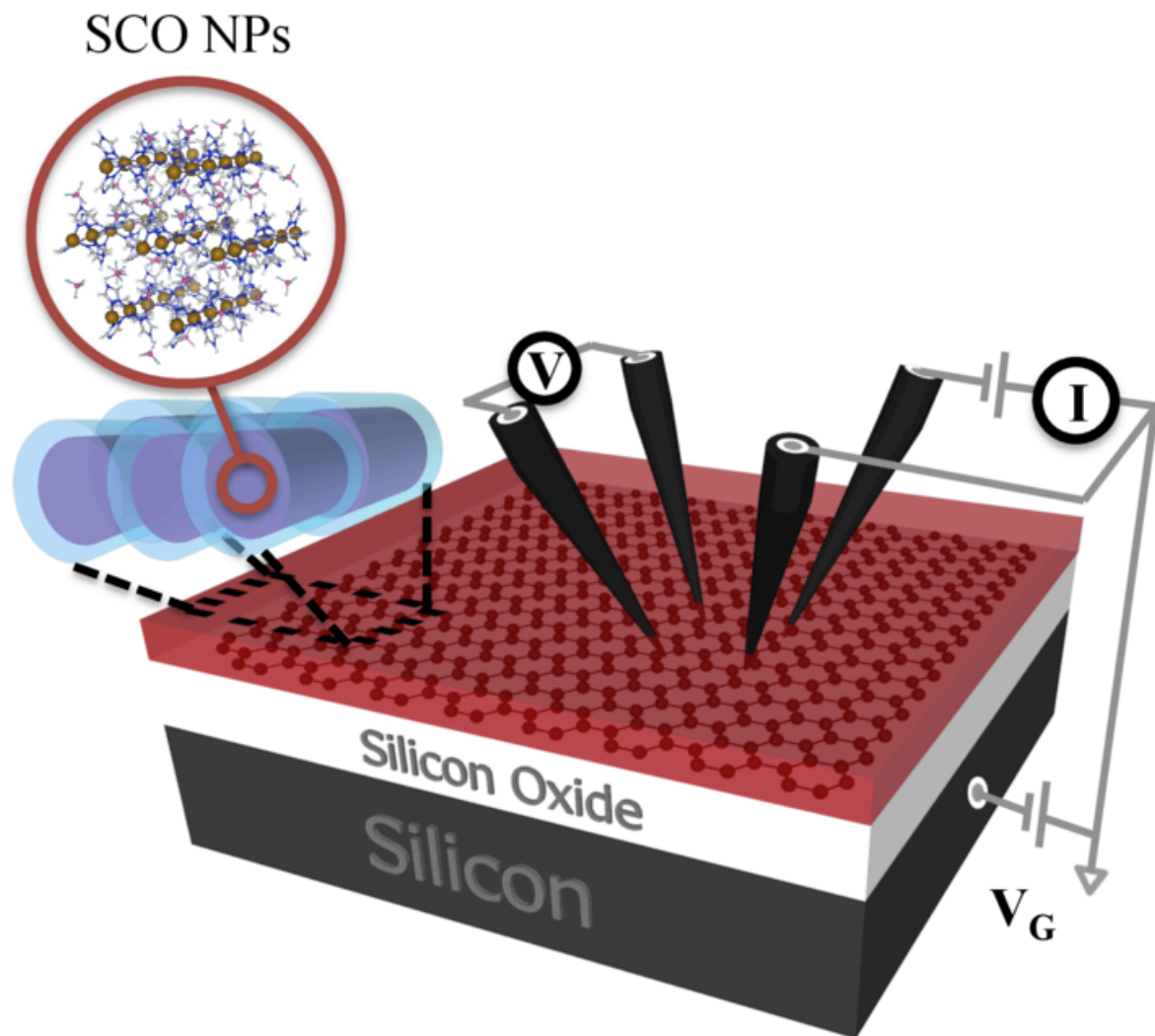


Suspension in octane



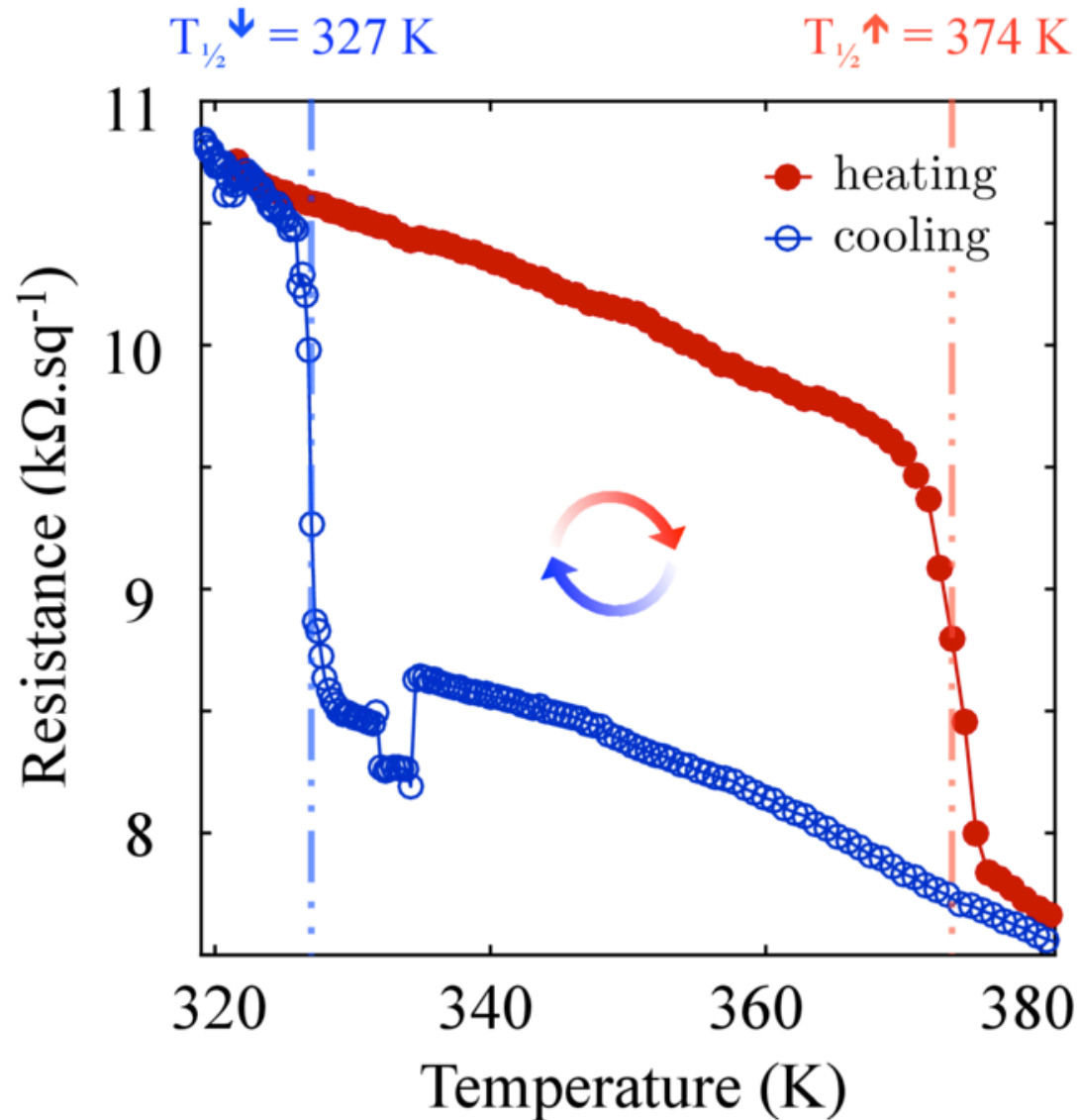


# 2D-networks of SCO nanoparticles on graphene



J. Dugay, EC, H. Van der Zant et al.  
*Nano Letters* **2017**, 17, 186

# Electrical properties of graphene



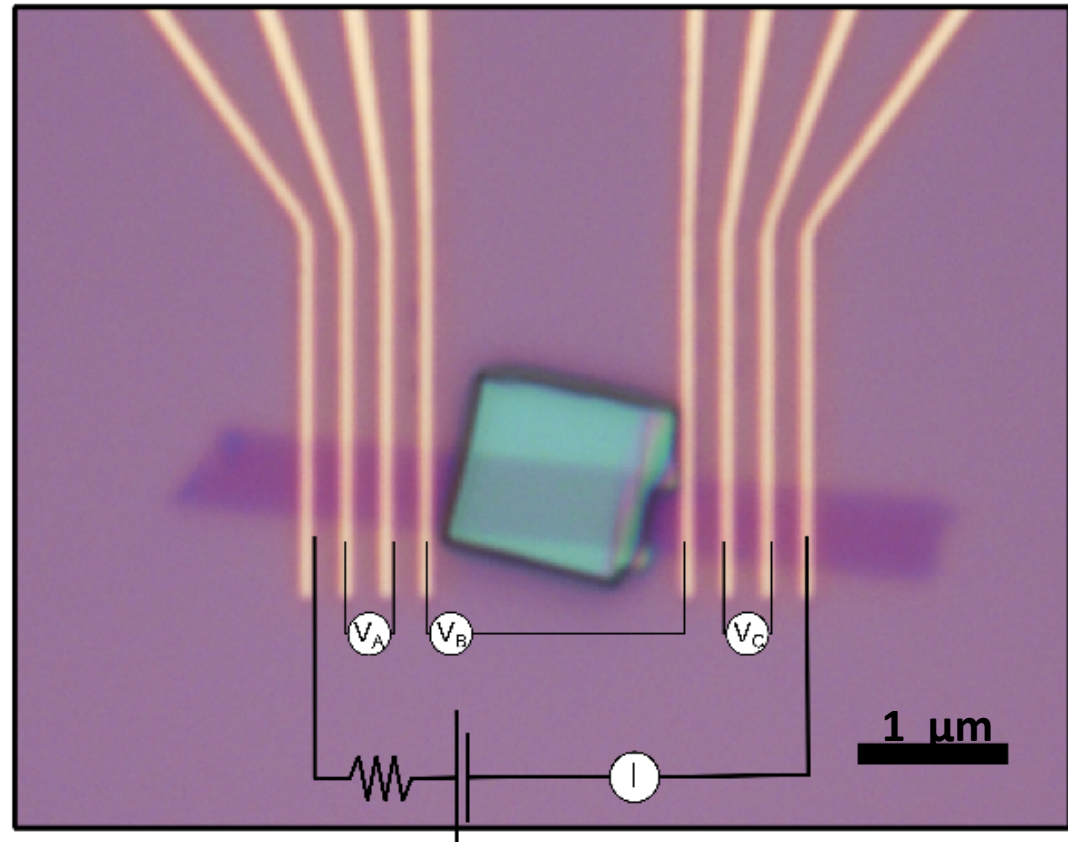
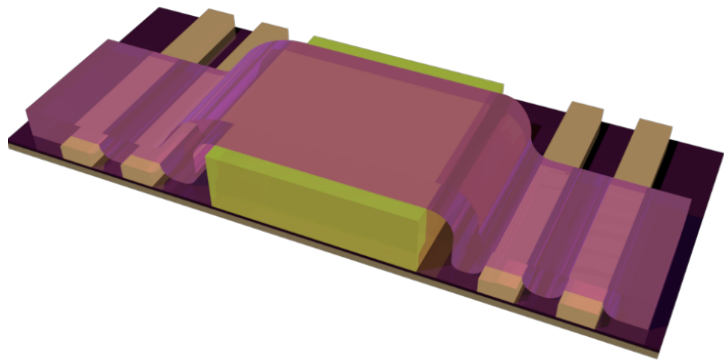
The spin state of the NPs is coupled to the transport properties of graphene

A graphene sensor of the spin state

*Electrical sensing of the spin*

J. Dugay, EC, H. Van der Zant et al.  
*Nano Letters* **2017**, 17, 186

# Hybrid electronic devices

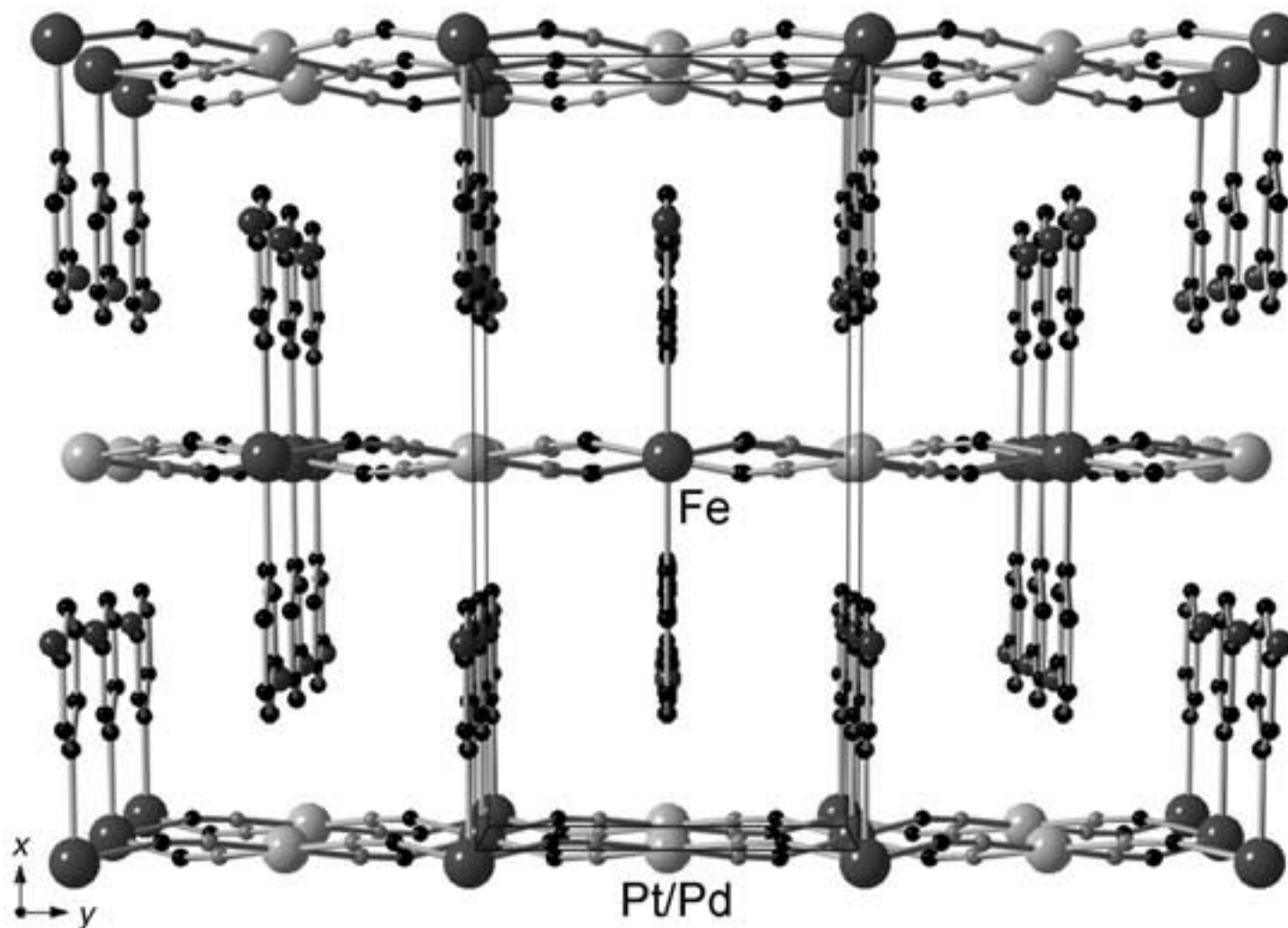


## SCO crystal/graphene heterostructures

Carla Boix, Samuel Mañas

# SCO crystal :

$\{\text{Fe}^{\text{II}}(\text{3-Xpy})_2[\text{Pt}^{\text{II}}(\text{CN})_4]\}$  interdigitated 2D MOF

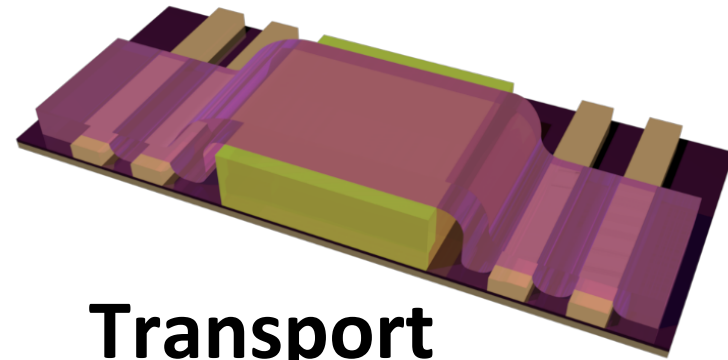
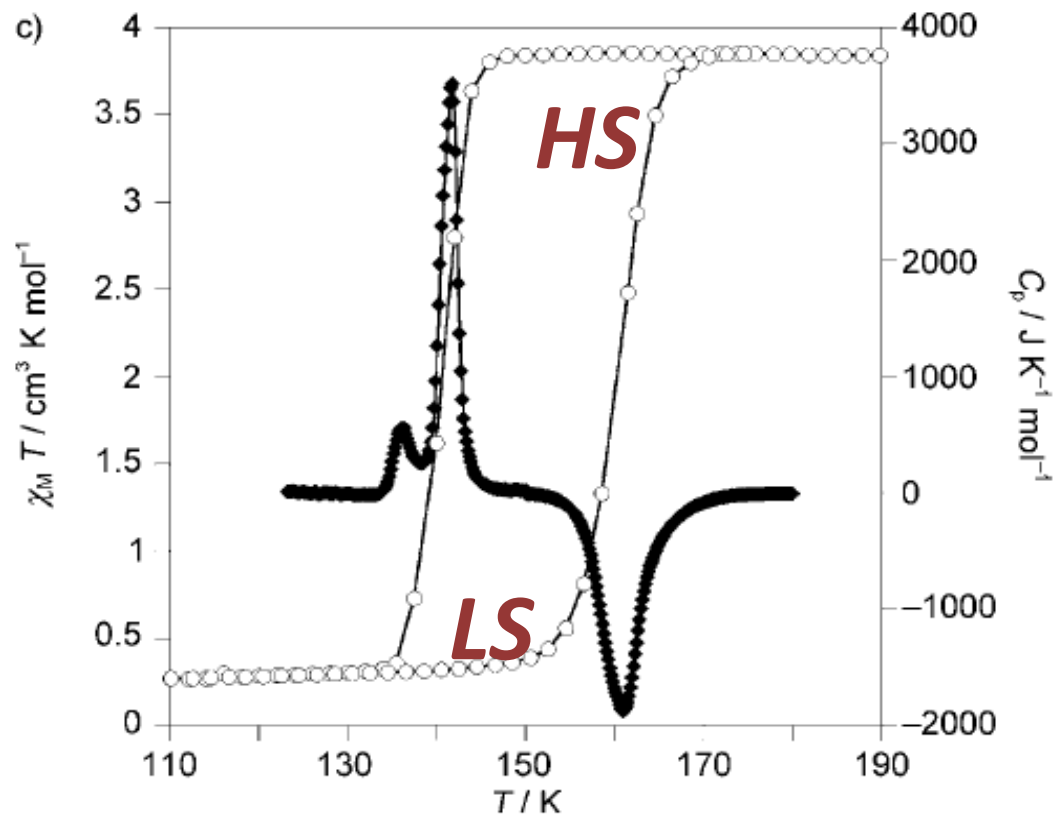


V. Martínez *et al.* *Chem. Eur. J.* **2009**, 15, 10960

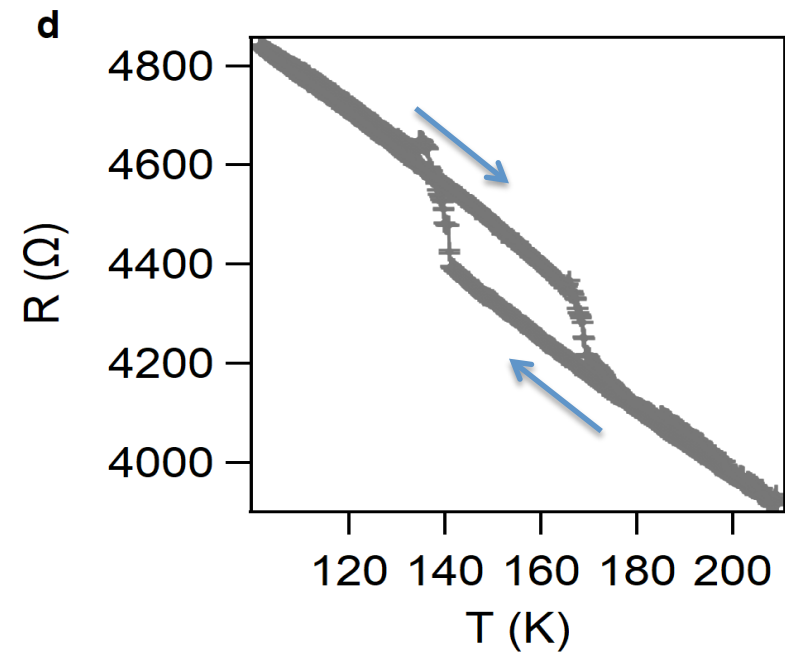
# Hybrid electronic devices

*Electrical sensing of the spin*

## Magnetism



## Transport

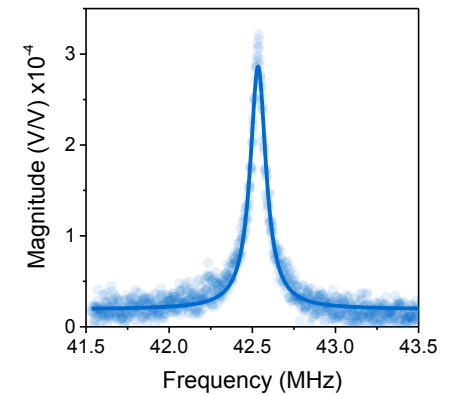
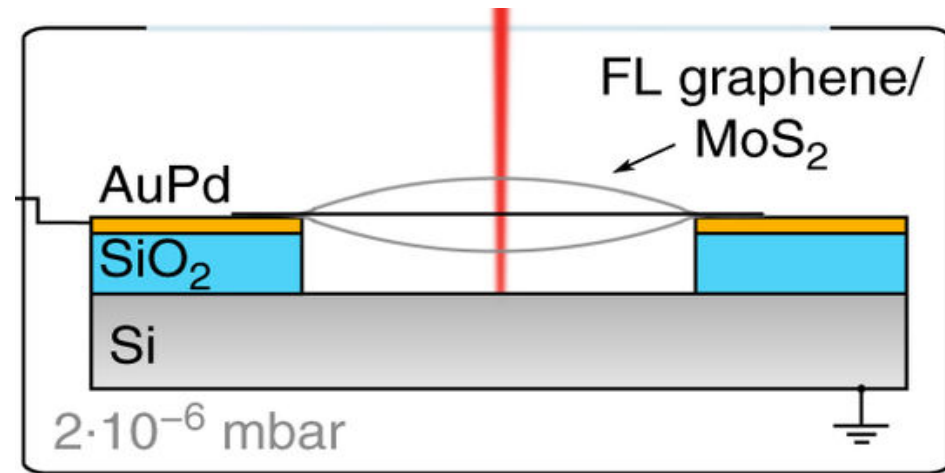
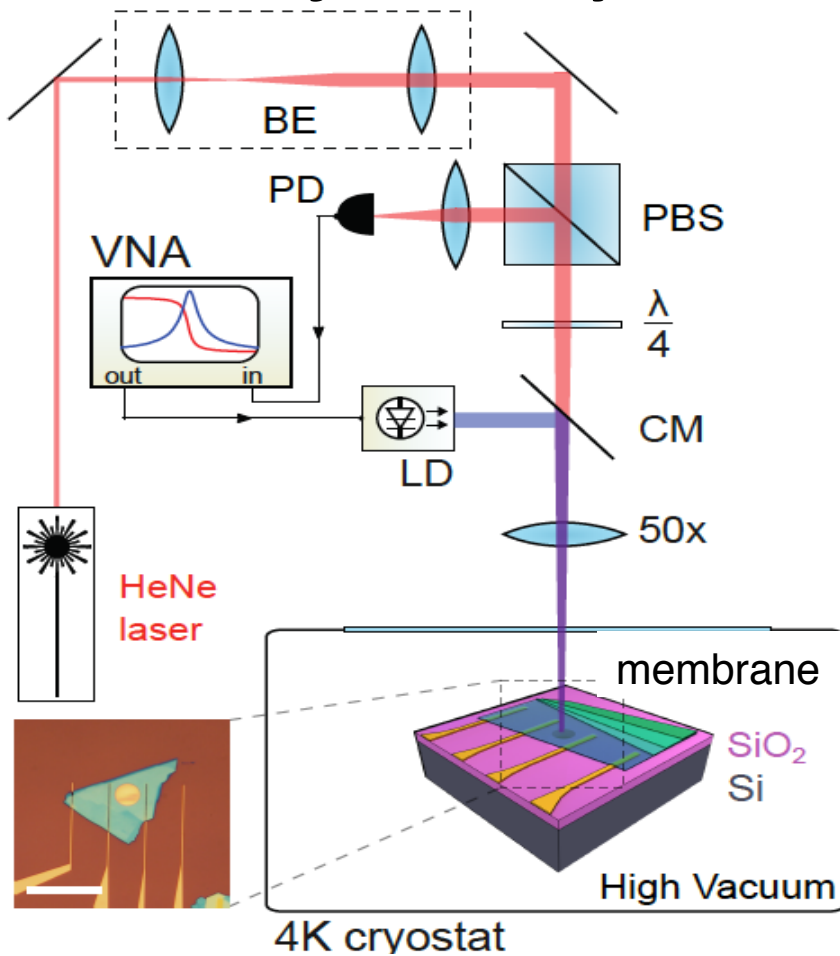


# MECHANICAL PROPERTIES

(M. Siskins, H. Van der Zant)

## *Mechanical motion of suspended membranes*

### *Laser interferometry*

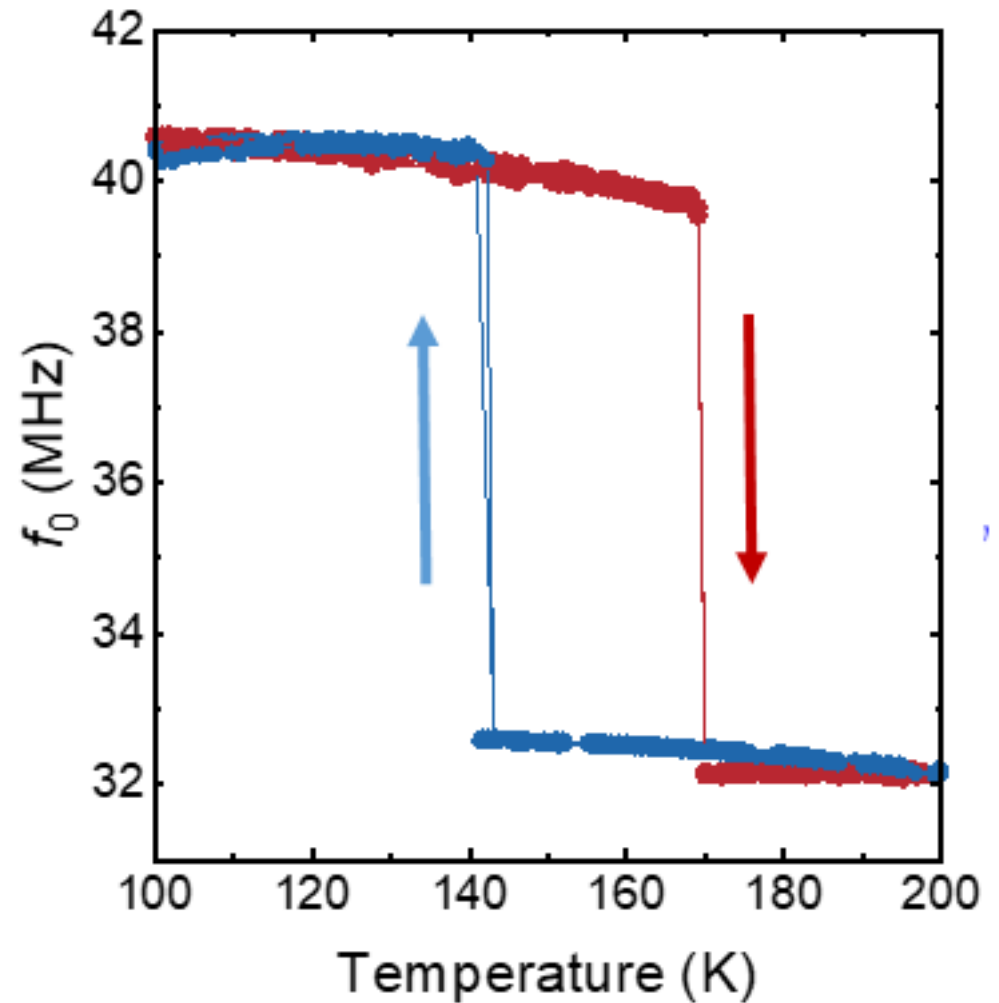
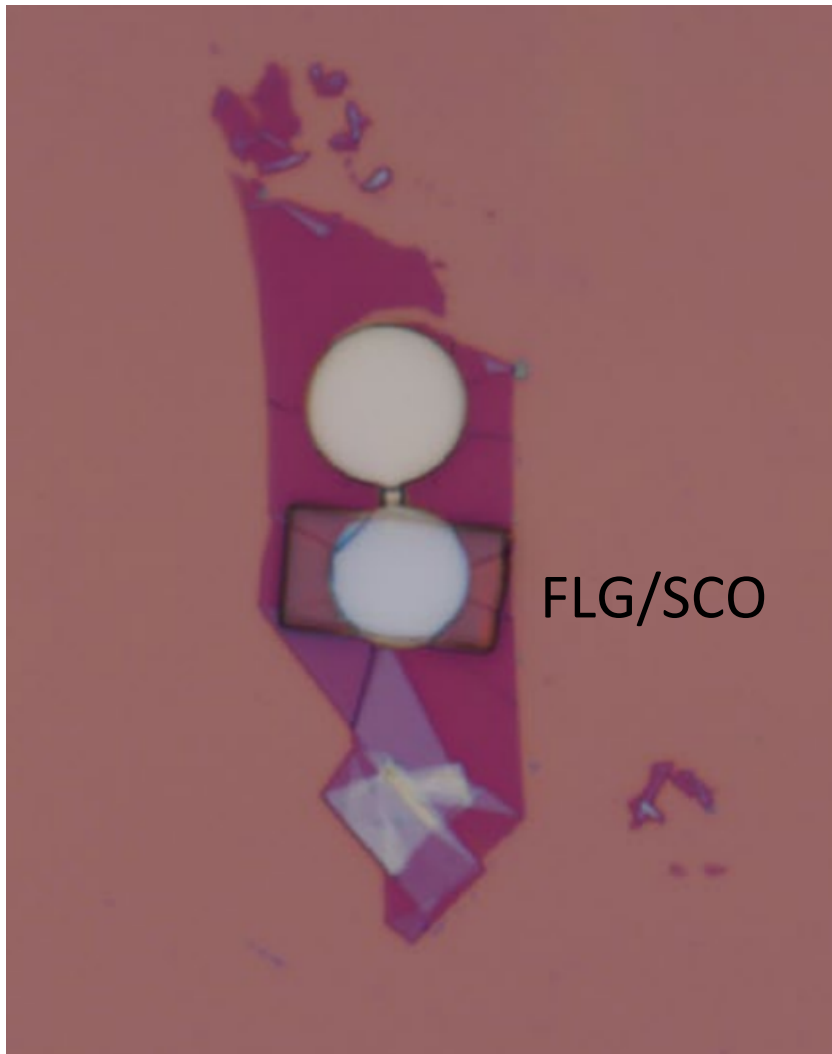


Micro drum

# MECHANICAL PROPERTIES

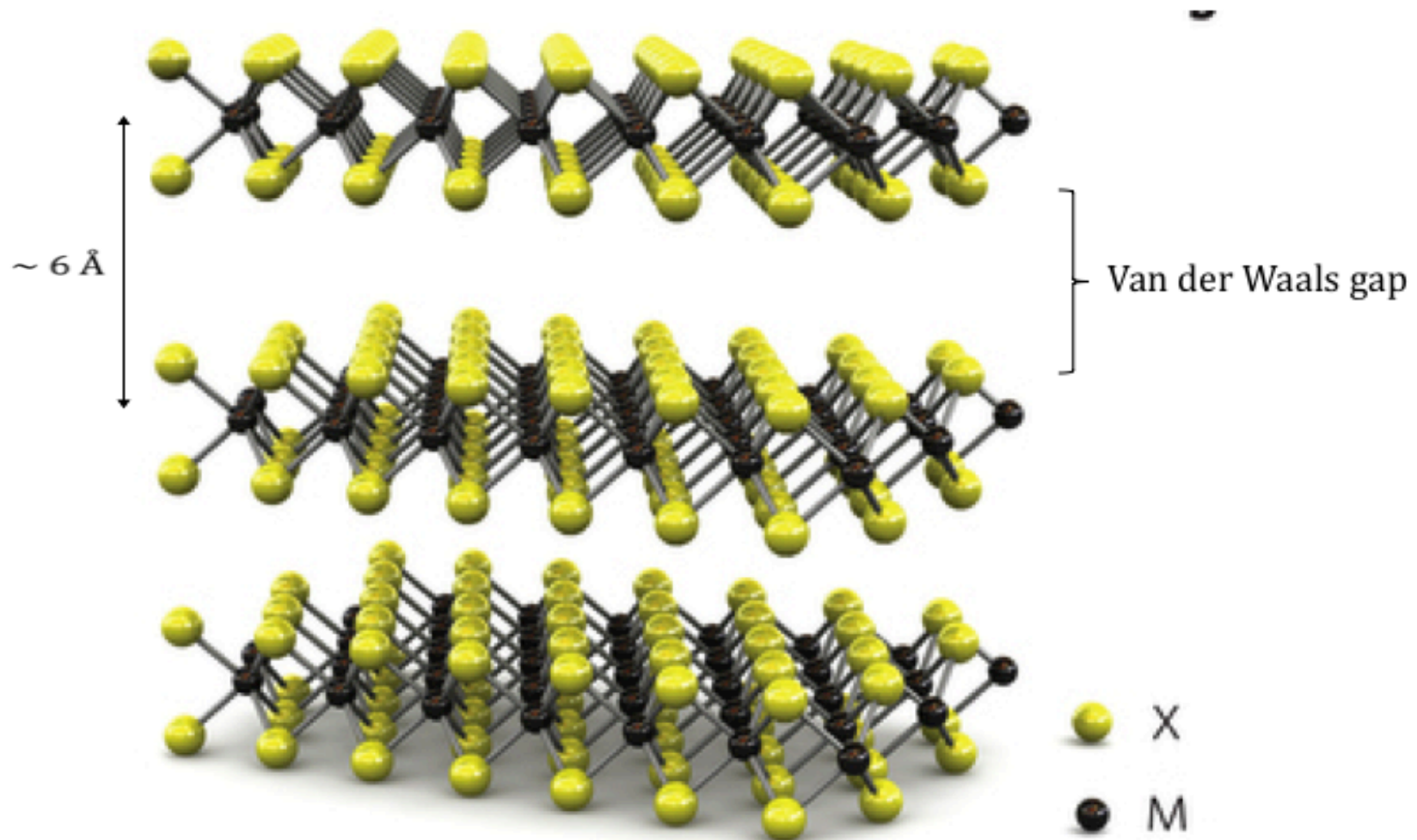
(M. Siskins, H. Van der Zant)

## *Mechanical sensing of the spin*



# $\text{MX}_2$ (Transition metal dichalcogenides)

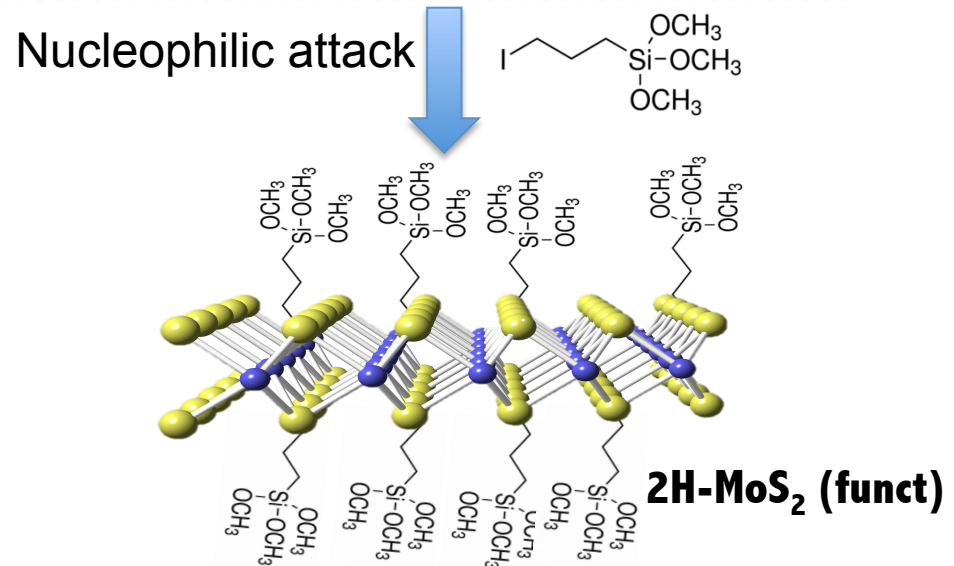
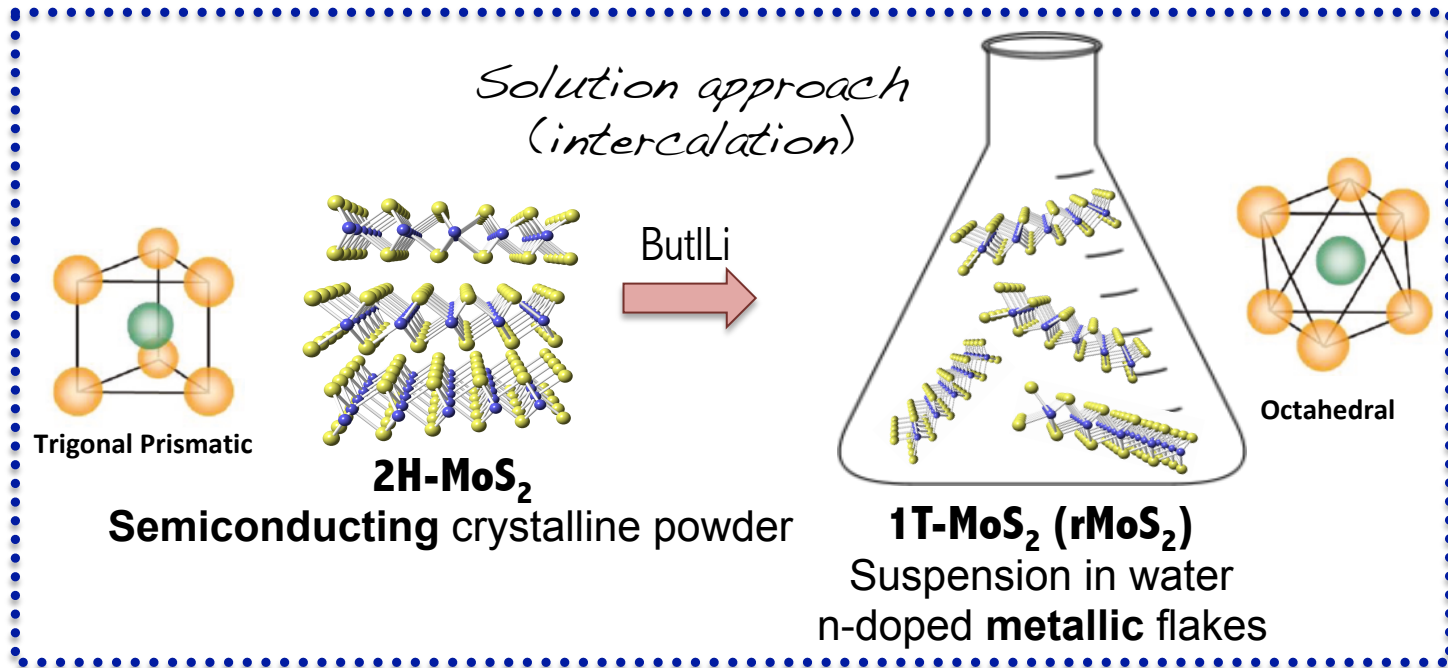
M = Ti, Zr, Hf, Nb, Ta, Mo, W...; X = S, Se, Te



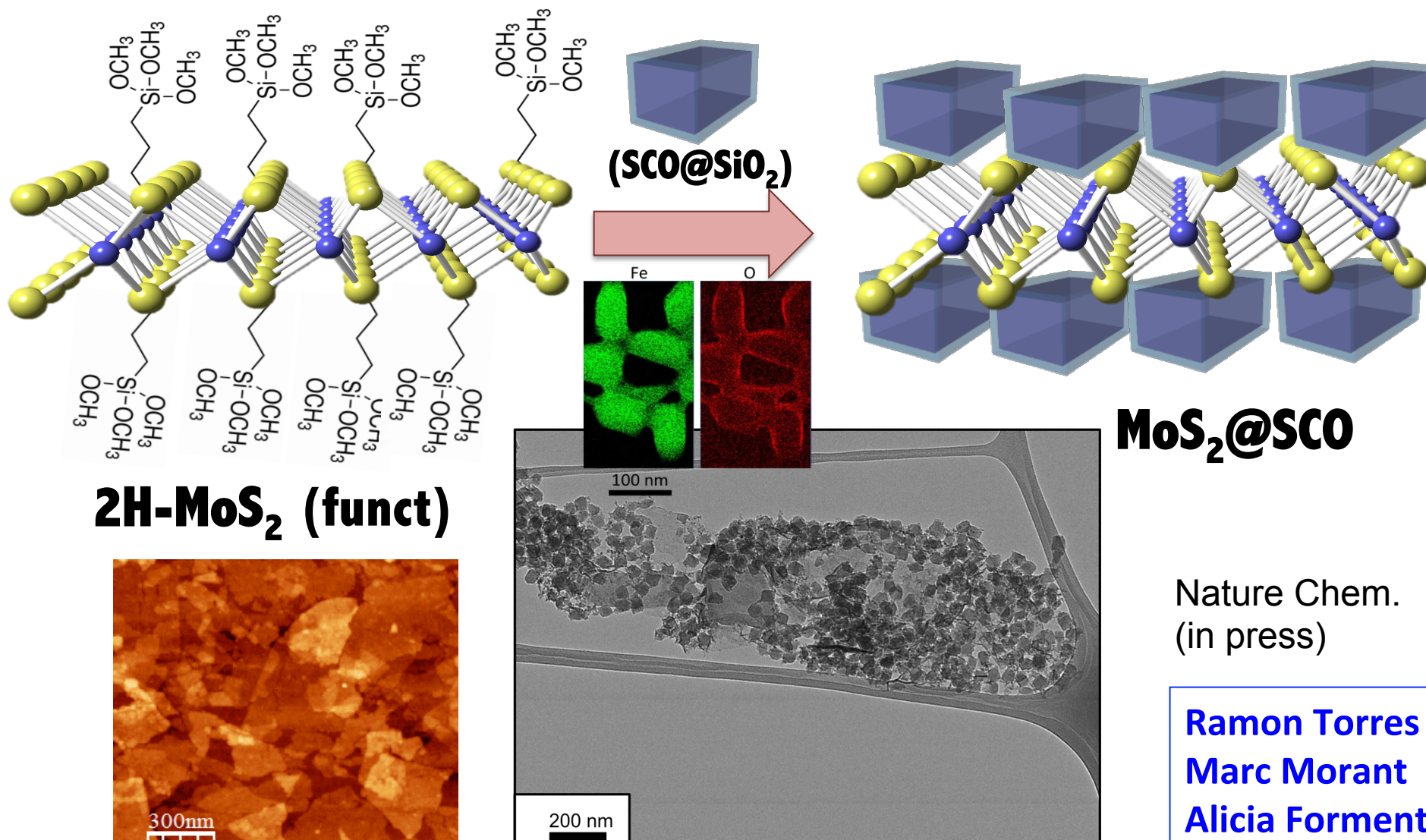
***Insulators, Semiconductors, Conductors, Superconductors***



# TRANSITION METAL DICHALCOGENIDES (TMDCs)



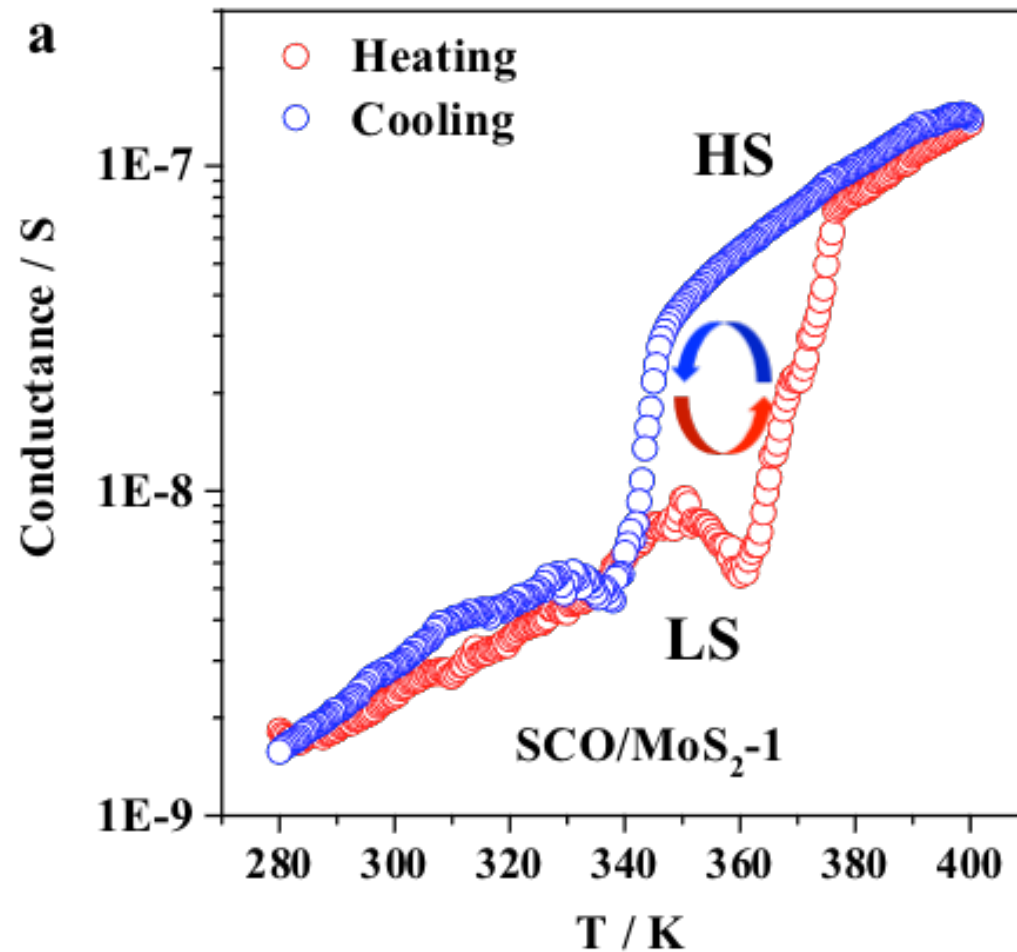
# SCO@SiO<sub>2</sub> nanoparticles on MoS<sub>2</sub>



# SCO@SiO<sub>2</sub> nanoparticles on MoS<sub>2</sub>

**TRANSPORT**

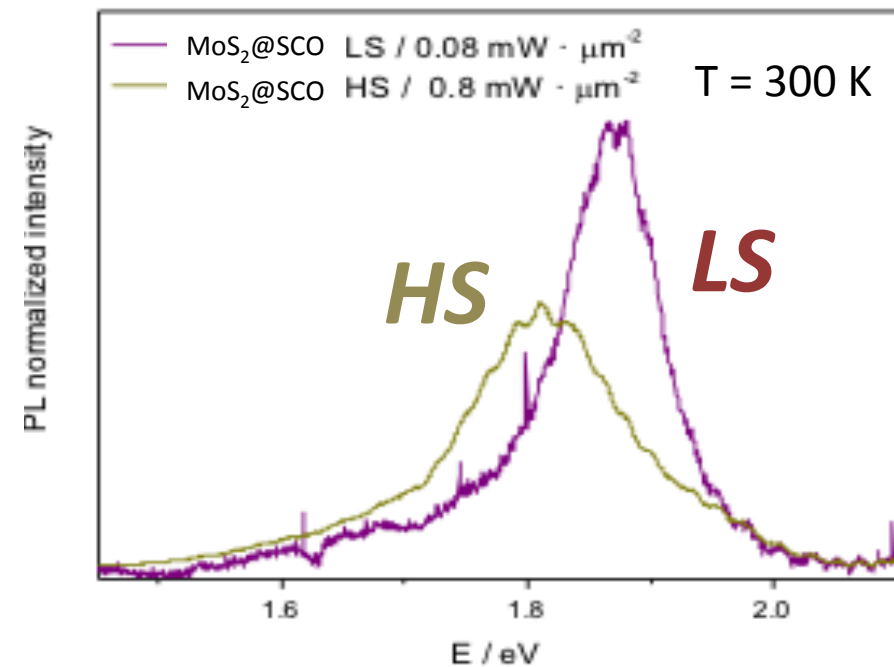
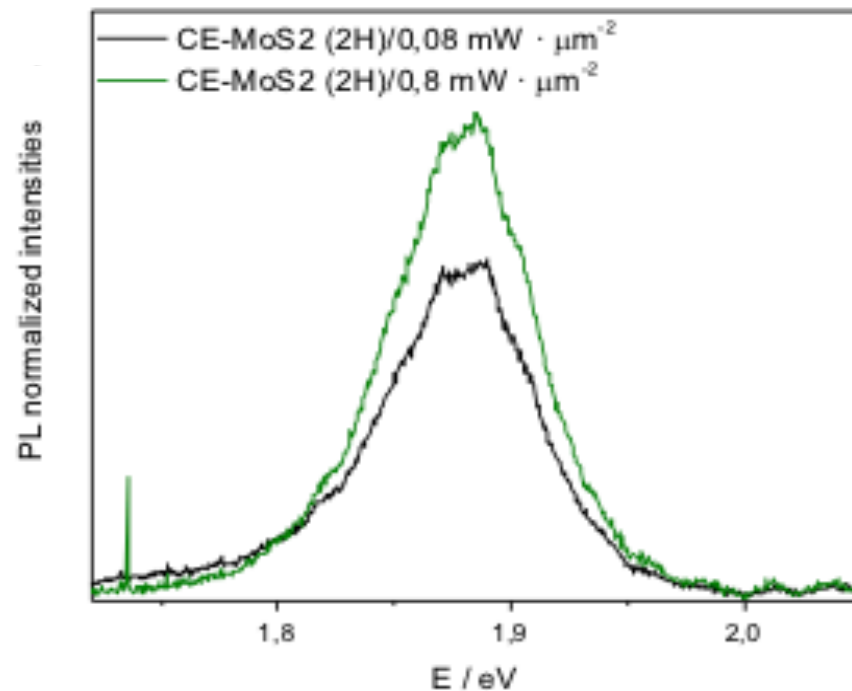
*Electrical sensing of the spin*



# SCO@SiO<sub>2</sub> nanoparticles on MoS<sub>2</sub>

## *Smart molecular/2D heterostructure*

### PHOTOLUMINESCENCE



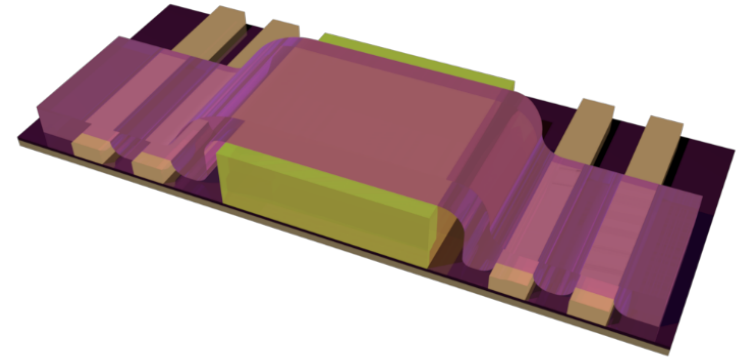
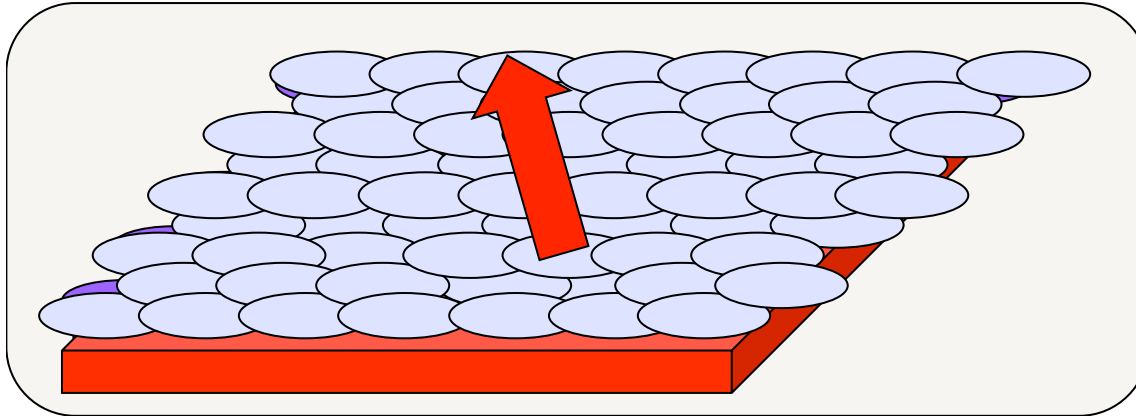
*Light-induced strain on the MoS<sub>2</sub>*

*Optical sensing of the spin*

Red shift (60 meV)  
*ca. 1 % of tensile strain*

Nature Chem., in press

# Take home message



## Smart molecular/2D heterostructures & devices:

- The spin switching in the molecular component affords a control over the *properties of the 2D material*.
- Change in the properties of the 2D material allows to *detect the molecular spin*.

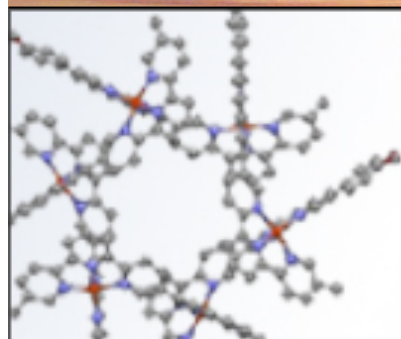
# Acknowledgment

## Univ. Valencia (ICMol)

- Samuel Mañas Valero
- Carla Boix
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- Ramón Torres-Cavanillas
- Victor García
- Alicia Forment
- Mónica Giménez-Marqués
- Miguel Clemente-León
- Josep Canet

## TU Delft

- H. Van der Zant
- M. Siskins



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- Spanish MINECO



**Consolider**

***Molecular  
Nanoscience***



**Unit of Excellence María de Maeztu**

- Generalitat Valenciana

***PROMETEO*** Program of Excellence

