

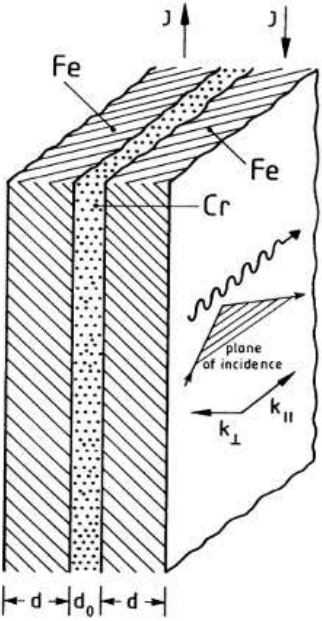
# Tunable spintronics with 2D magnets.

**Carla Boix Constant**

*Institute of Molecular Science (ICMol) – University of Valencia*  
Research Team on Molecular Materials - 22/05/2025

11<sup>th</sup> Workshop on 2D Materials – W2DM2025

# Spintronics



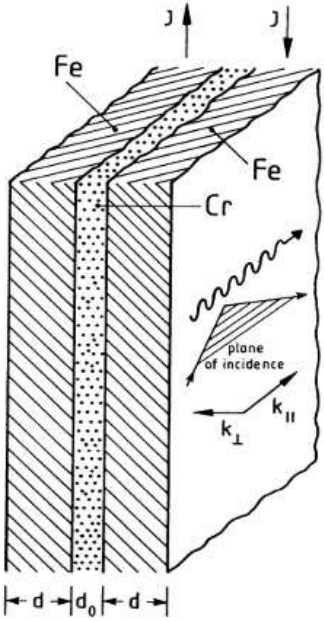
# Spintronics



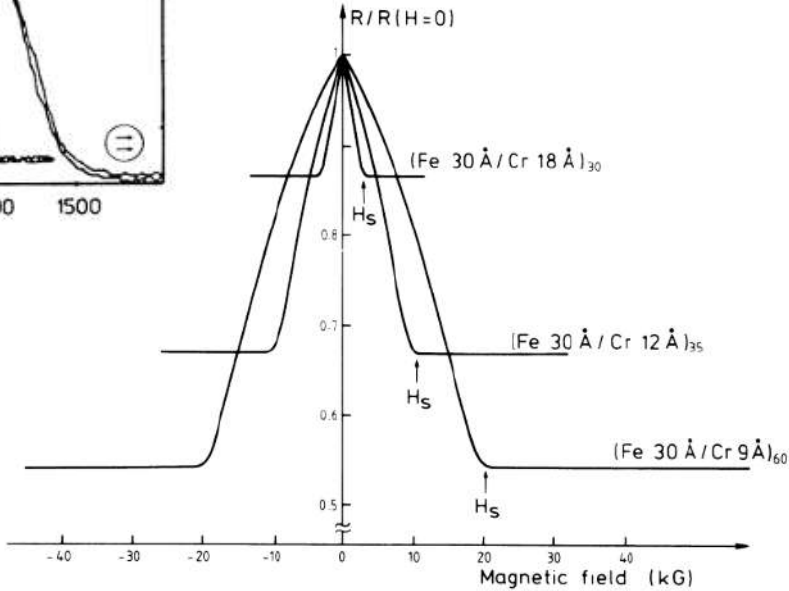
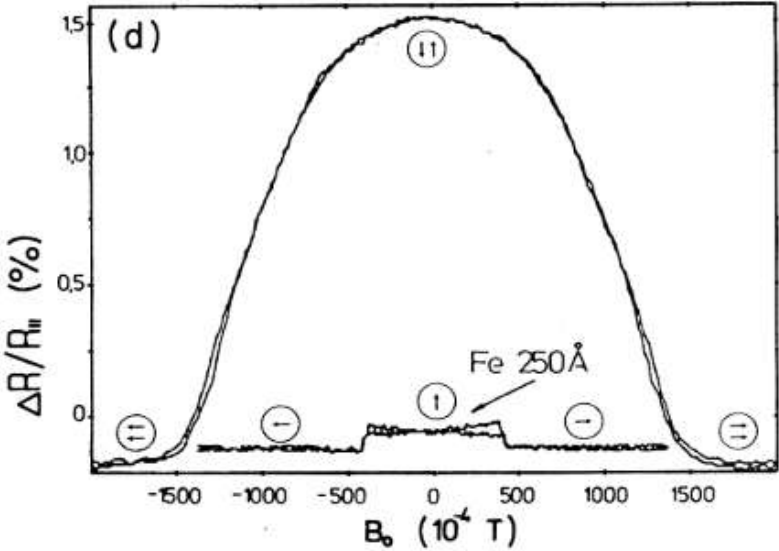
Nobel Prize in Physics 2007

Albert Fert and Peter Grünberg

“for the discovery of Giant Magnetoresistance”



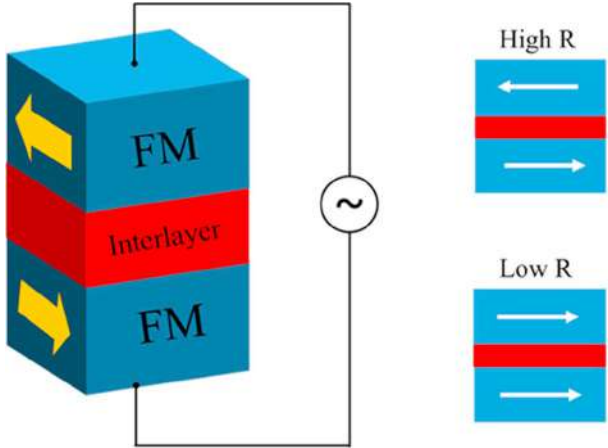
*Phys. Rev. B* **39**, 4828(R) (1989).



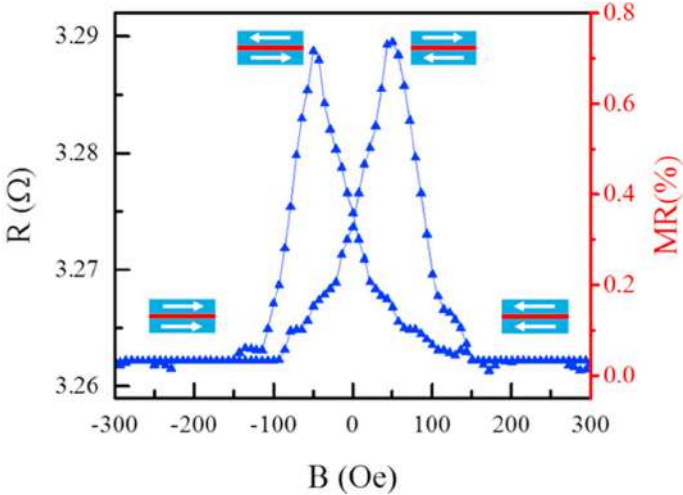
*Phys. Rev. Lett.* **61**, 2472 (1988).

# Spintronics.

➤ Spin-valve:

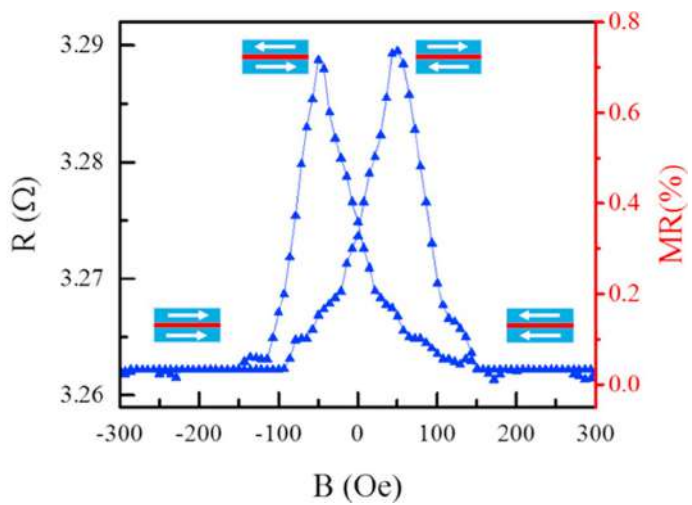
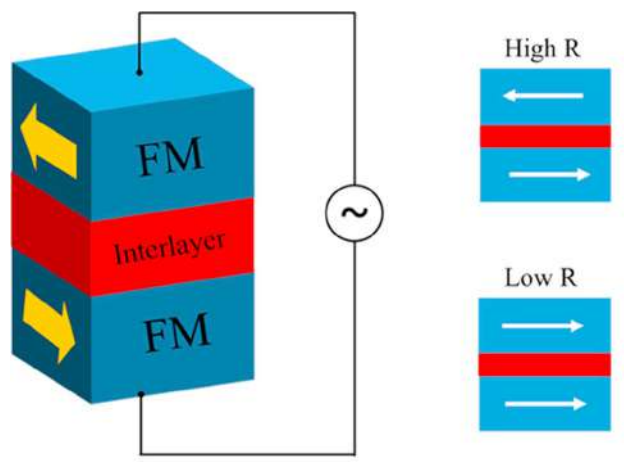


*Journal of Magnetism and Magnetic Materials* **429**, 330-333 (2017).



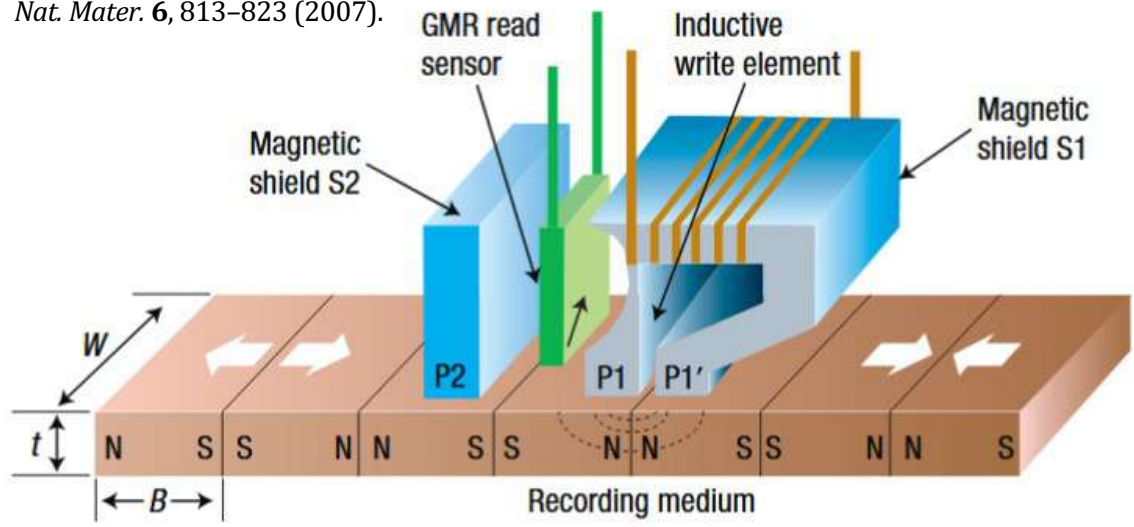
**Spintronics.**

➤ **Spin-valve:**



*Journal of Magnetism and Magnetic Materials* **429**, 330-333 (2017).

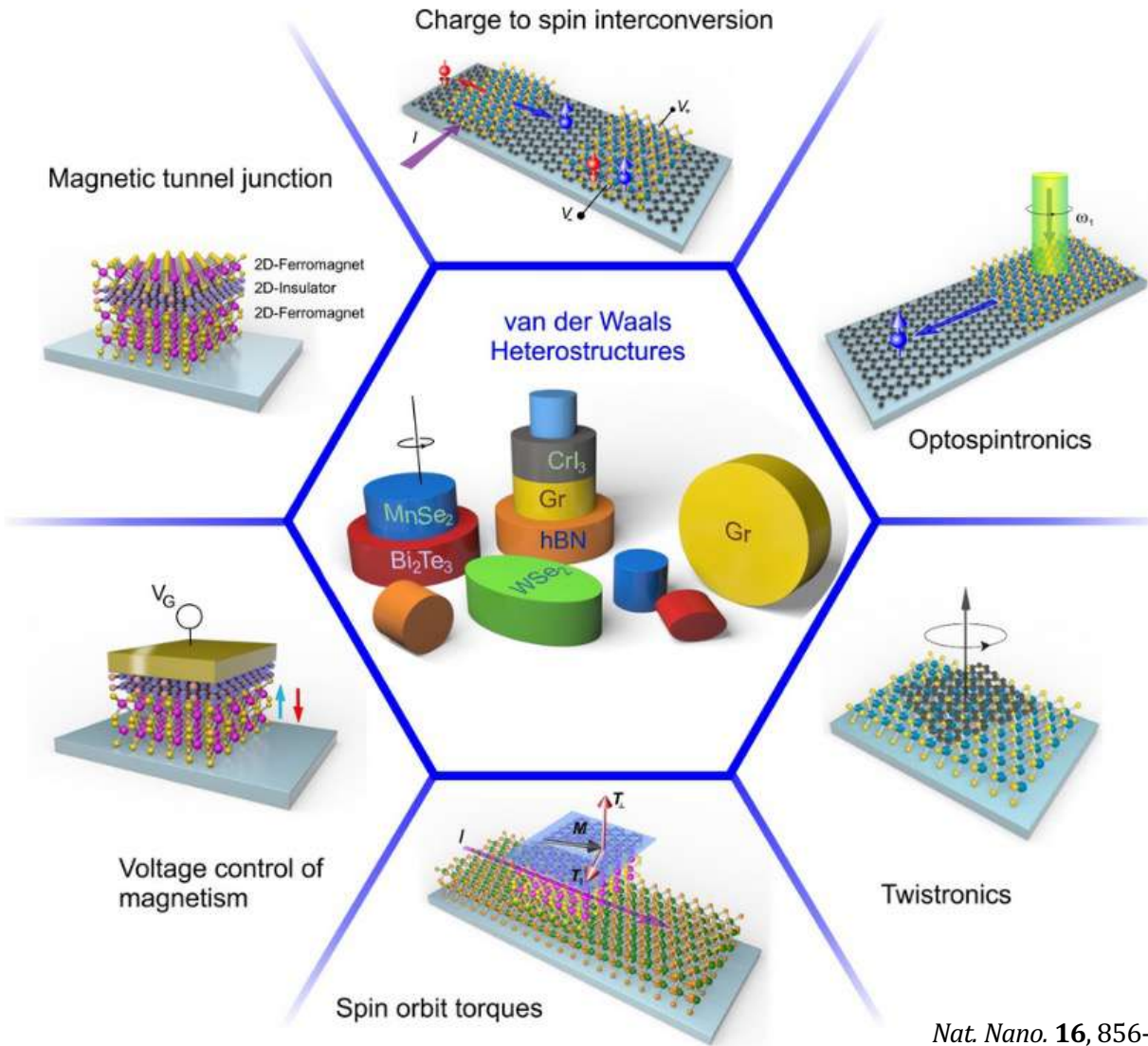
*Nat. Mater.* **6**, 813–823 (2007).



**Deskstar 16GP (IBM 1997).**

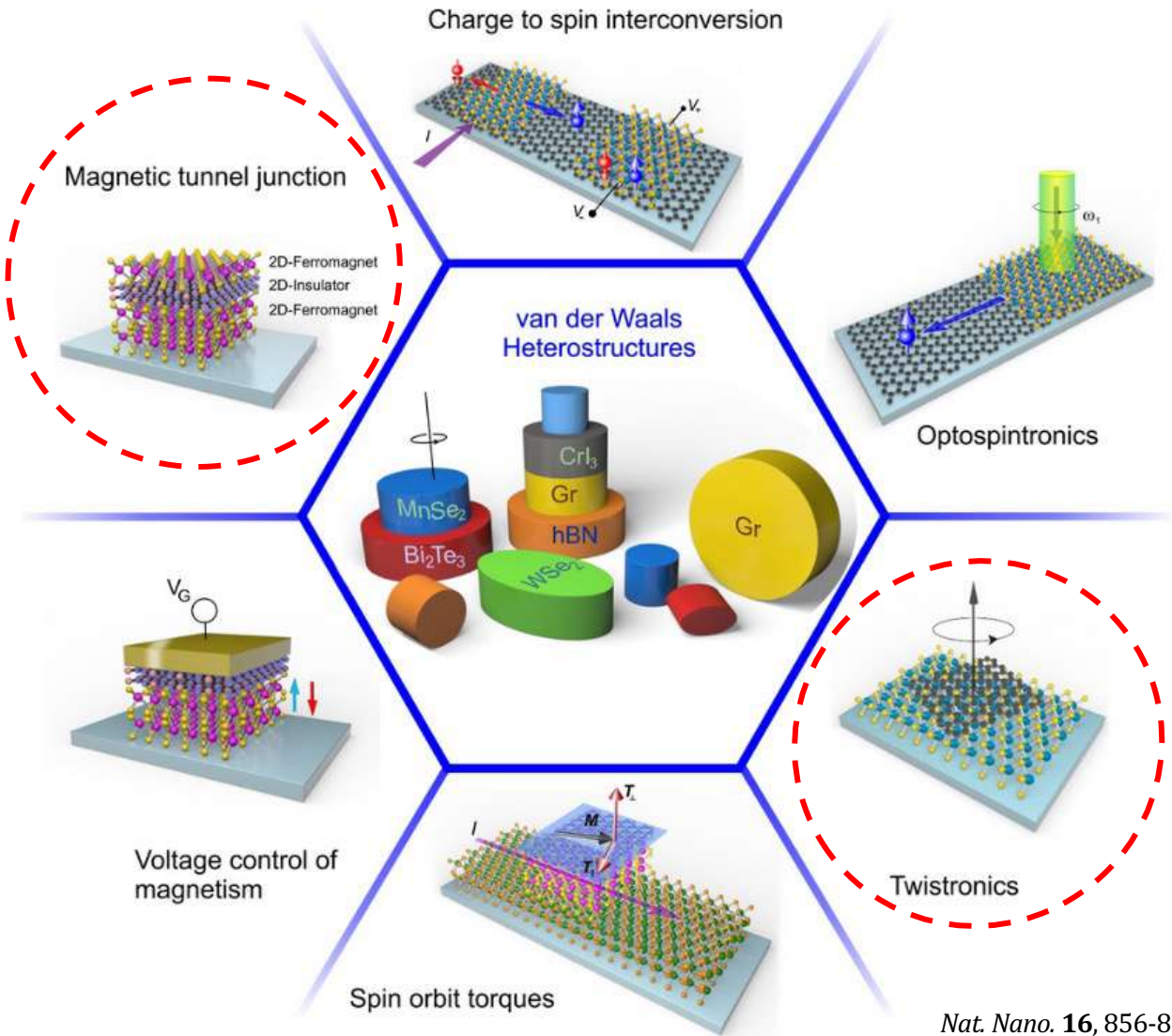
# van der Waals heterostructures for spintronics

## ➤ Role of 2D magnetic materials:



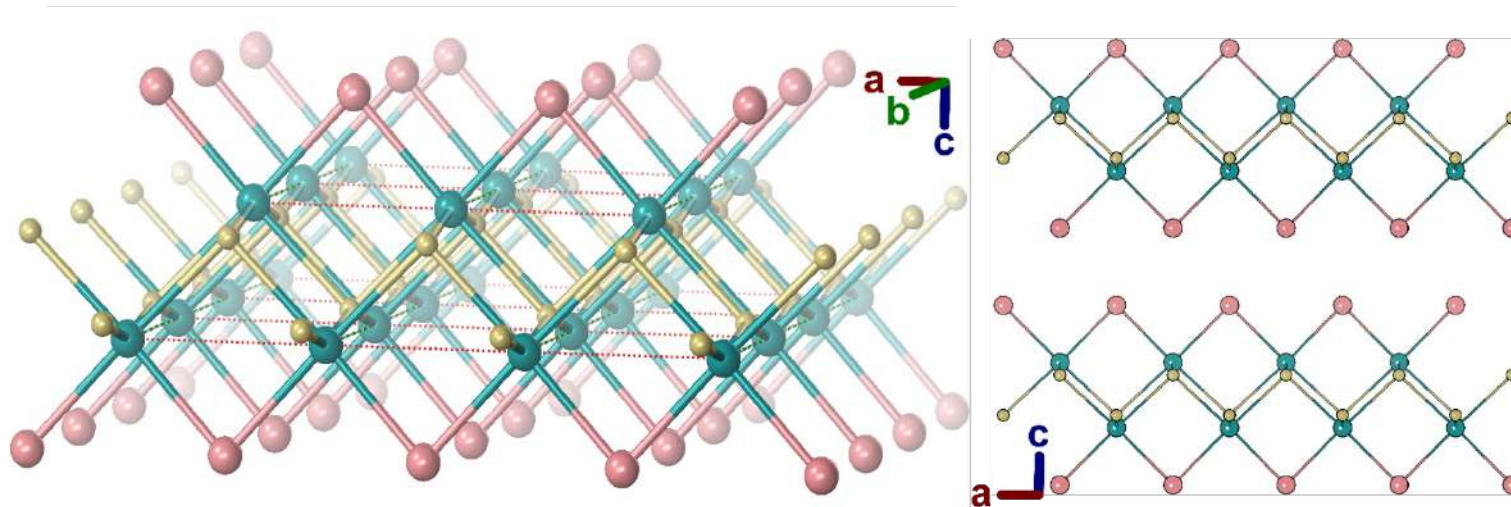
# van der Waals heterostructures for spintronics

➤ **Role of 2D magnetic materials:**



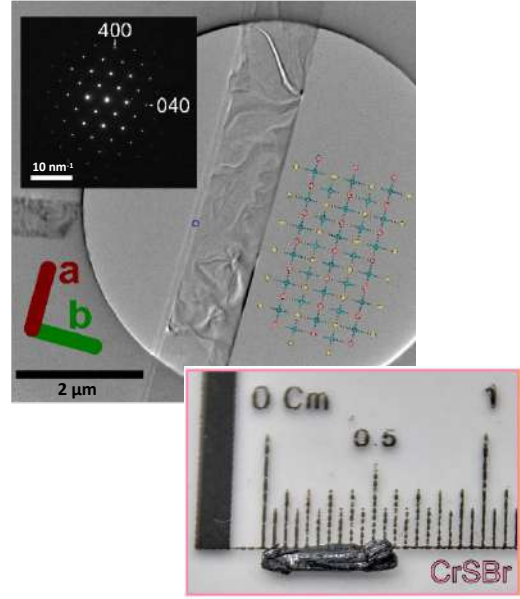
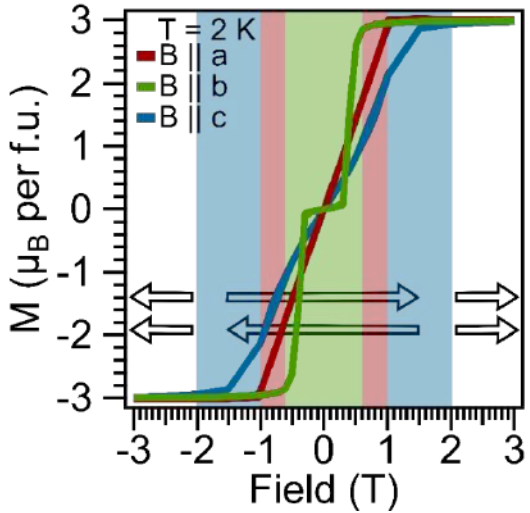
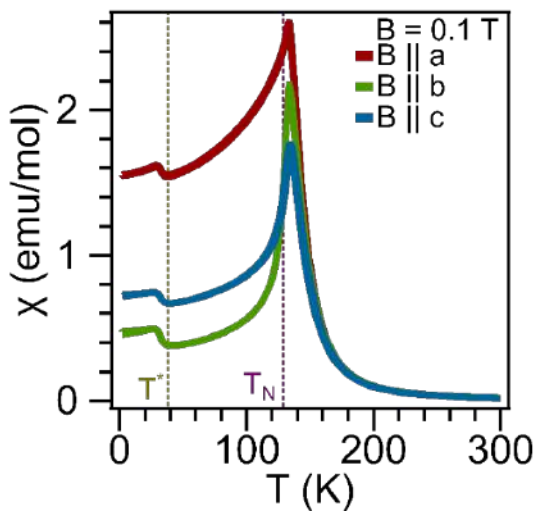
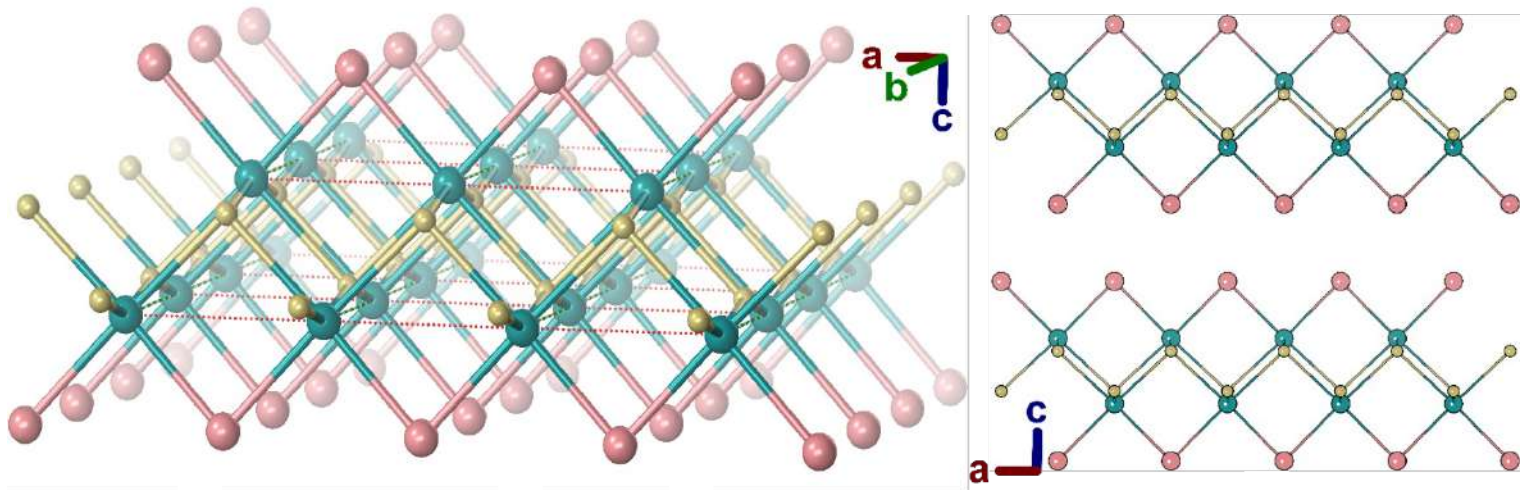
# The metamagnet CrSBr

*Adv. Mater.* **34**, 2204940 (2022).



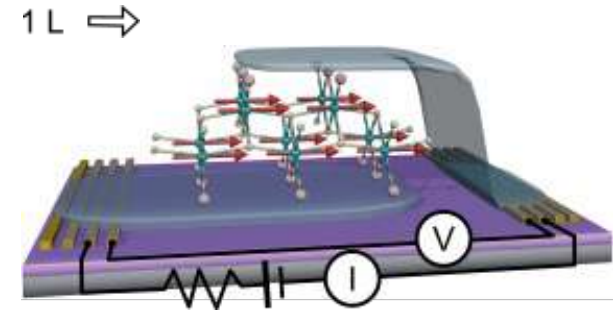
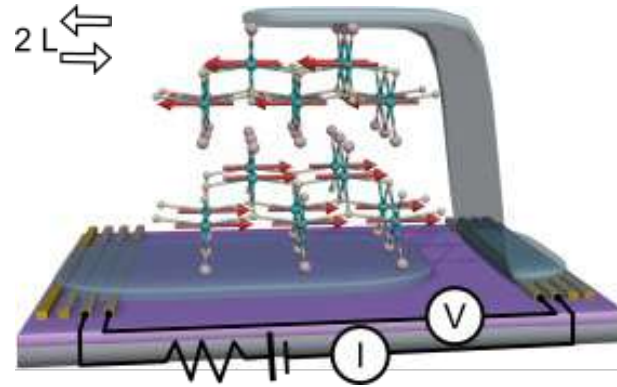
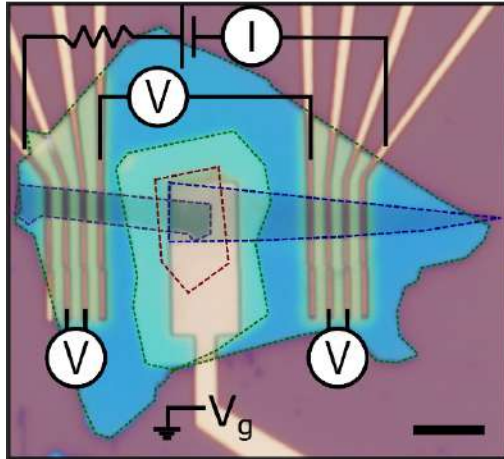
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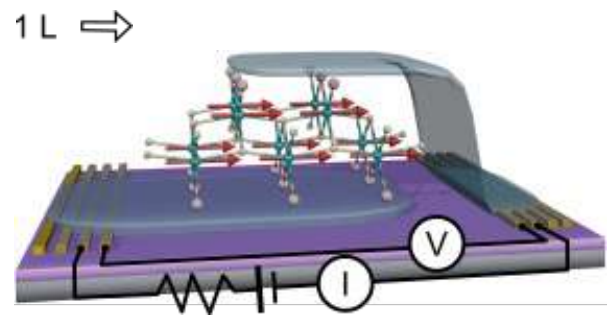
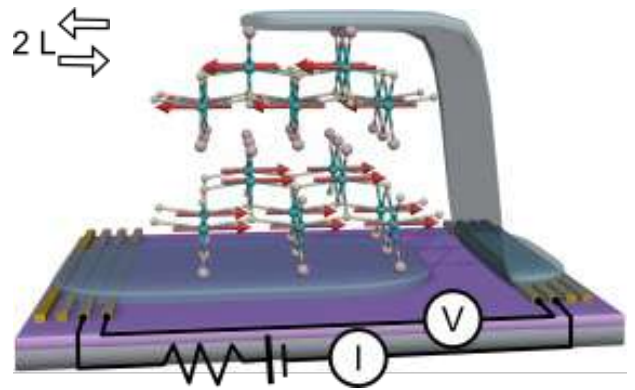
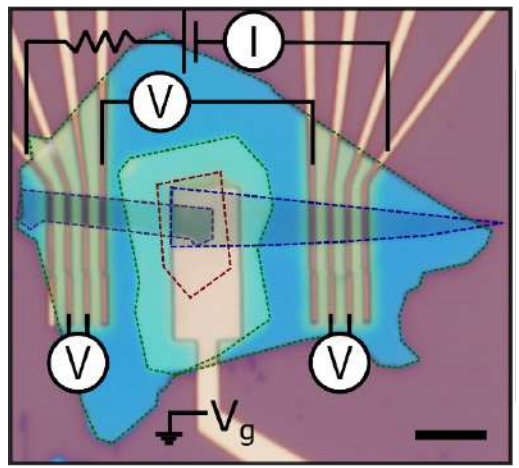
## Vertical vdW heterostructures

*Adv. Mater.* **34**, 2204940 (2022).

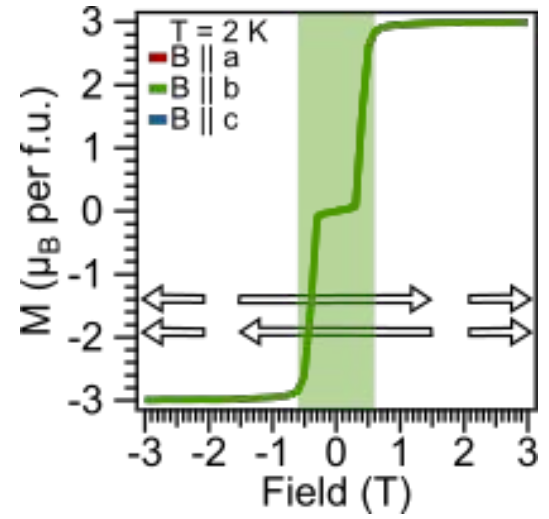


# Vertical vdW heterostructures

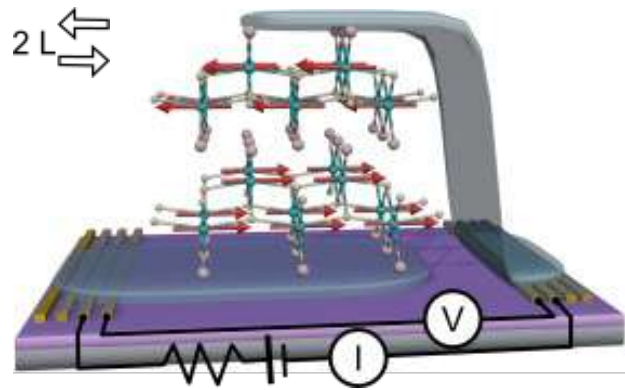
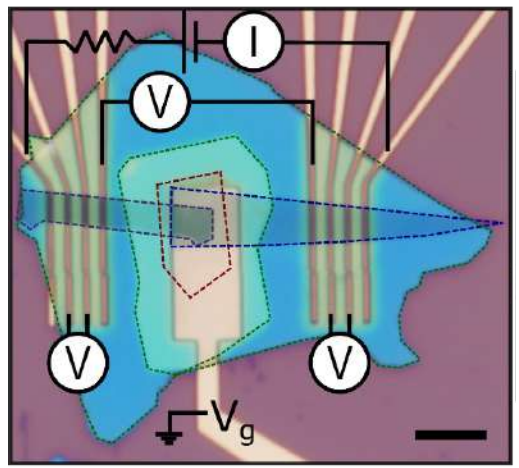
*Adv. Mater.* **34**, 2204940 (2022).



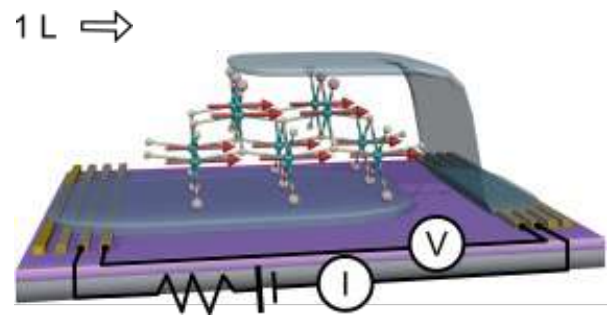
**Bulk**



# Vertical vdW heterostructures

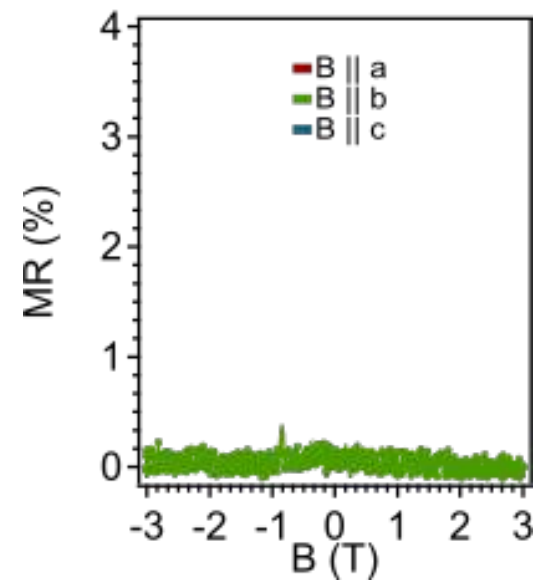
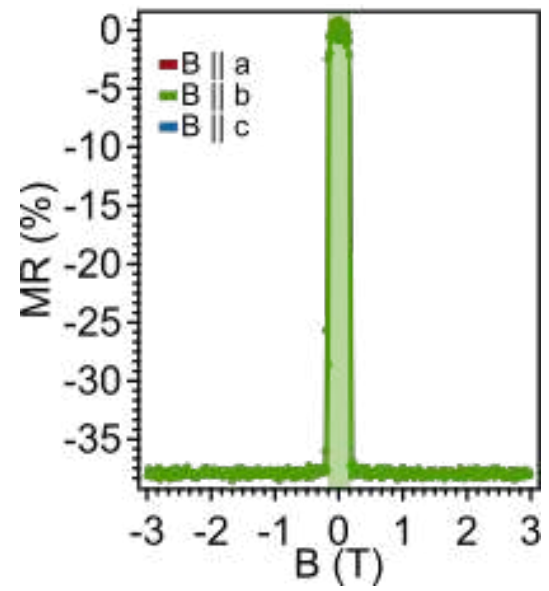
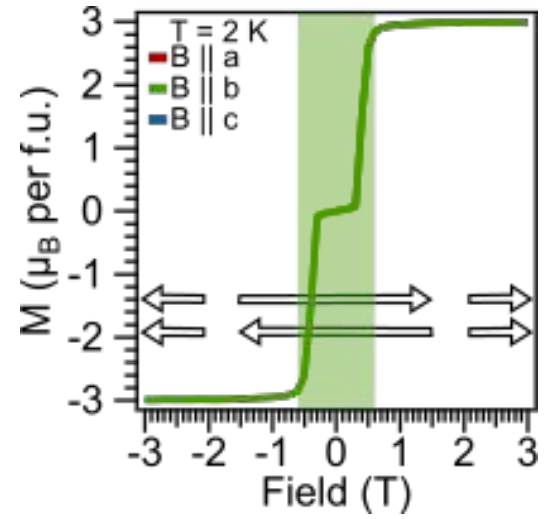


$$MR (\%) = \frac{R(B) - R(0)}{R(0)} \cdot 100$$

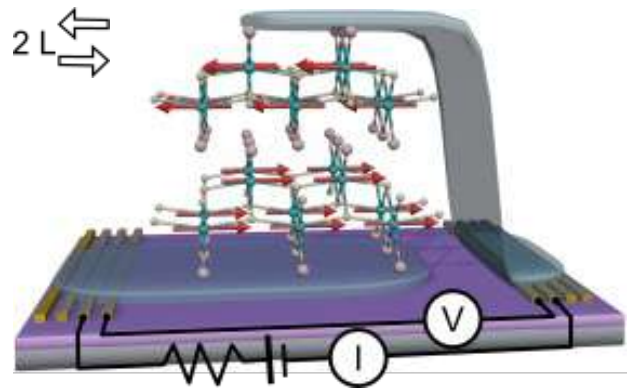
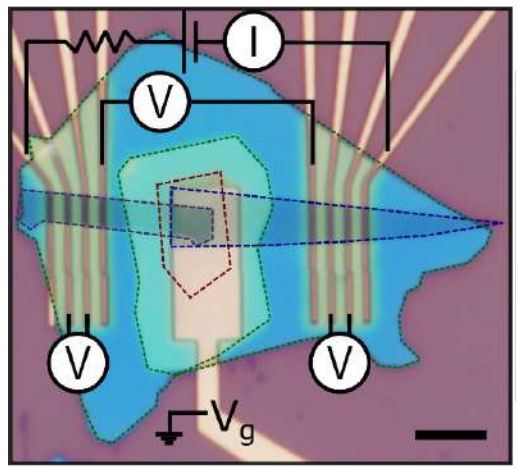


## ➤ 2D magnetization.

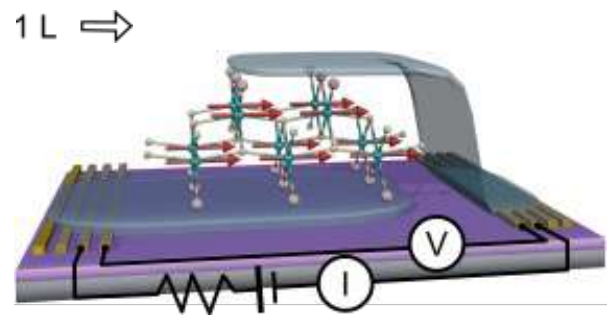
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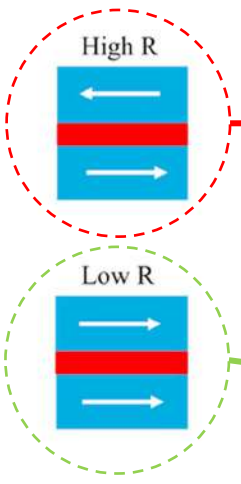
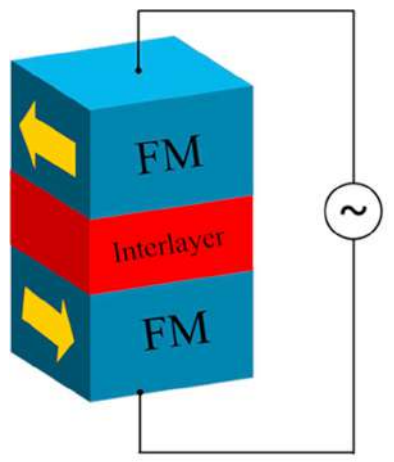
# Vertical vdW heterostructures



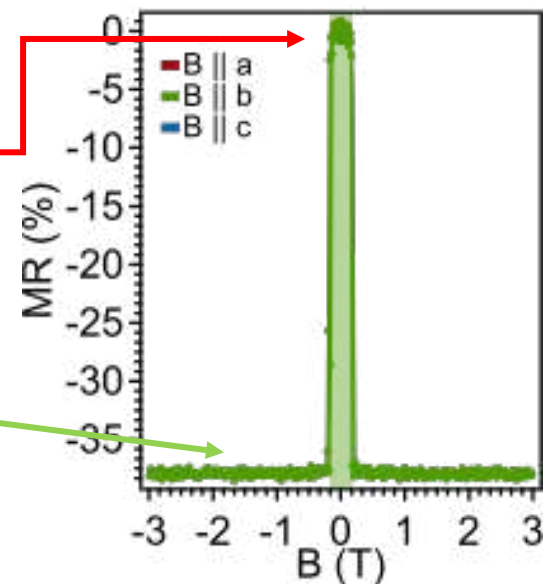
$$MR (\%) = \frac{R(B) - R(0)}{R(0)} \cdot 100$$



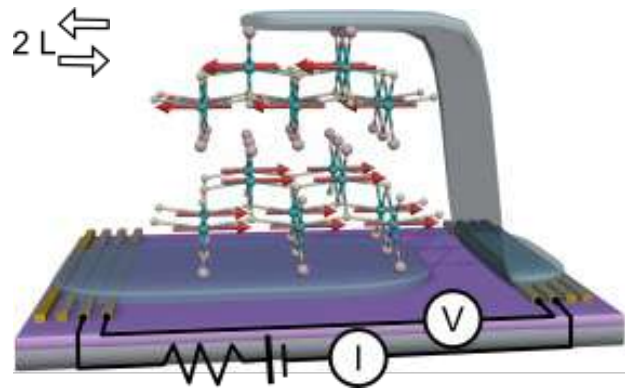
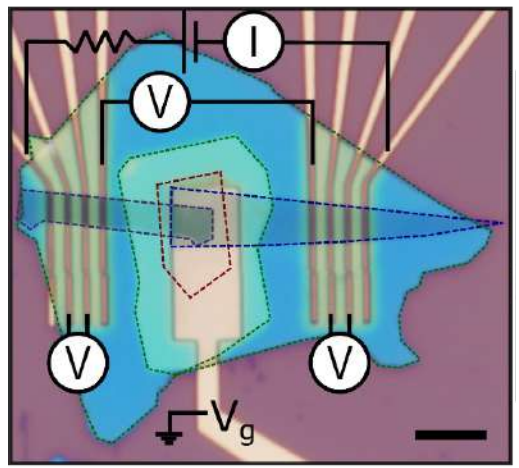
## ➤ 2D magnetization.



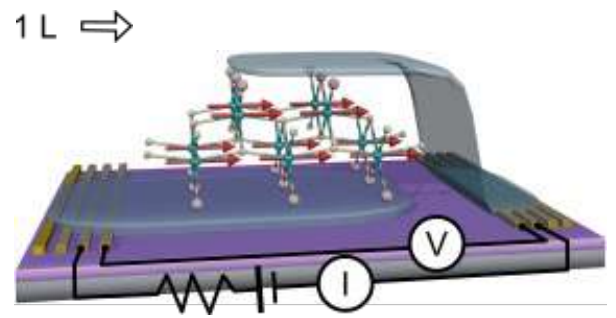
Spin-valve like behavior in 2L CrSBr.



# Vertical vdW heterostructures

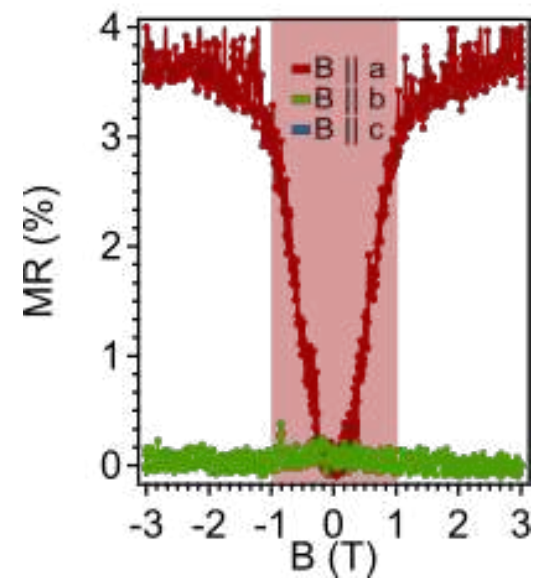
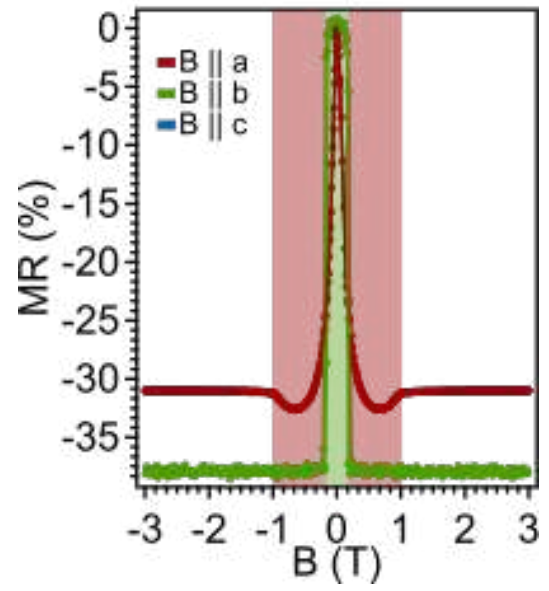
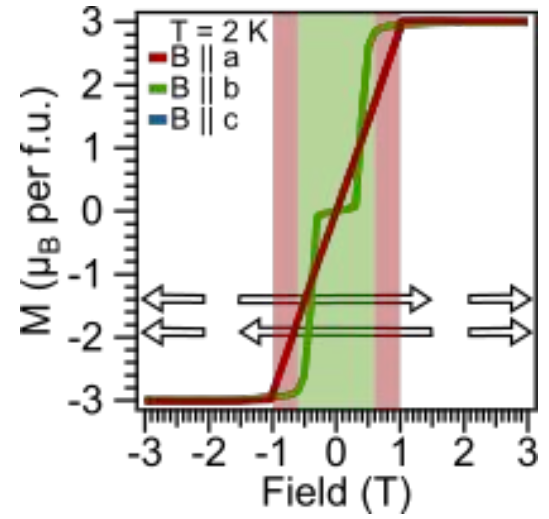


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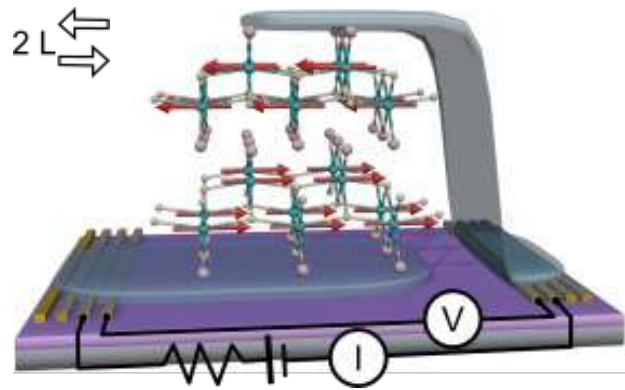
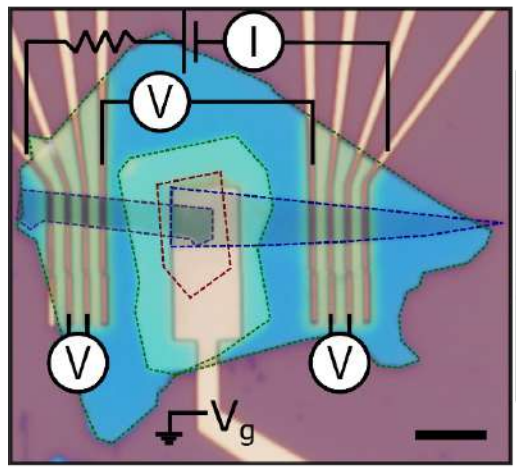


## ➤ 2D magnetization.

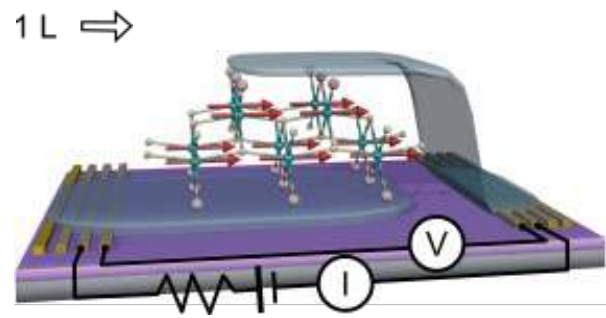
Bulk



# Vertical vdW heterostructures

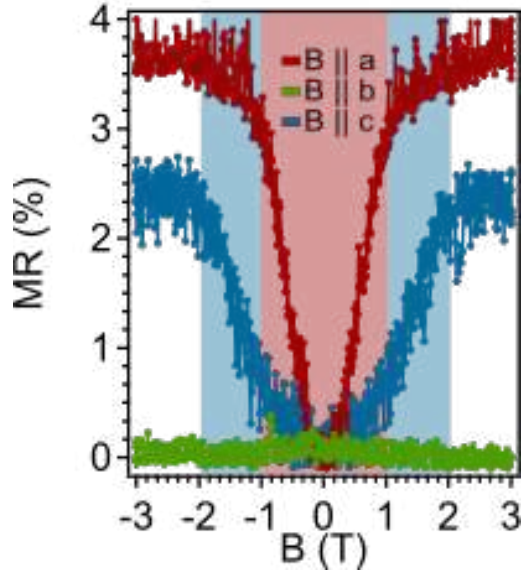
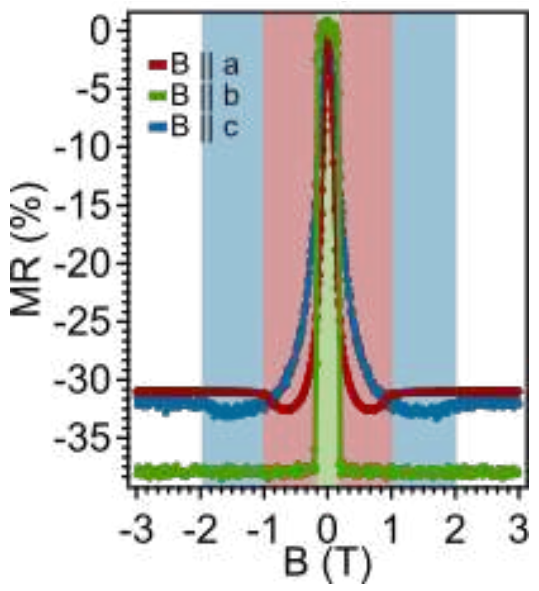
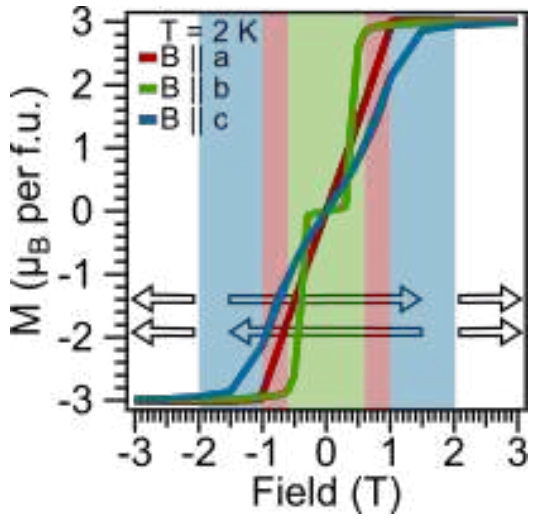


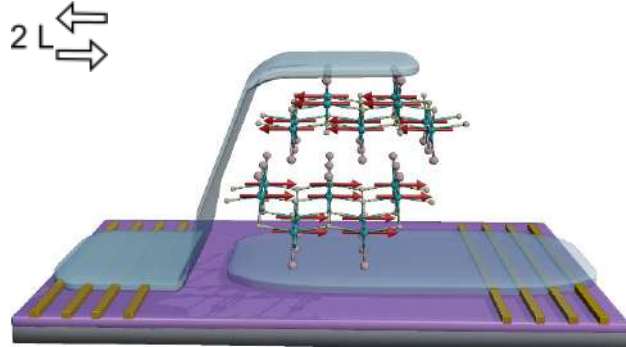
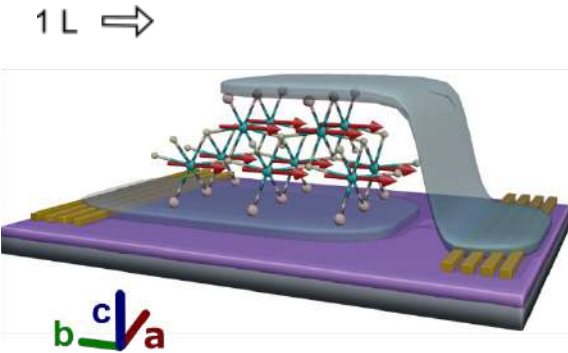
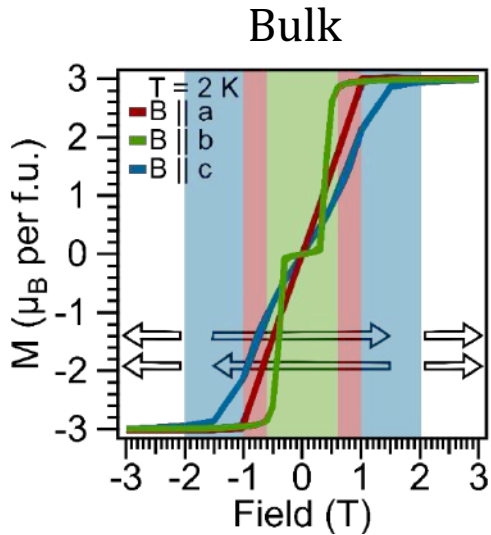
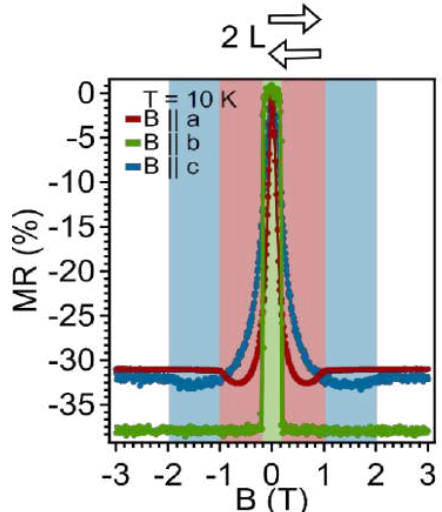
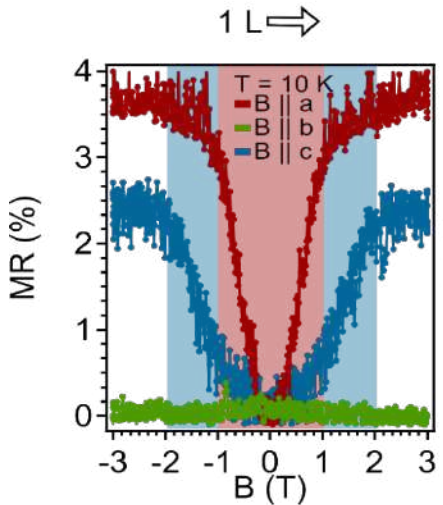
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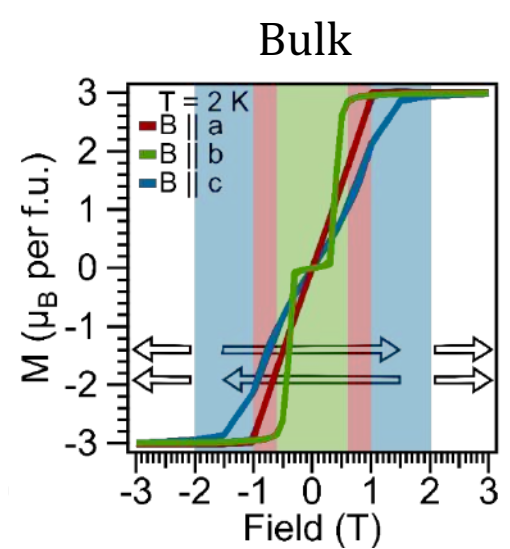
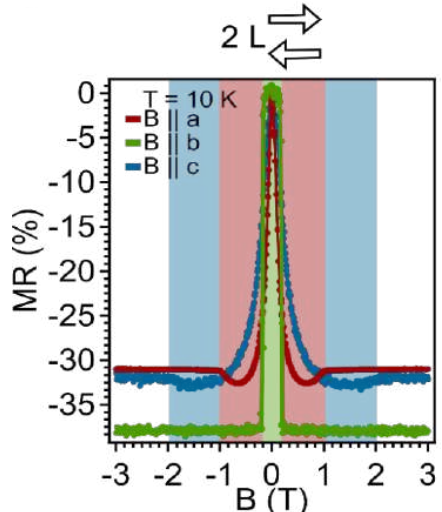
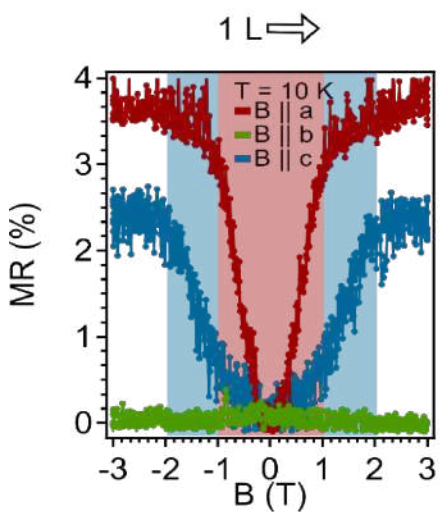


## ➤ 2D magnetization.

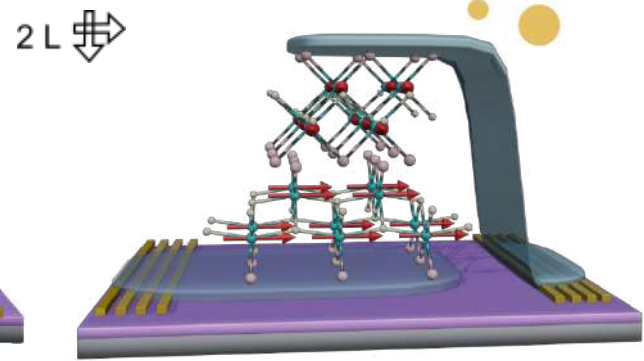
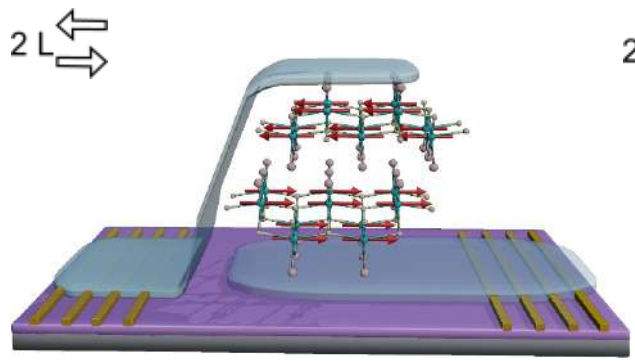
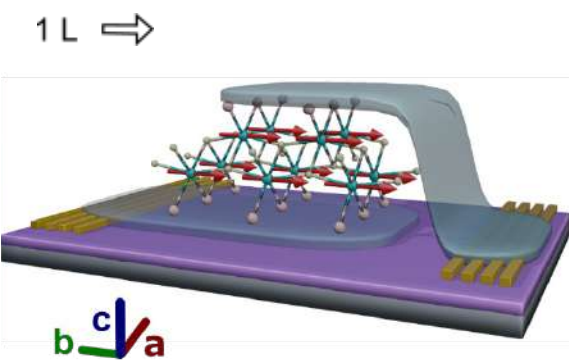
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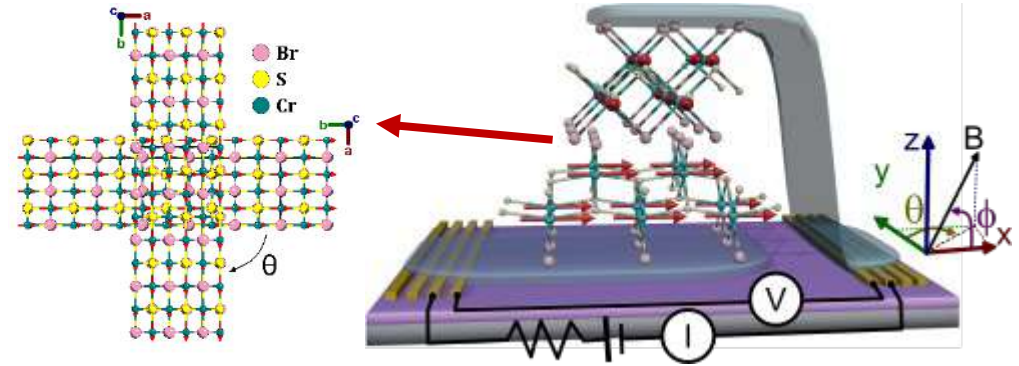
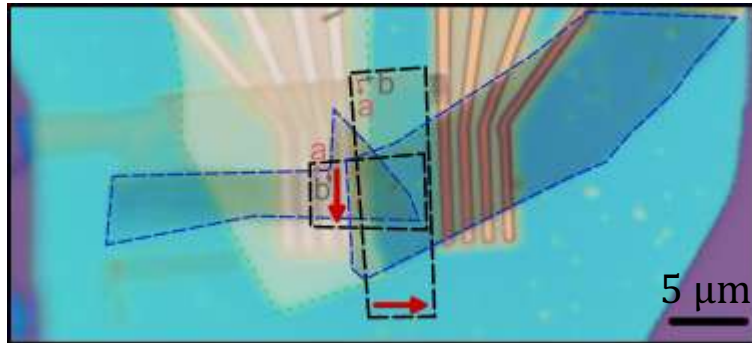


**Creating artificial magnets by twisting.**



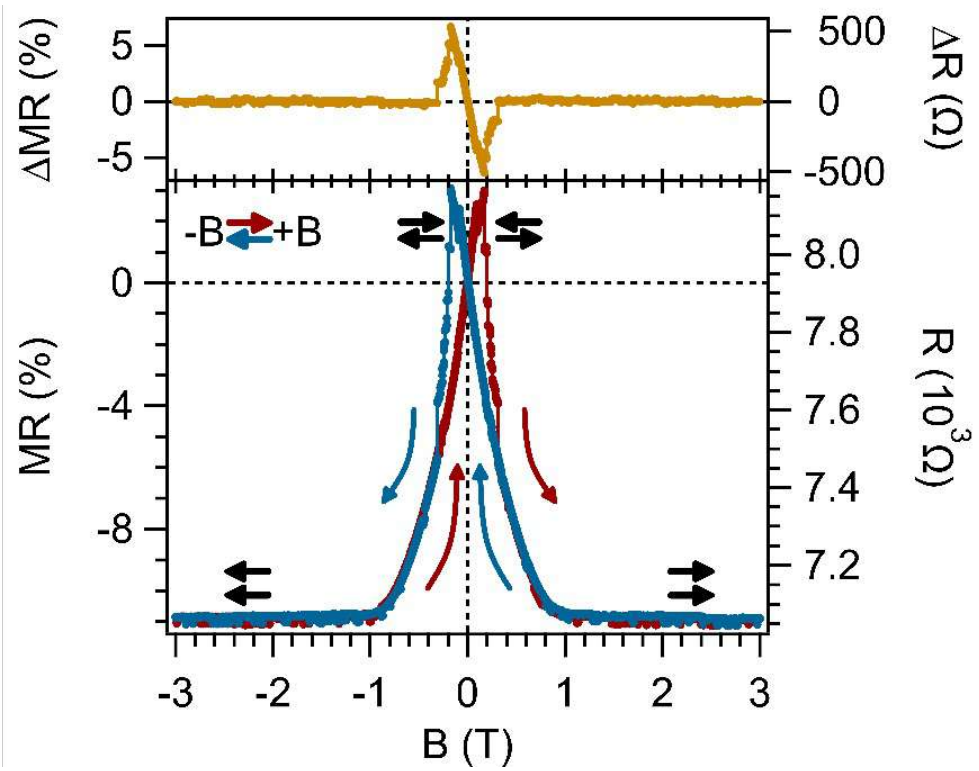
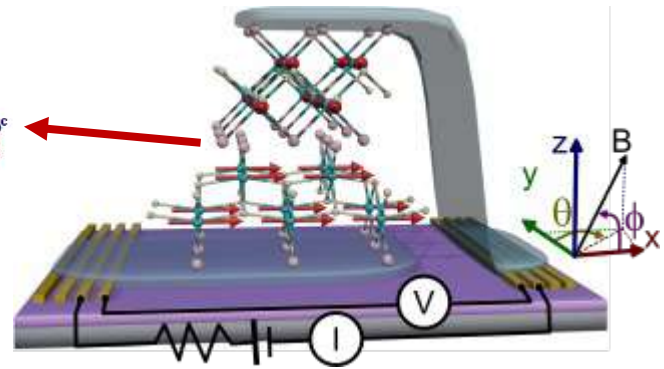
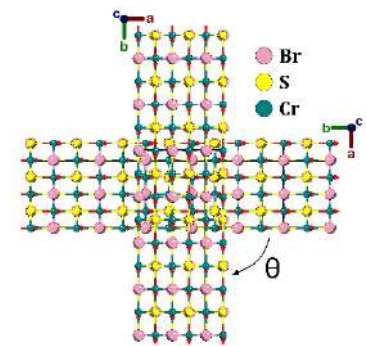
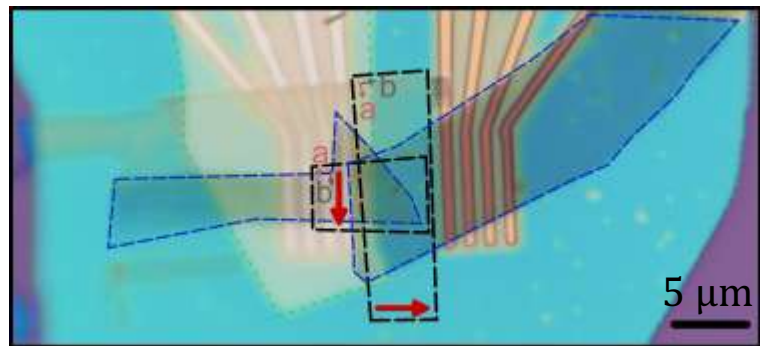
## CrSBr with a *twist*

*Nat. Mater.* **23**, 212-218 (2024).



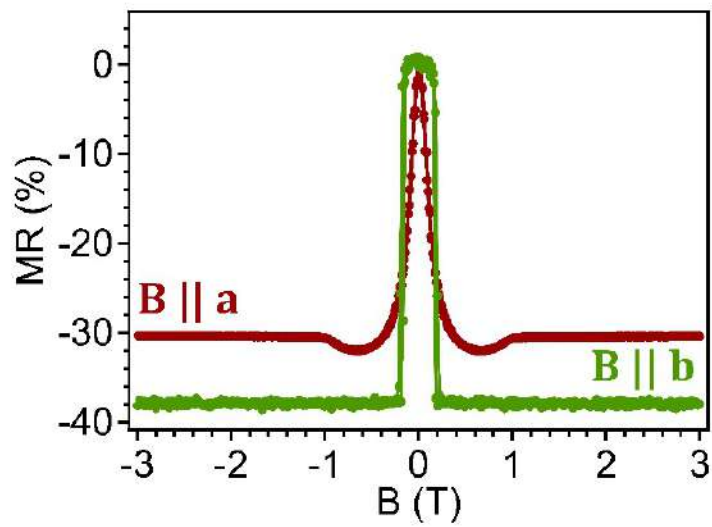
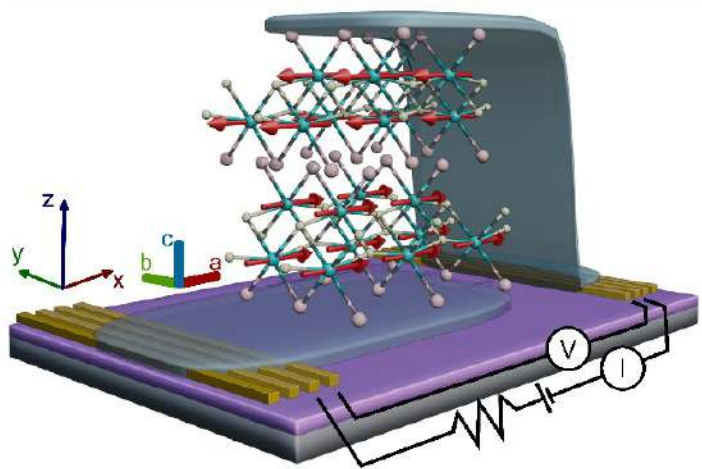
**CrSBr with a *twist***

*Nat. Mater.* **23**, 212-218 (2024).

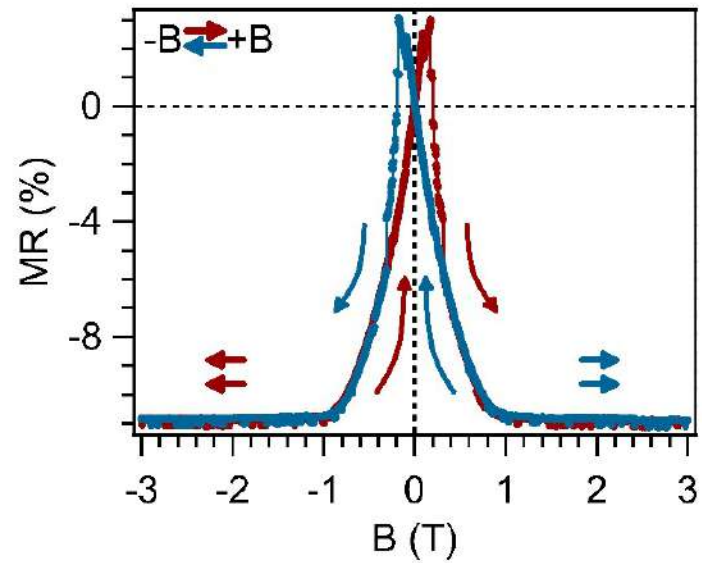
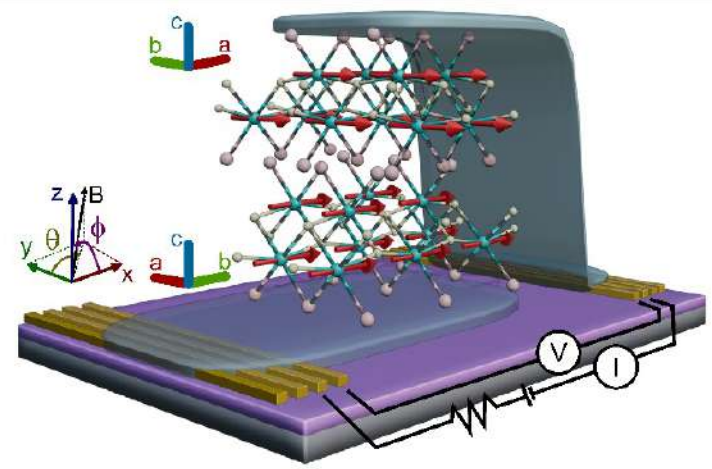


➤ **Hysteresis opening.**

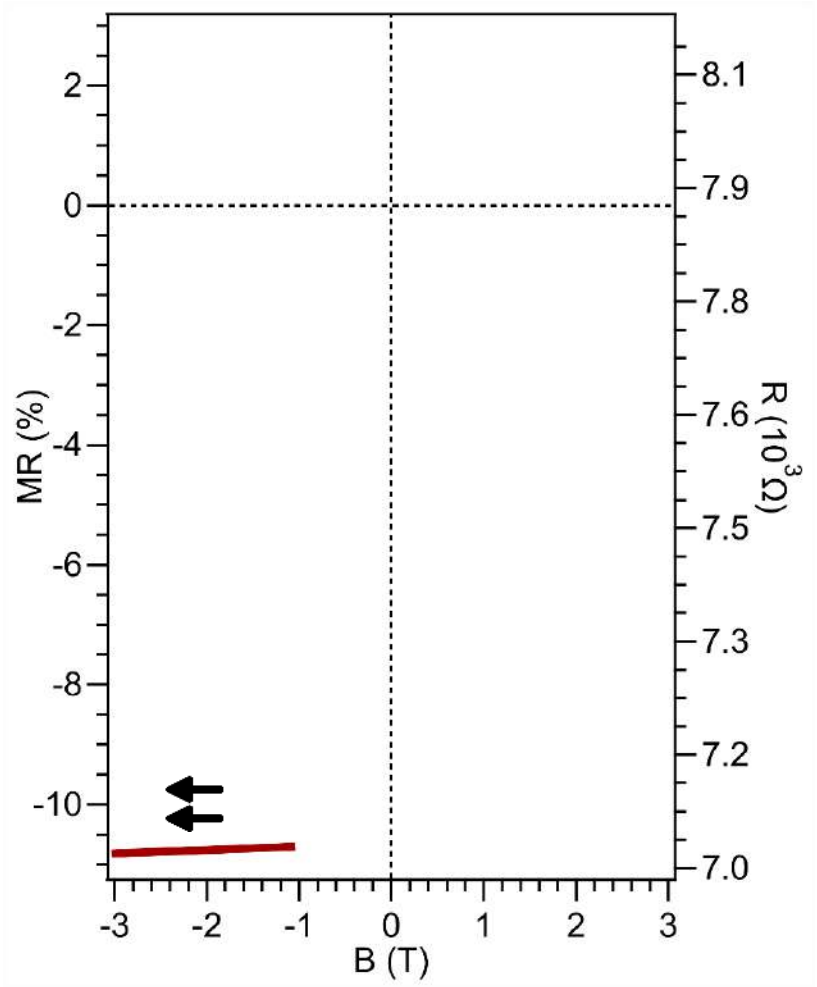
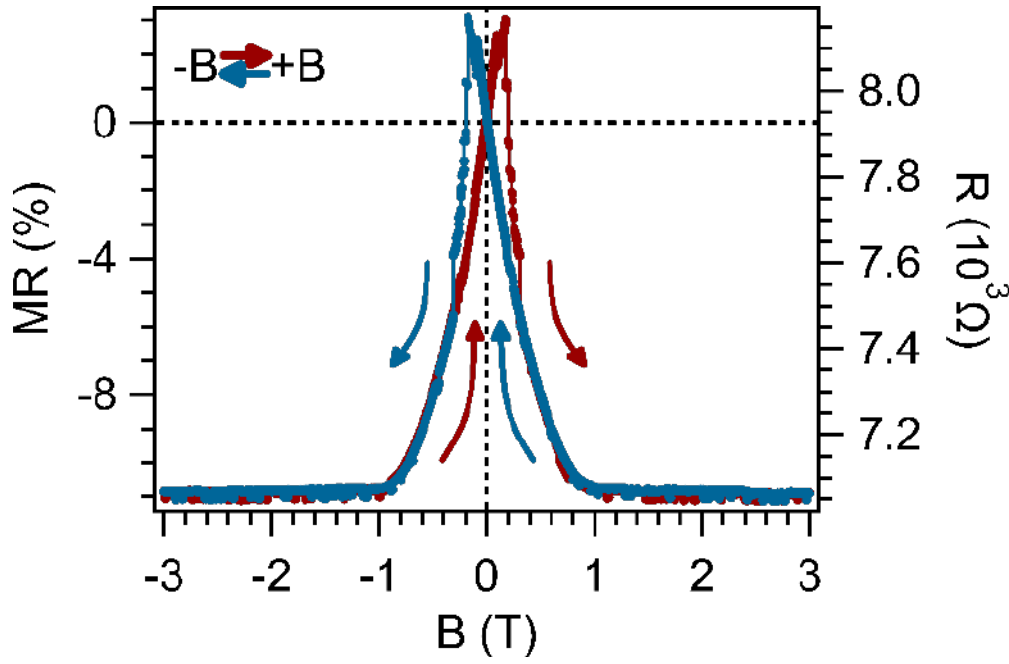
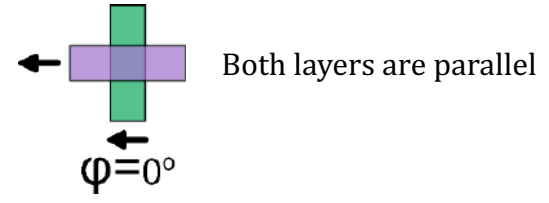
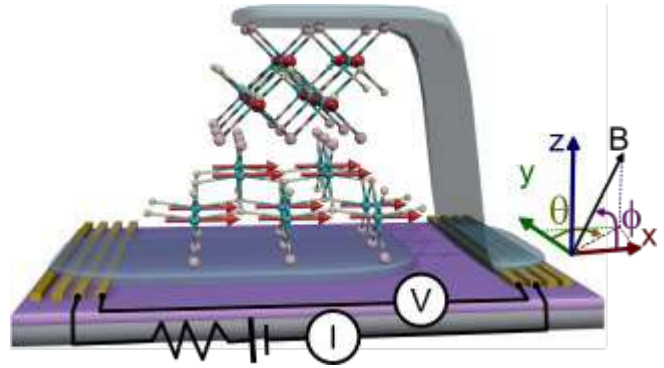
*Adv. Mater.* **34**, 2204940 (2022).



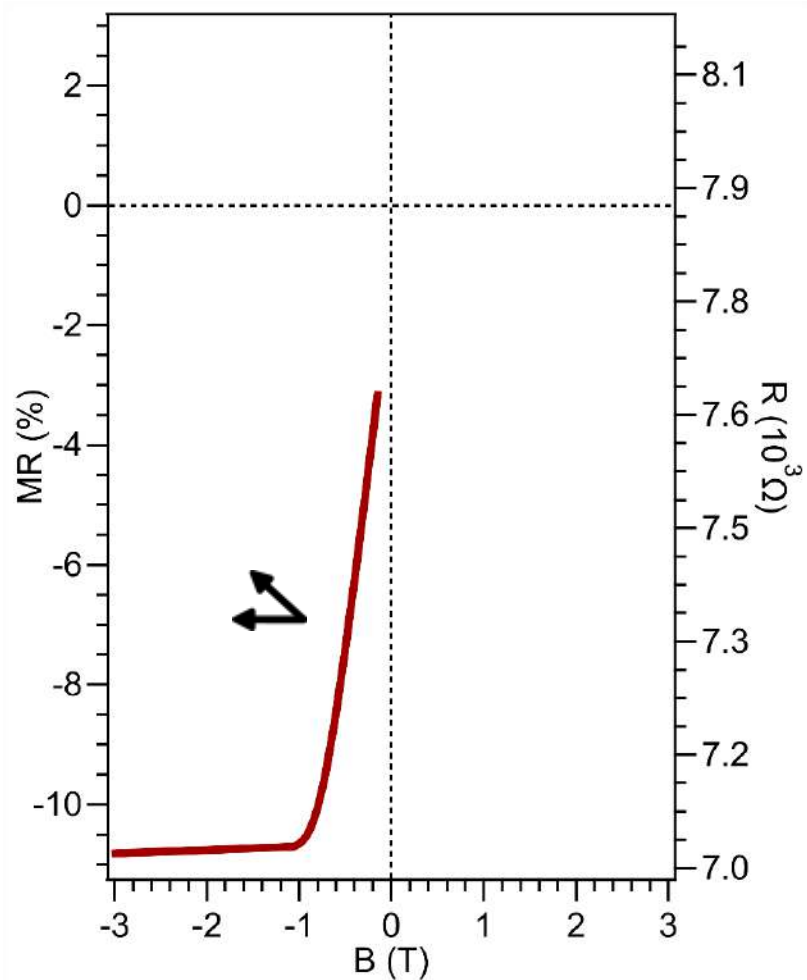
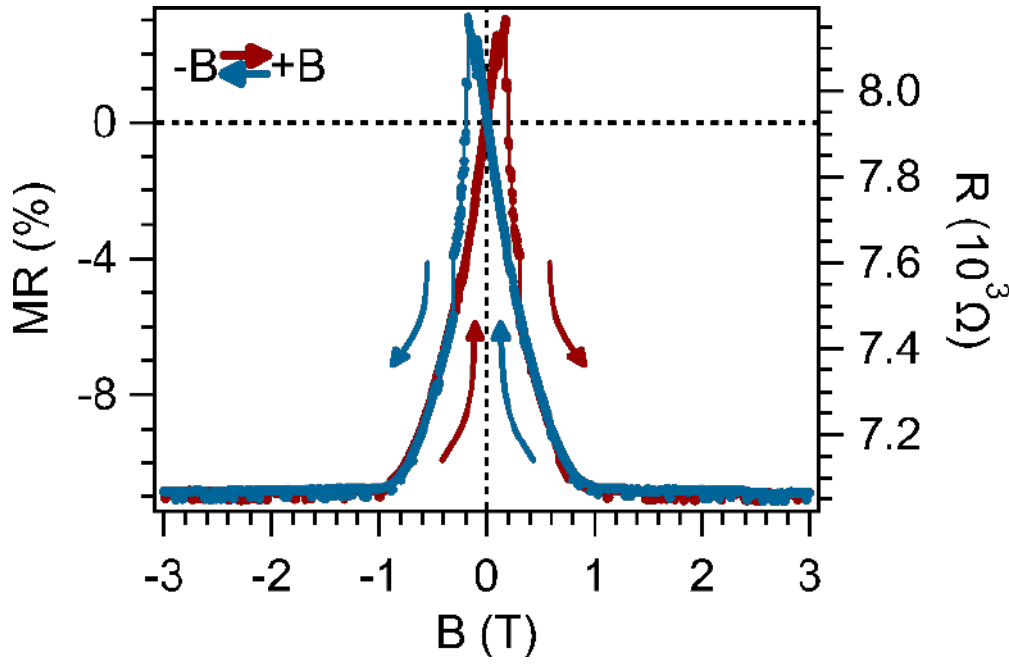
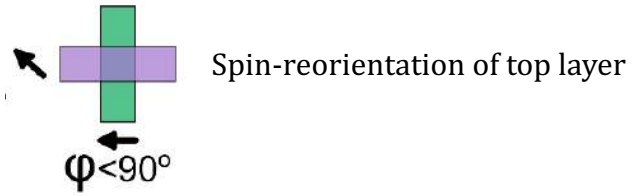
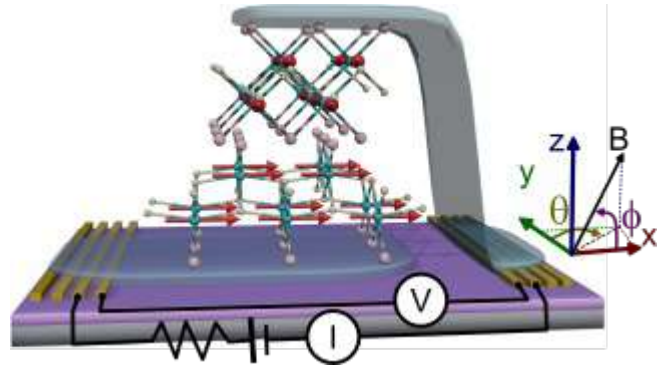
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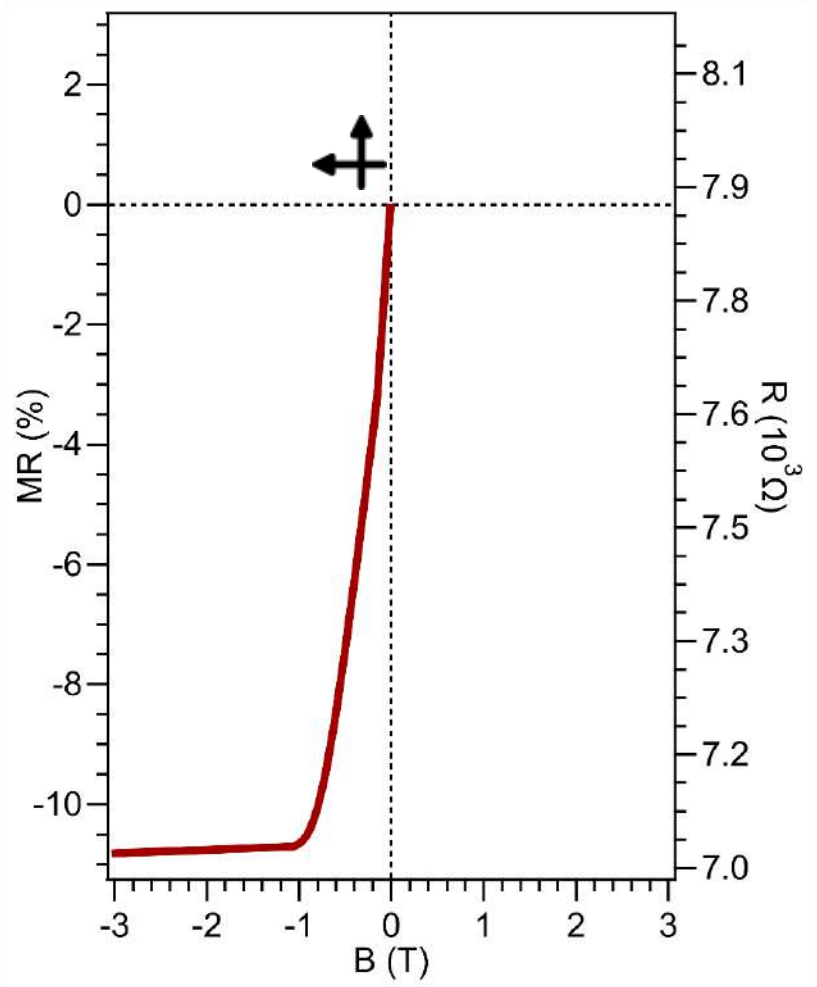
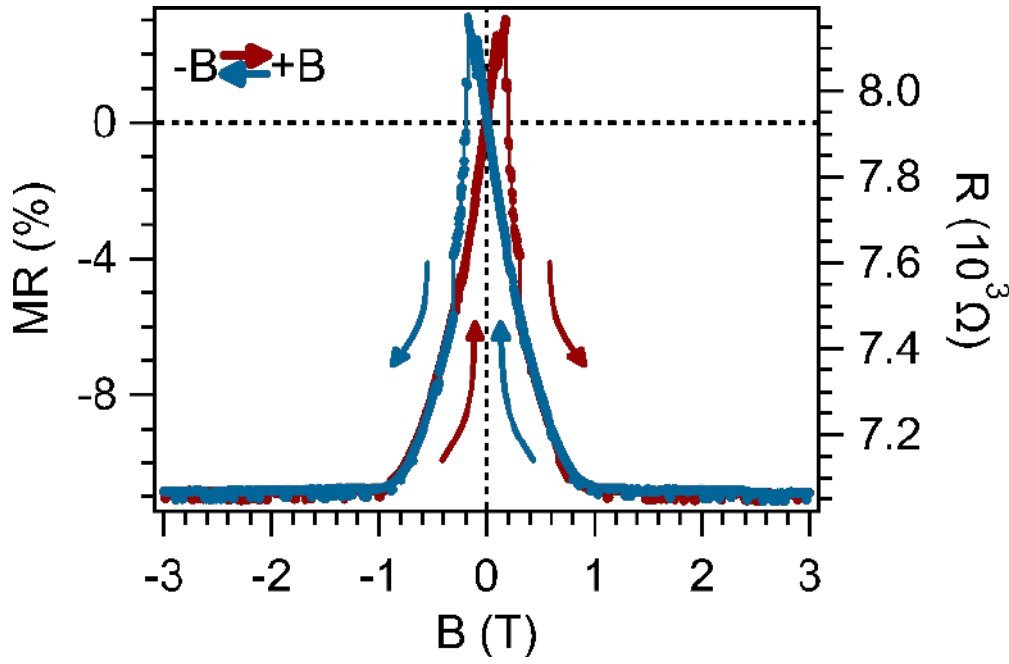
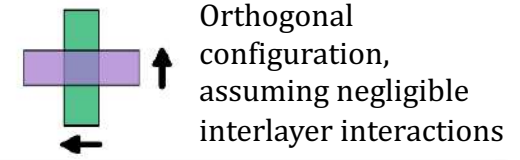
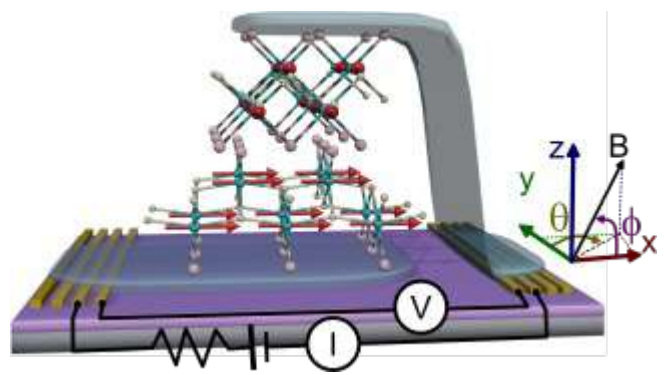
# Spin switching mechanisms



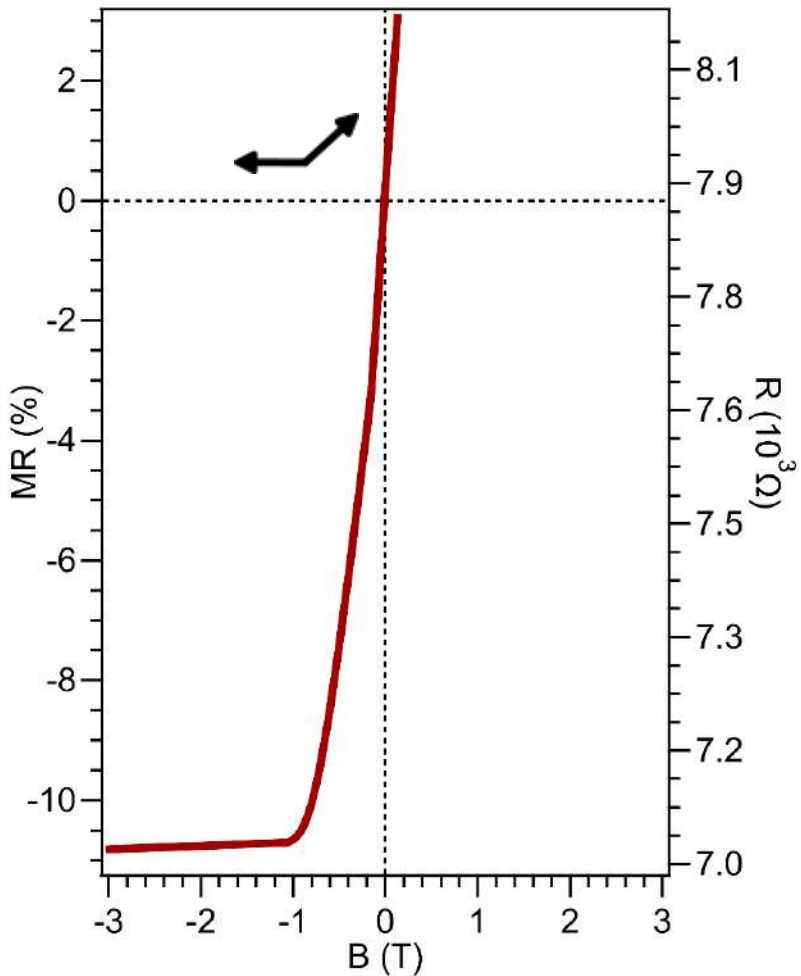
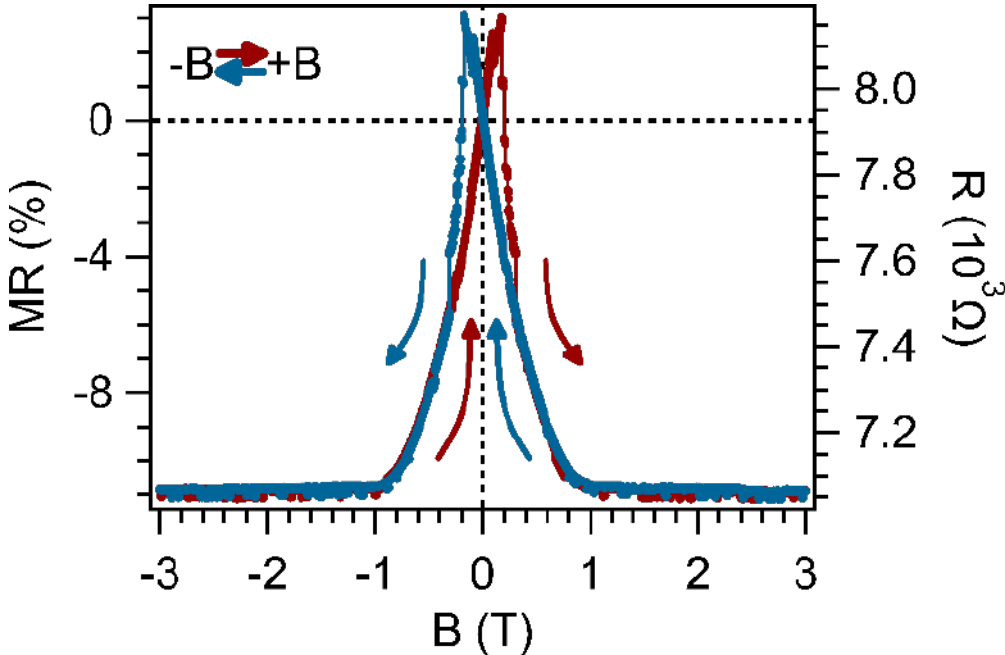
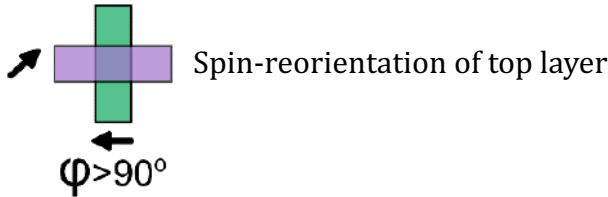
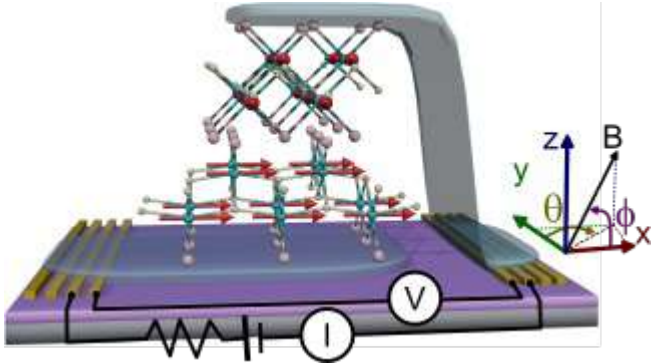
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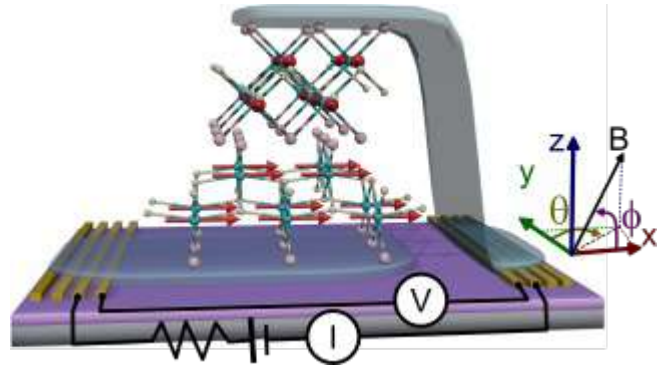
# Spin switching mechanisms



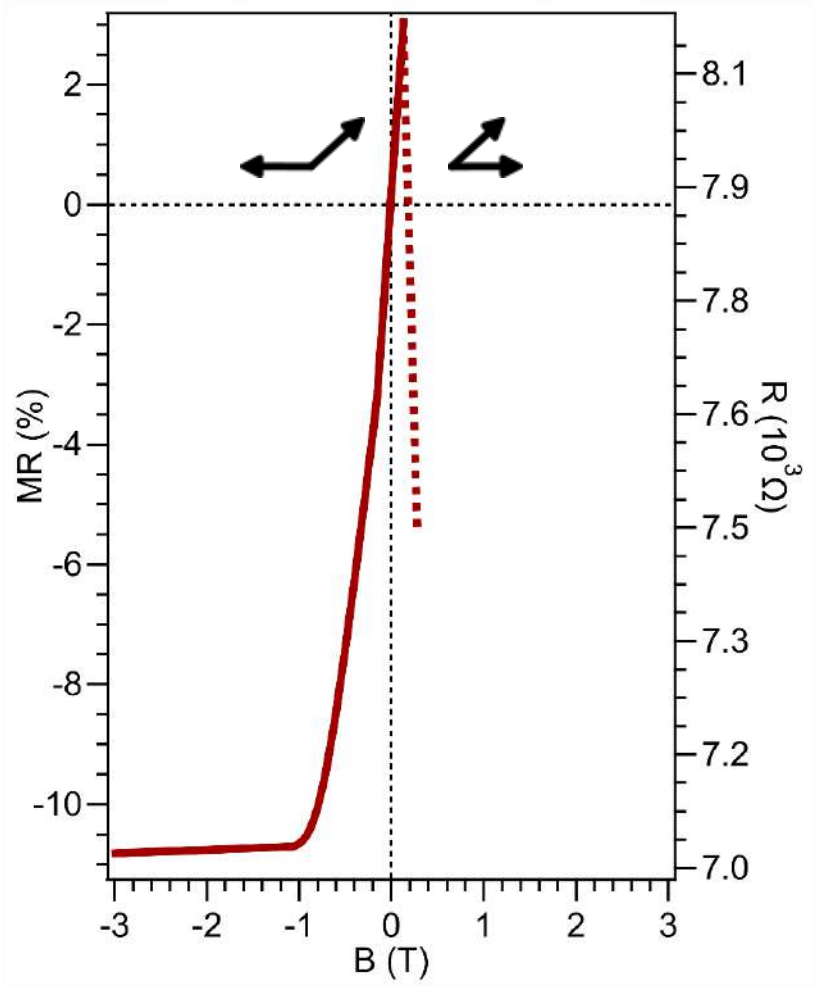
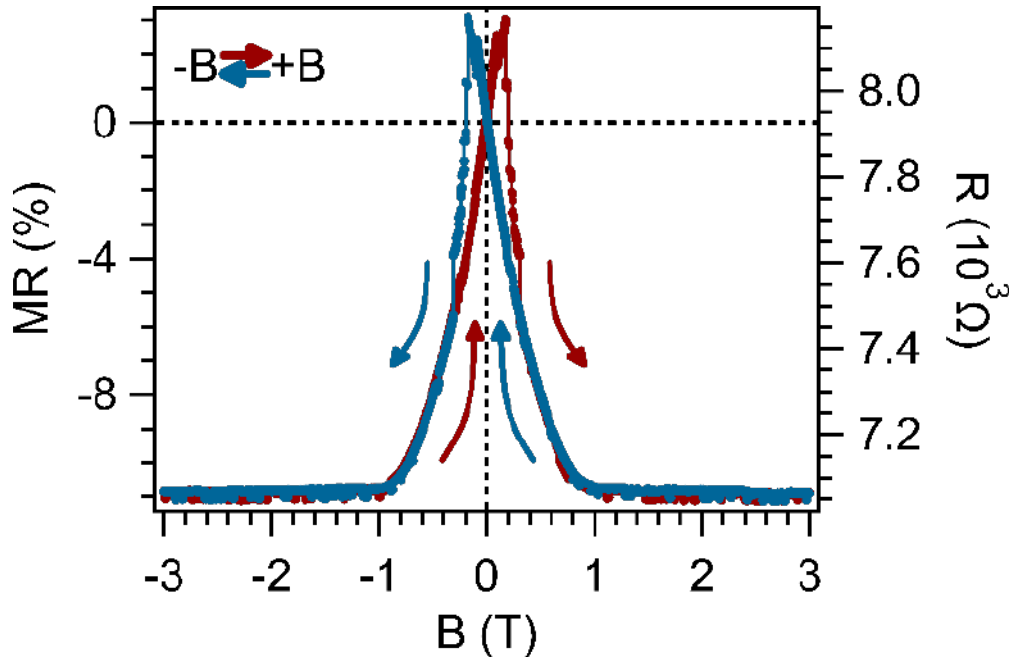
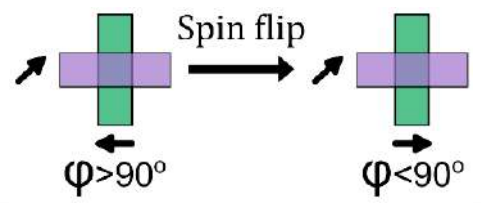
# Spin switching mechanisms



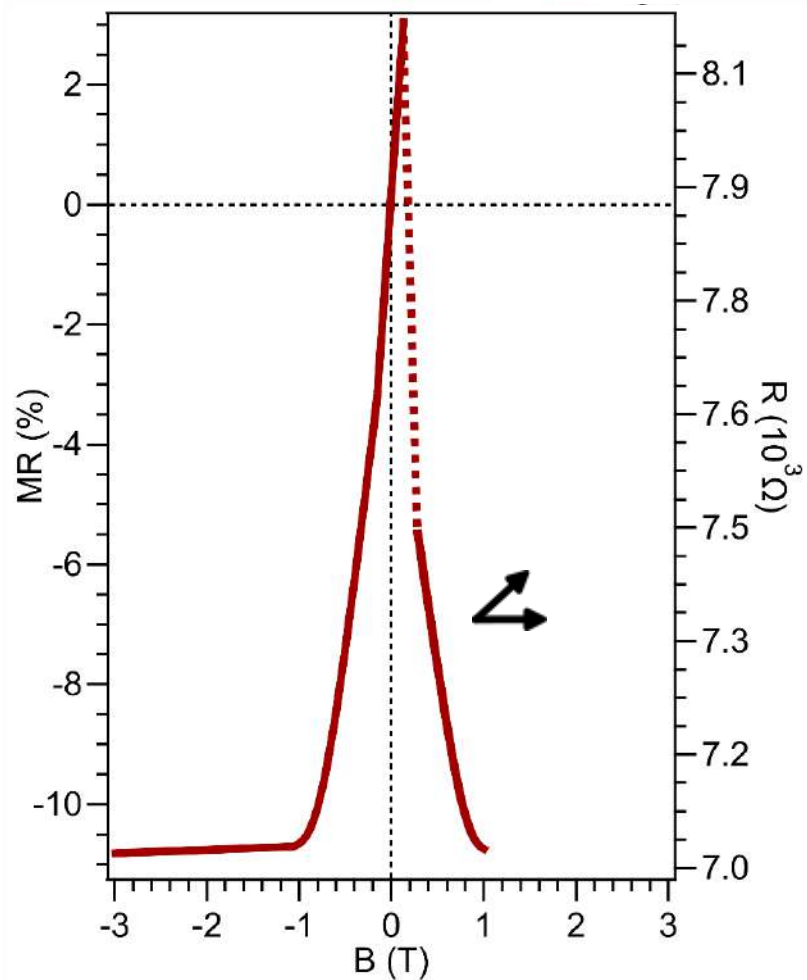
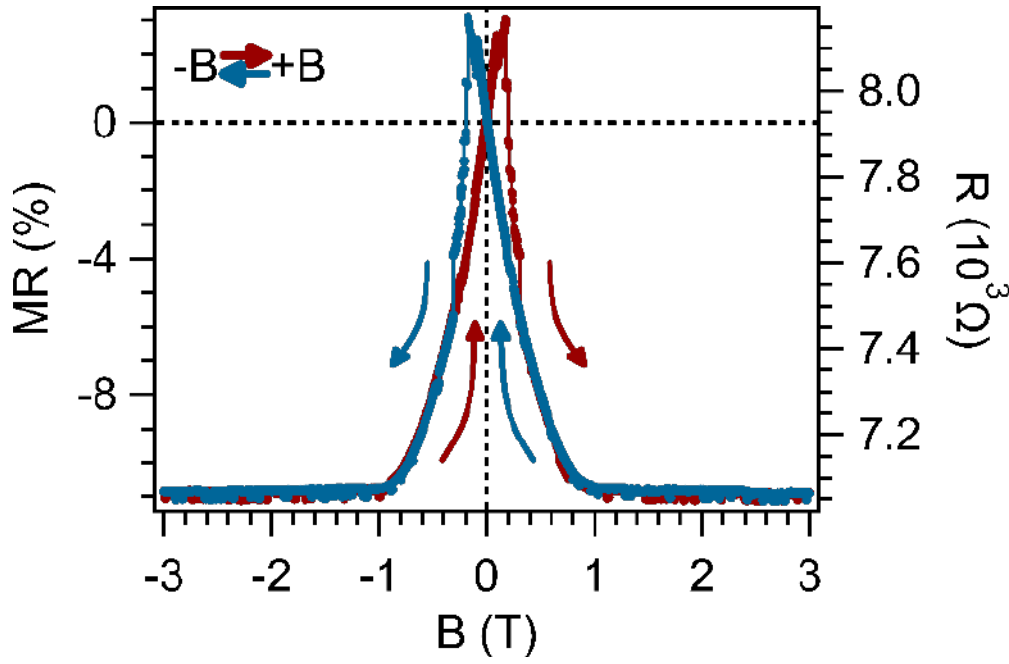
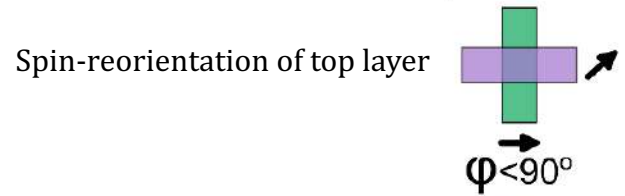
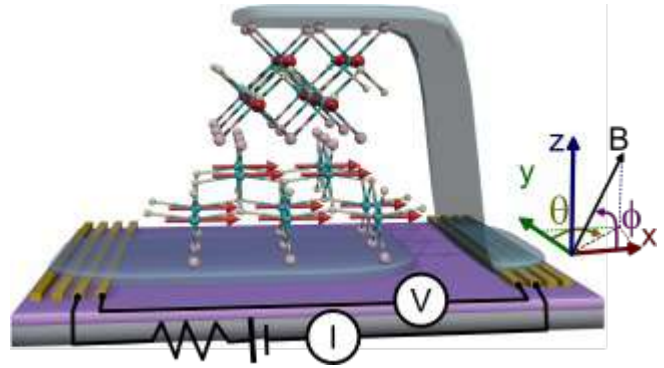
# Spin switching mechanisms



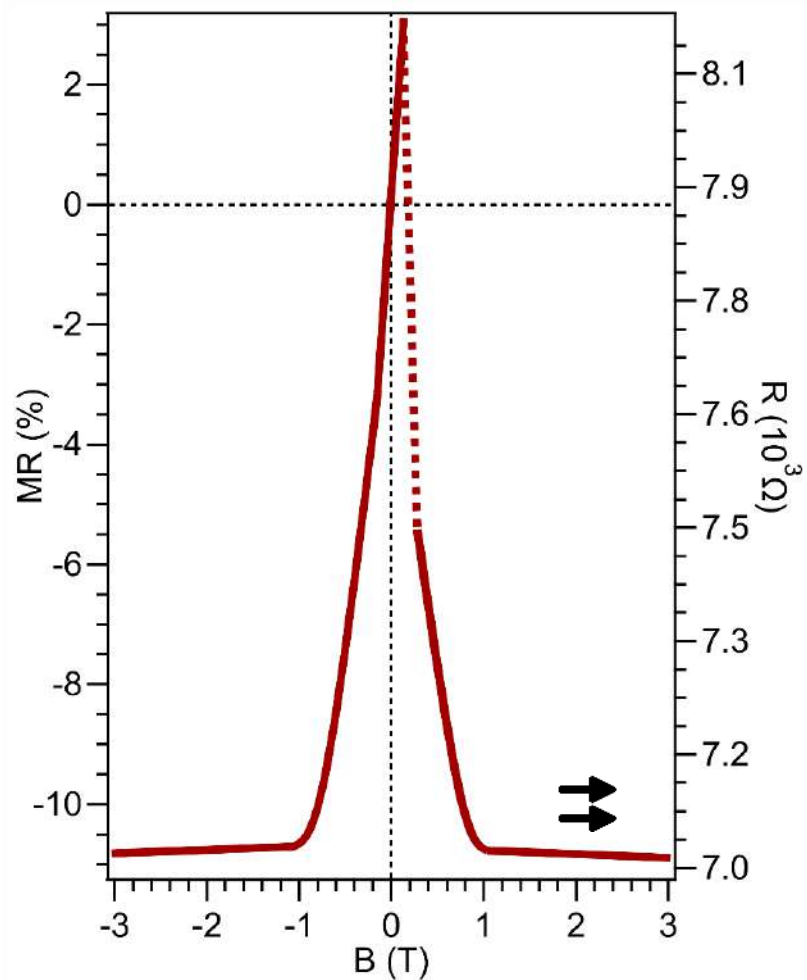
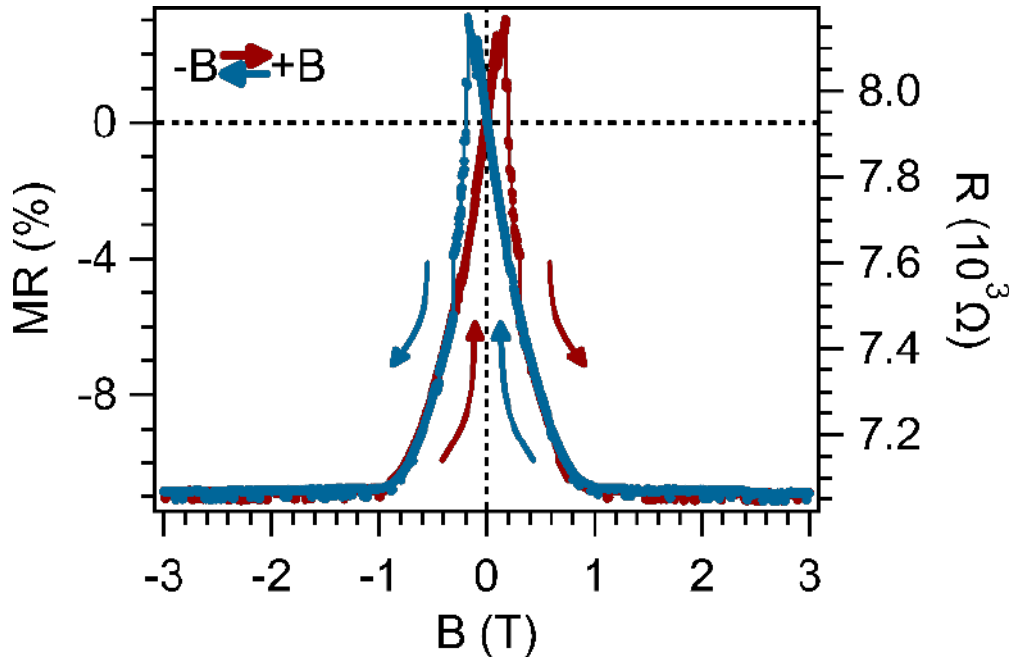
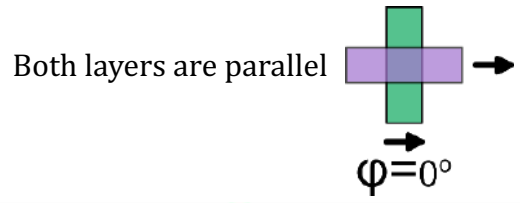
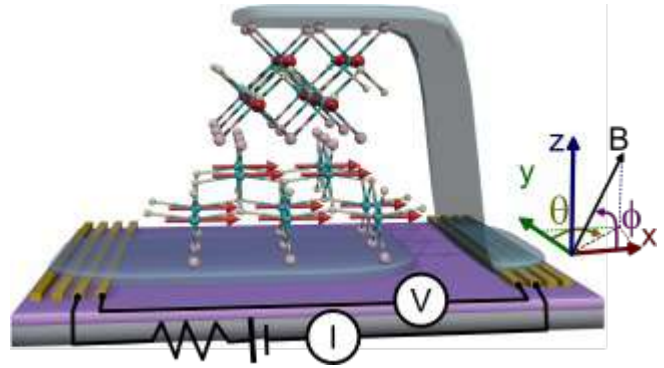
Spin-flip of bottom layer



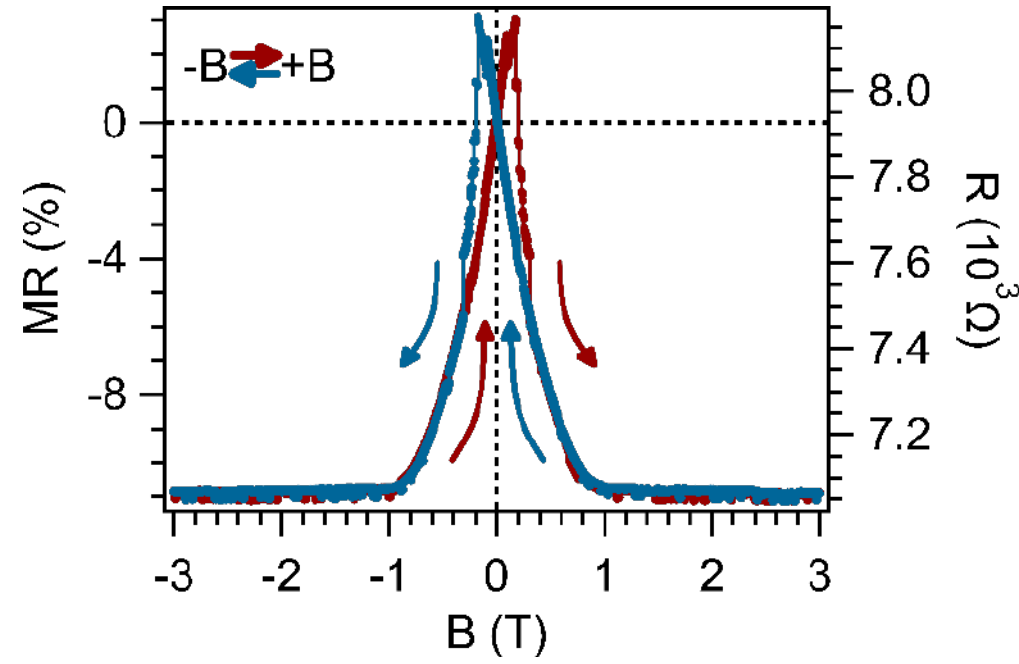
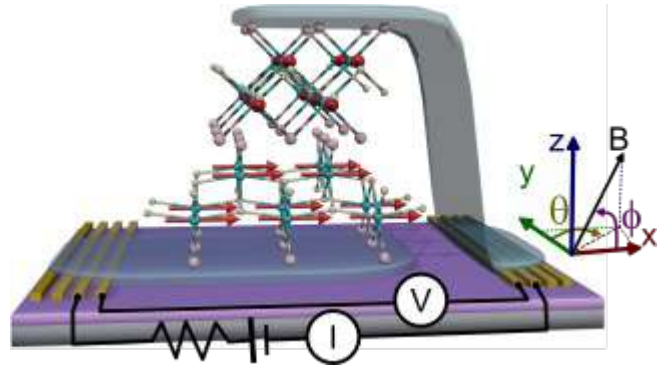
# Spin switching mechanisms



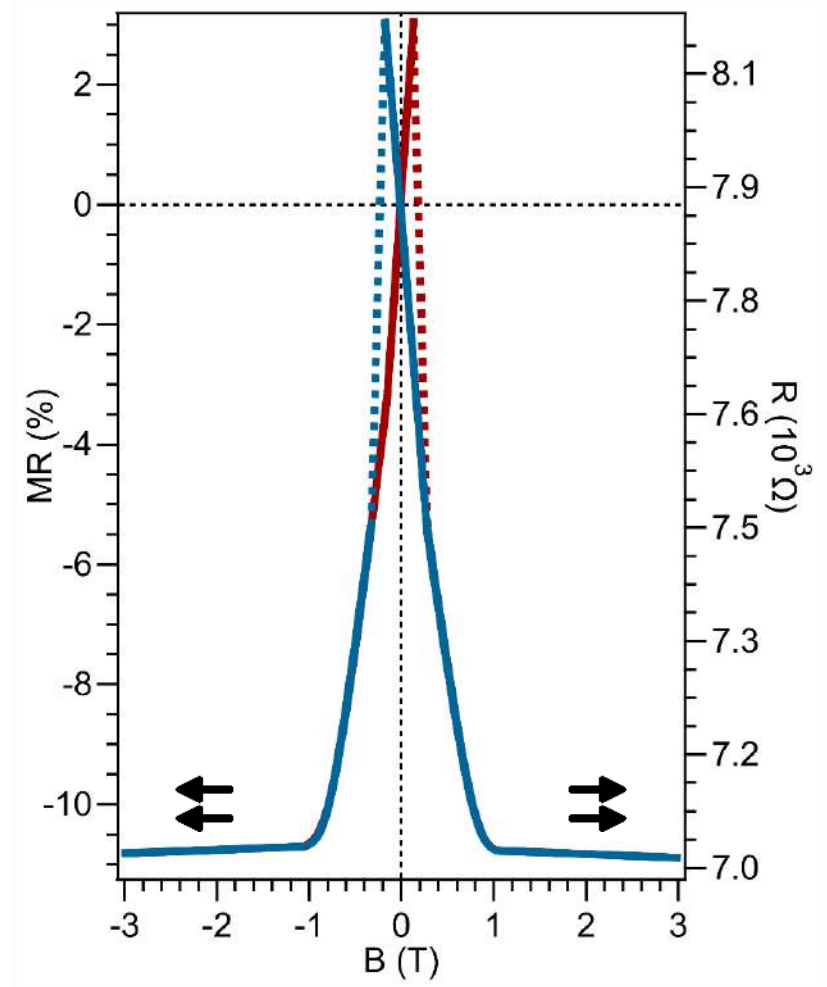
# Spin switching mechanisms



# Spin switching mechanisms

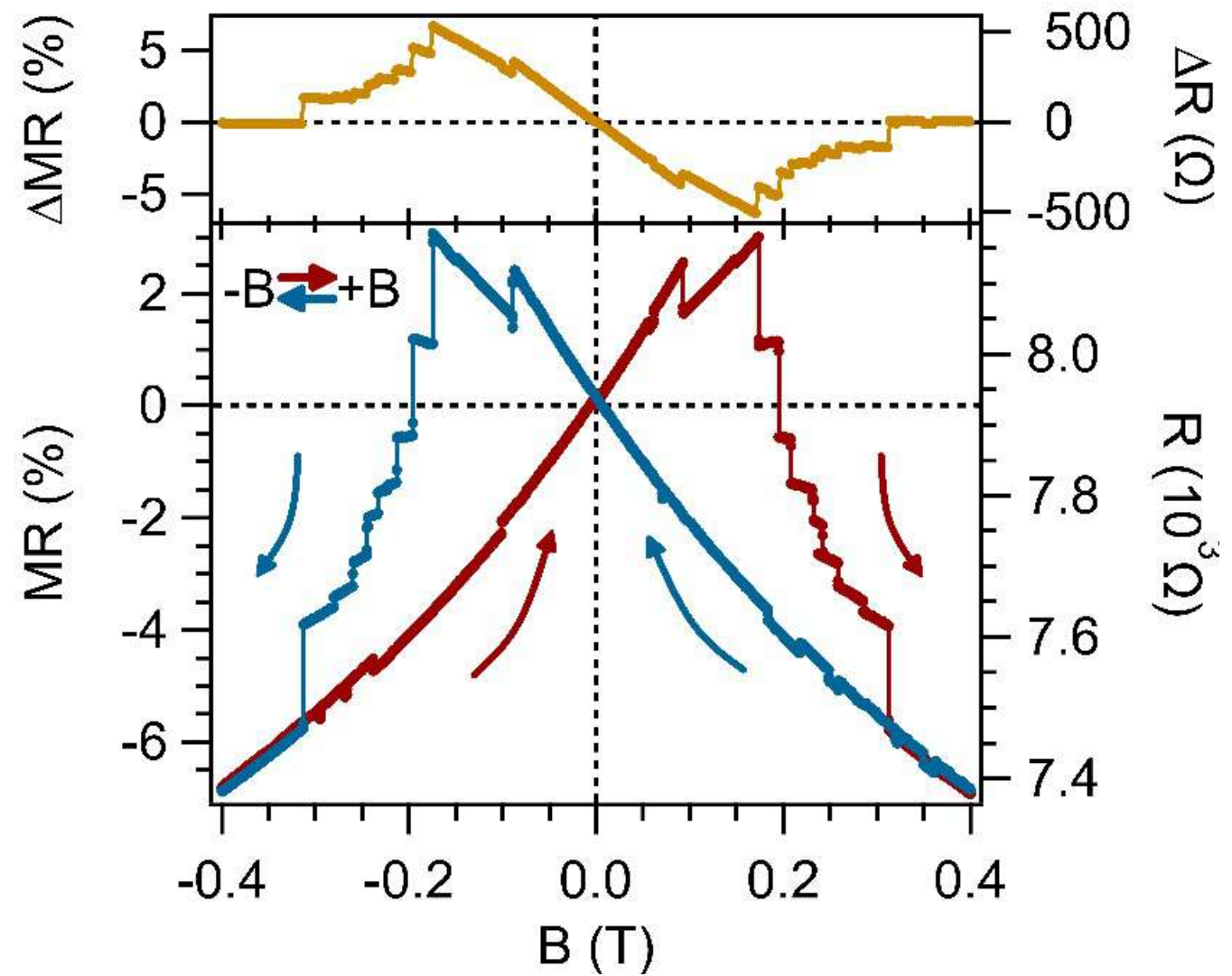


Symmetric curve when  $+B \rightarrow -B$



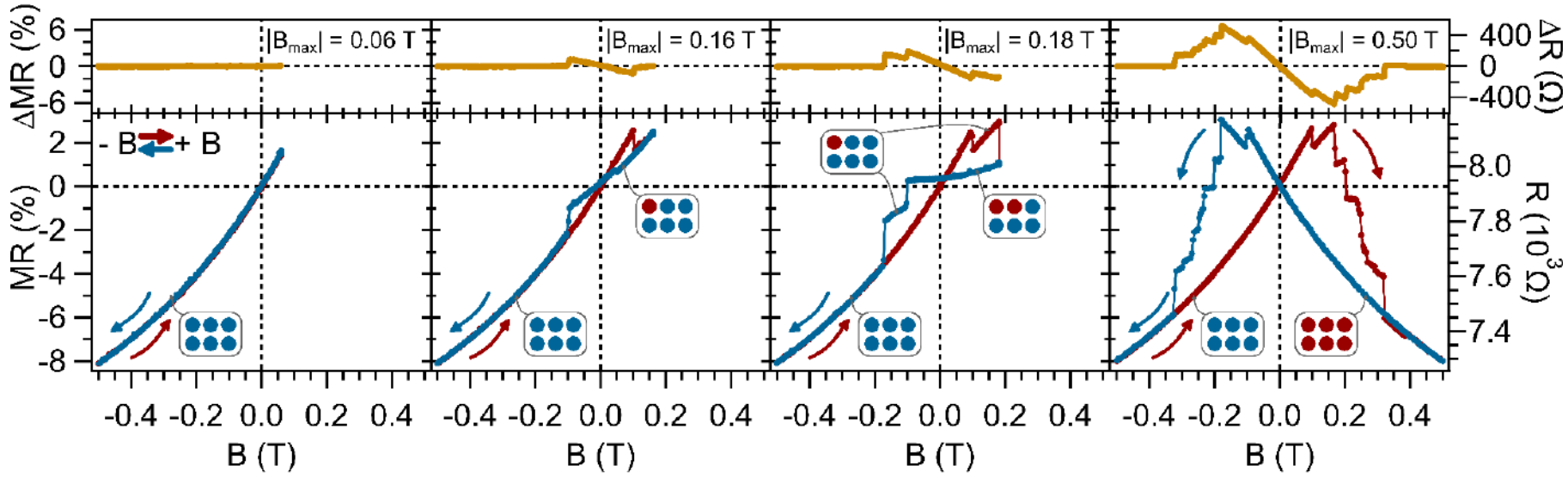
# Twisted CrSBr monolayers

➤ **Multistep magnetization.**



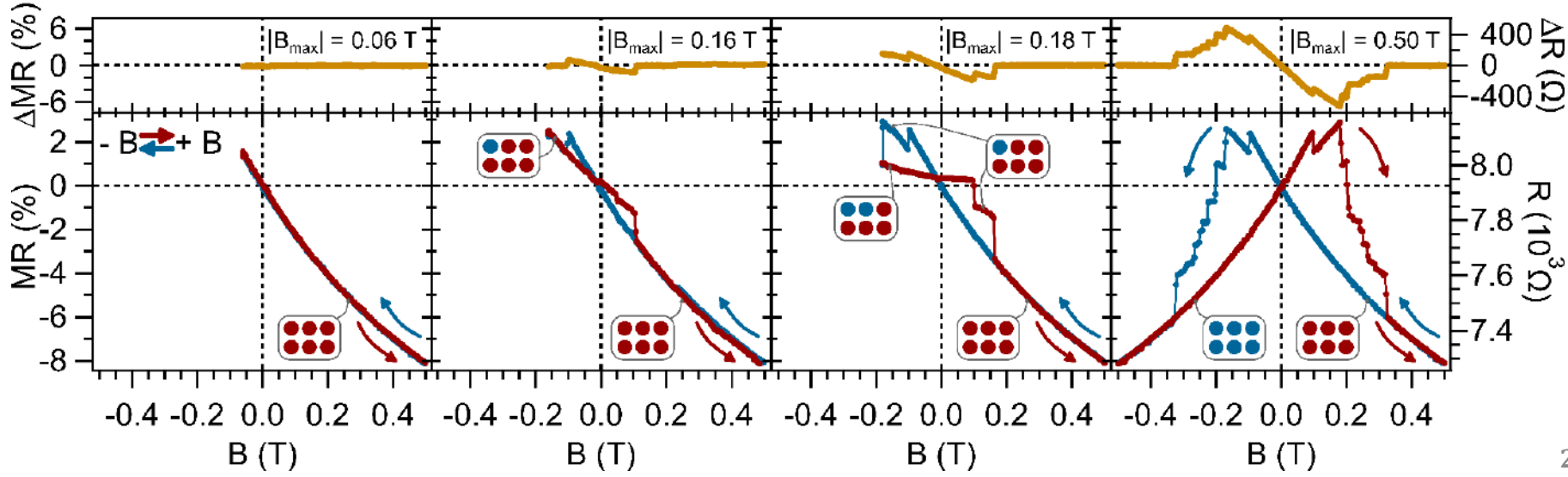
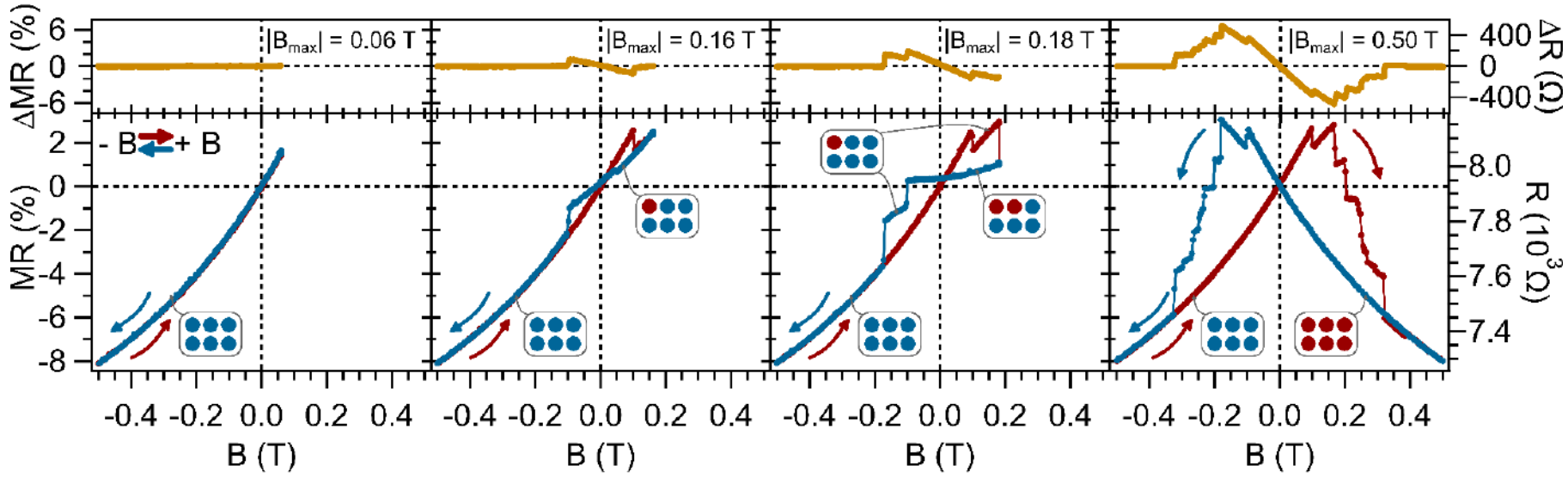
# Twisted CrSBr monolayers

## ➤ First Order Reversal Curves (FORCs):



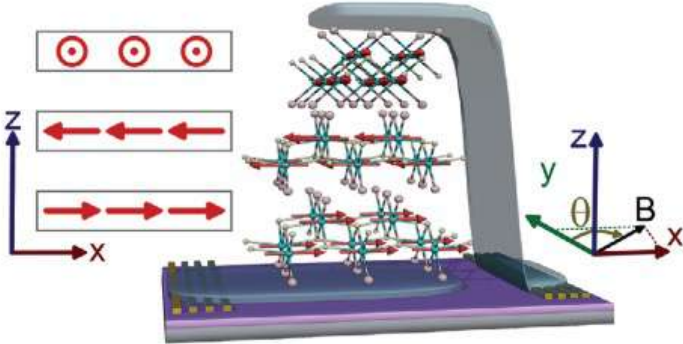
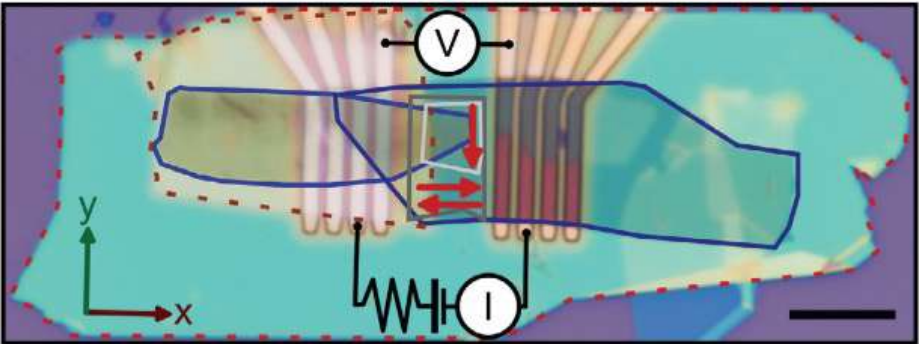
# Twisted CrSBr monolayers

➤ First Order Reversal Curves (FORCs):



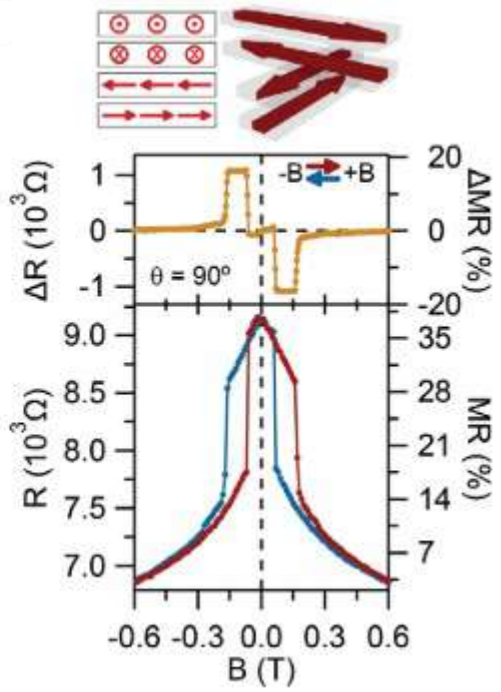
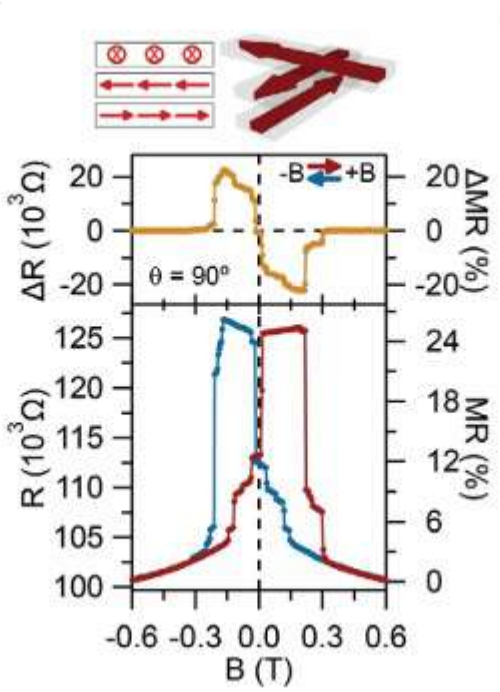
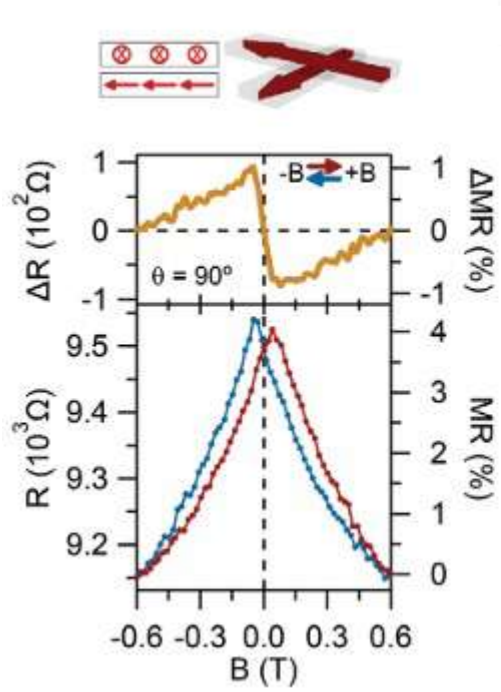
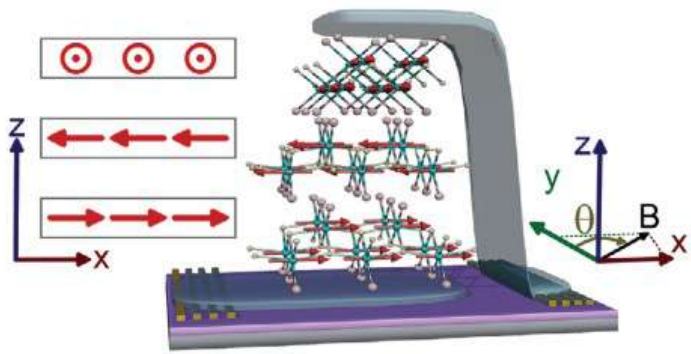
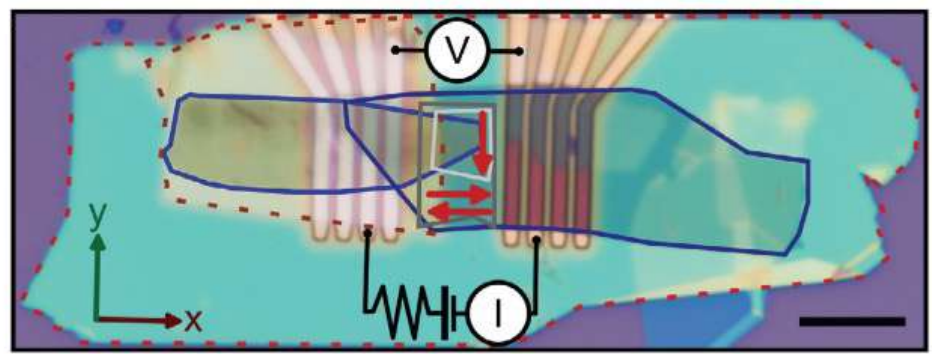
# CrSBr with a *twist*: different number of layers.

*Adv. Mater.* **37**, 2415774 (2025).



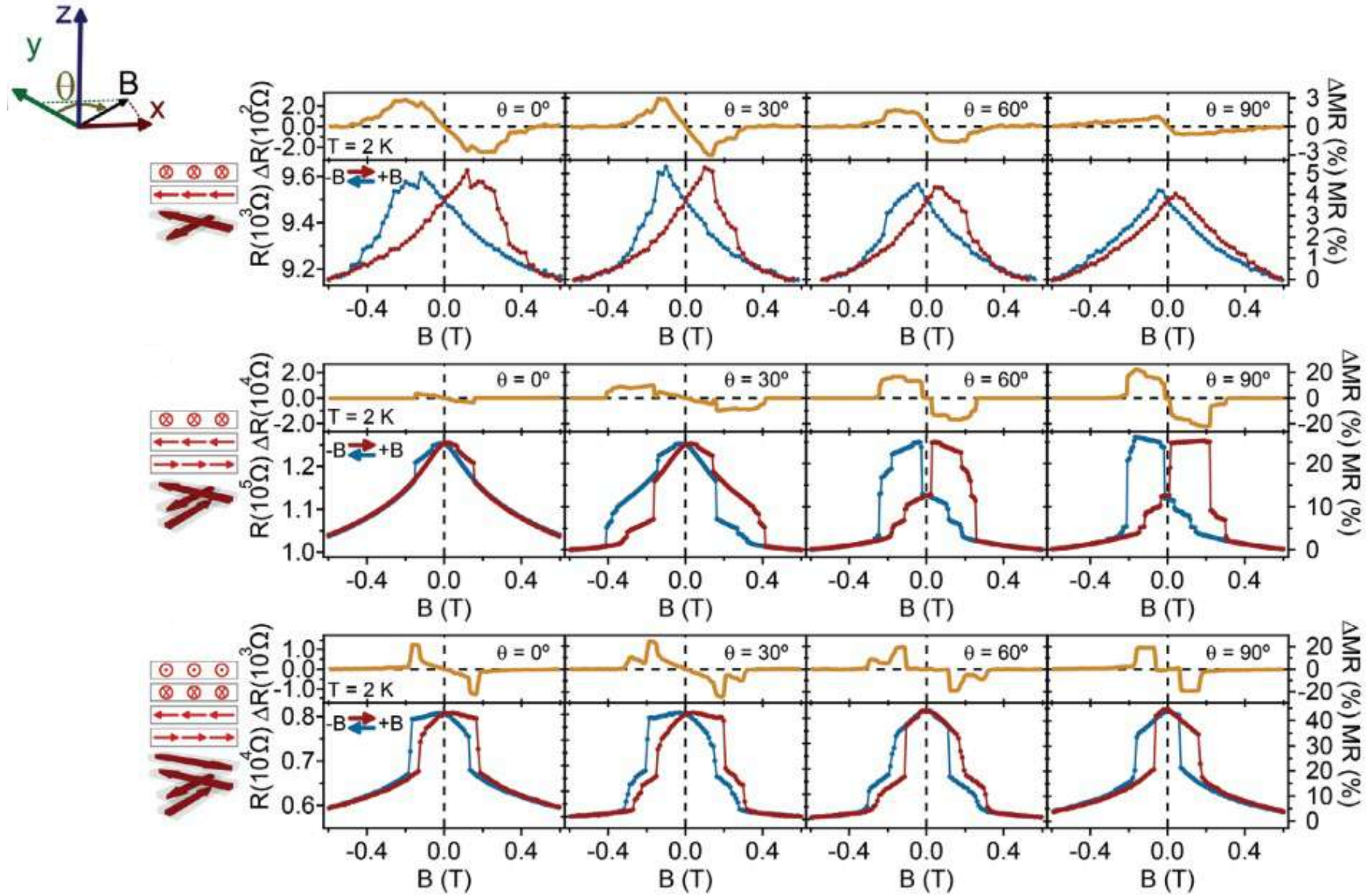
CrSBr with a *twist*: different number of layers.

Adv. Mater. 37, 2415774 (2025).

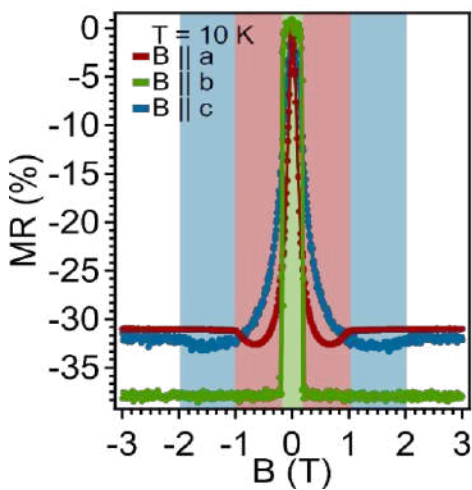


# CrSBr with a *twist*: different number of layers.

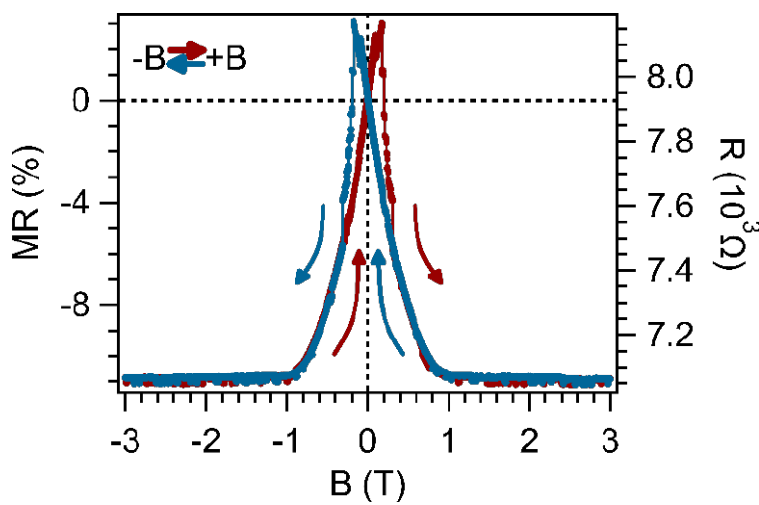
*Adv. Mater.* **37**, 2415774 (2025).



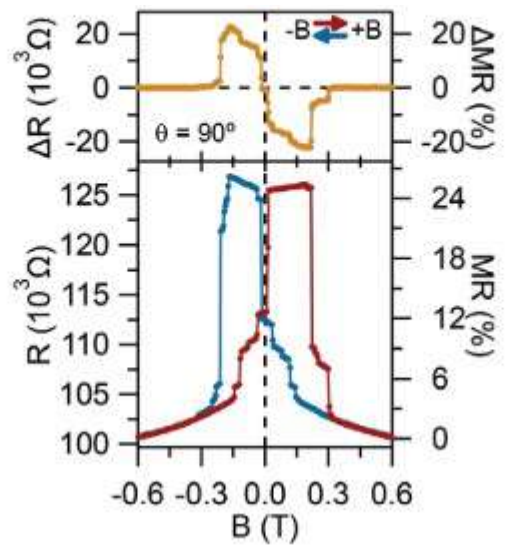
*Adv. Mater.* **34**, 2204940 (2022).



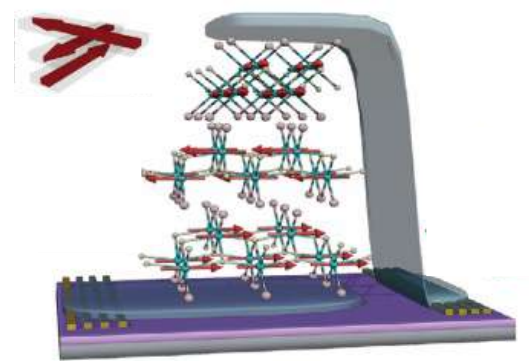
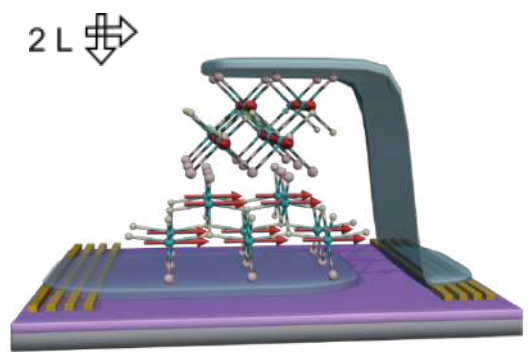
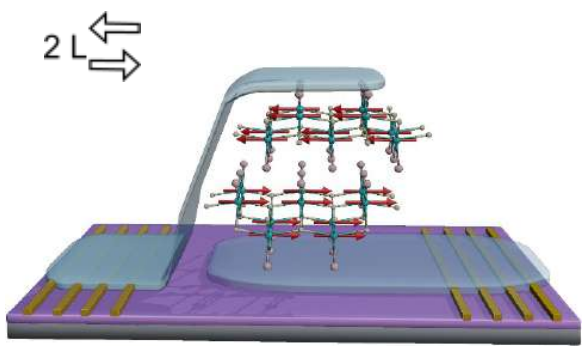
*Nat. Mater.* **23**, 212-218 (2024).



*Adv. Mater.* **37**, 2415774 (2025).



# Creating artificial magnets by twisting.





**Prof. Eugenio Coronado**  
**Dr. Samuel Mañas-Valero**  
Ángel López Muñoz  
Dr. José J. Baldoví  
Clara Miranda-Pérez  
Andrey Rybakov  
Alberto M. Ruiz

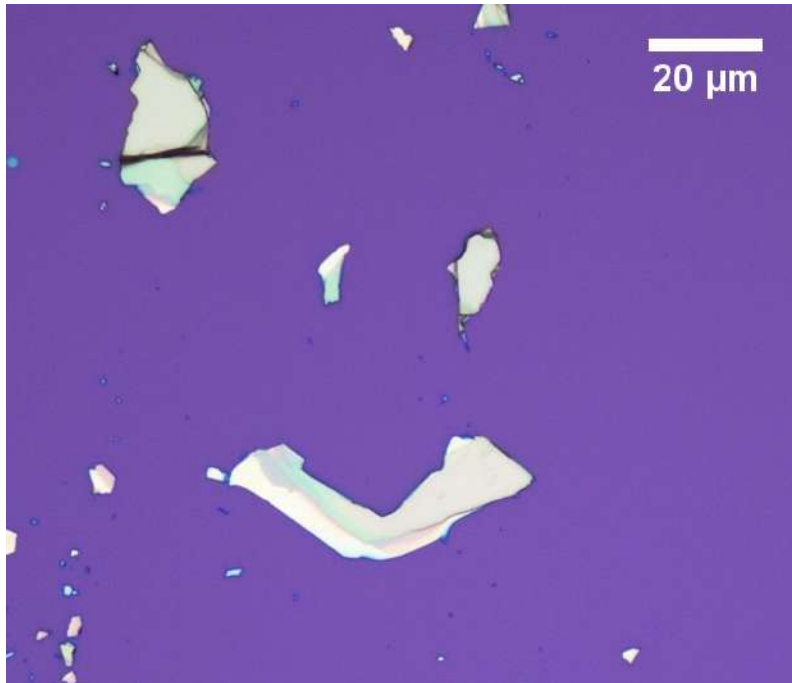
Dr. Aleksander Konieczny  
Dr. Sébastien Pillet

Dr. Elton J. G. Santos  
Dr. Sarah Jenkins

Dr. Ricardo Rama-Eiroa



Prof. Jaime Ferrer  
Dr. Gabriel Martínez-Carracedo



**THANK YOU FOR YOUR  
KIND ATTENTION!**

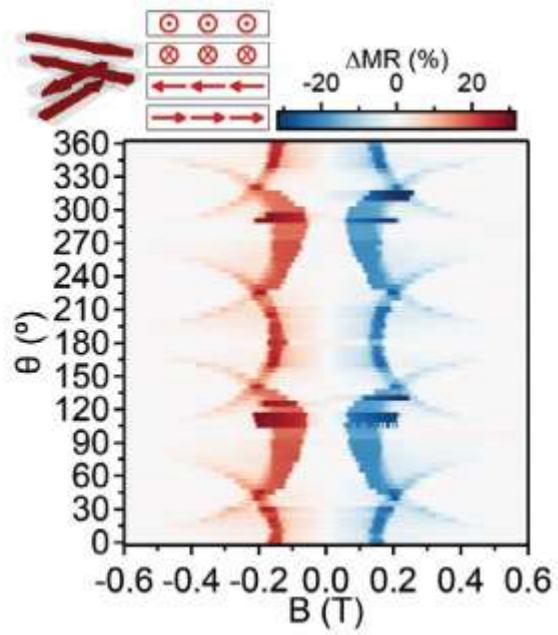
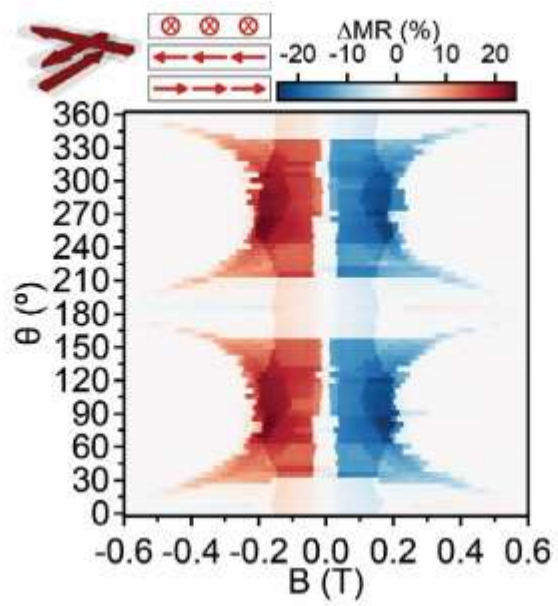
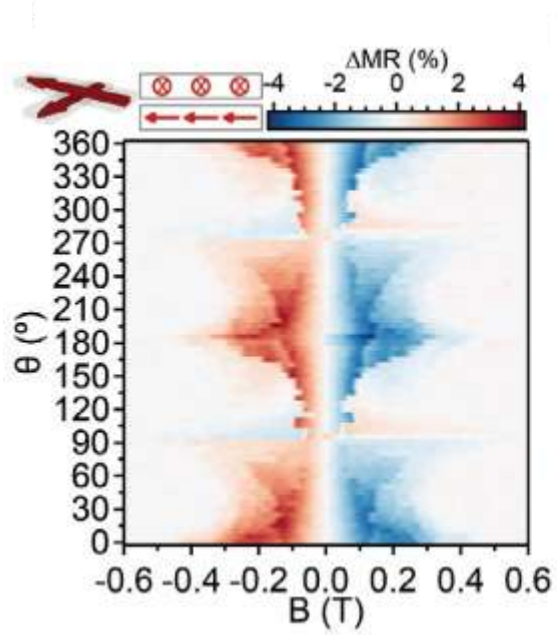
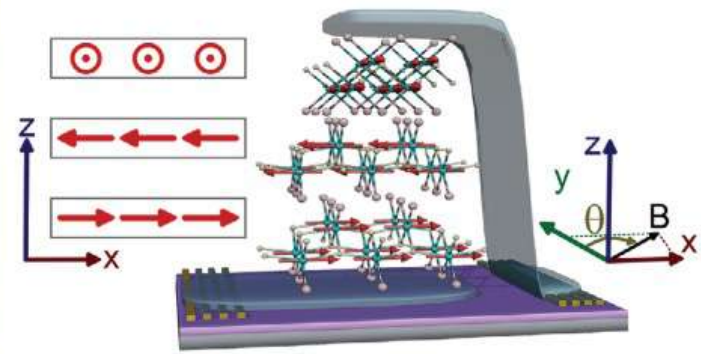
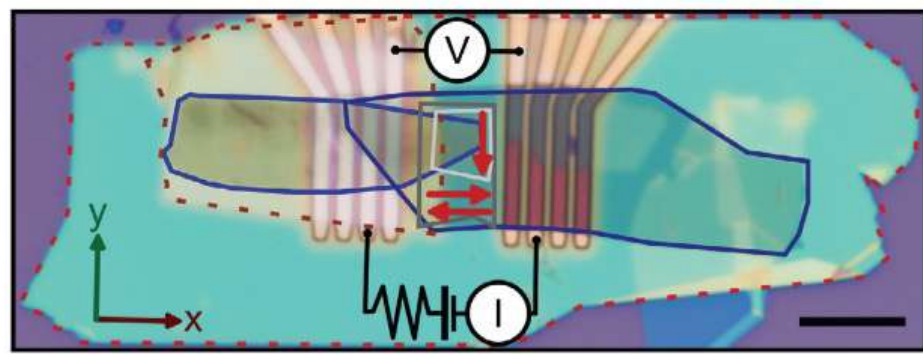
**Carla Boix Constant**  
*Email: carla.boix@uv.es*

*Institute of Molecular Science (ICMol) – University of Valencia*  
Research Team on Molecular Materials  
11<sup>th</sup> Workshop on 2D Materials – W2DM2025



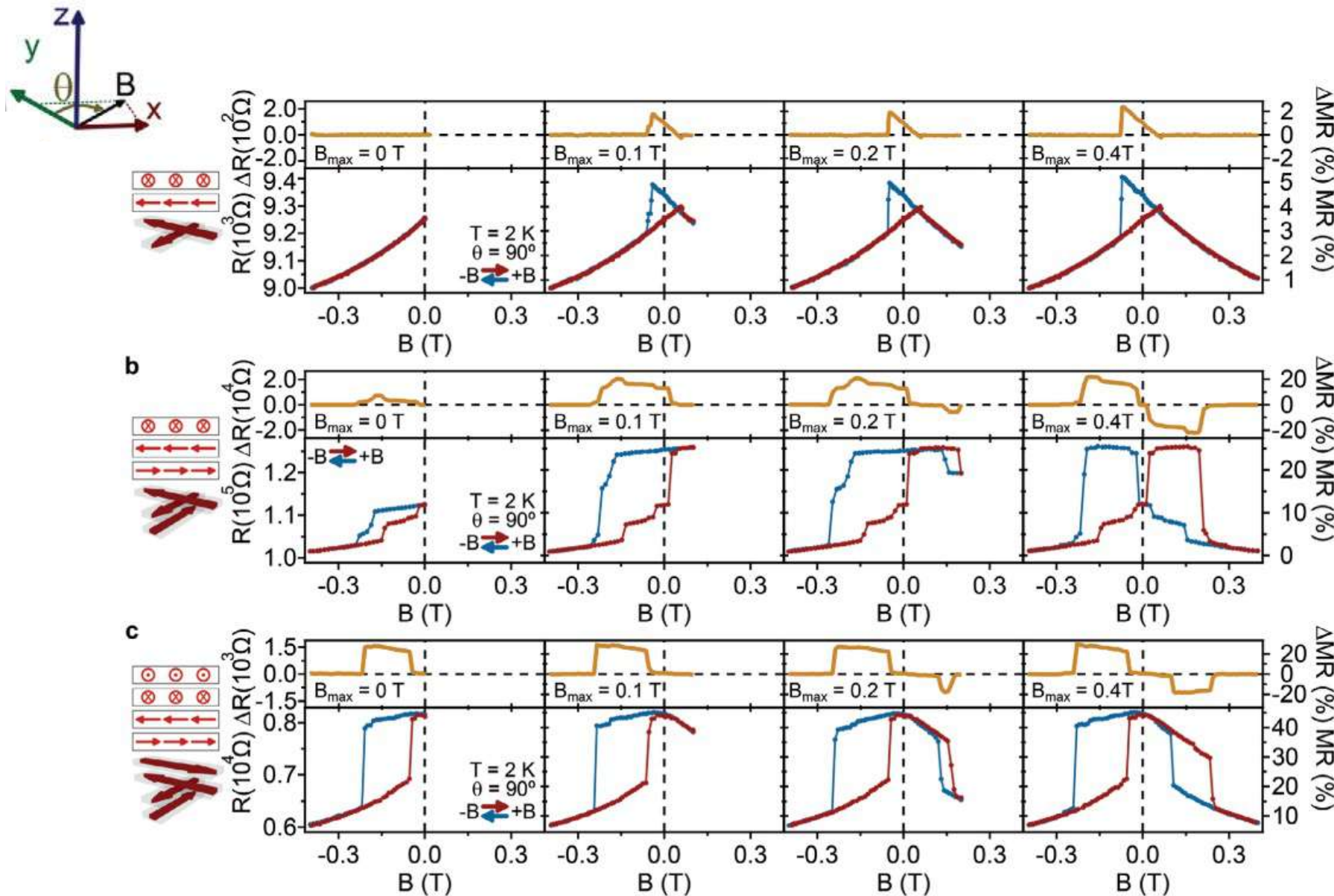
**CrSBr with a *twist*: different number of layers.**

*Adv. Mater.* **37**, 2415774 (2025).



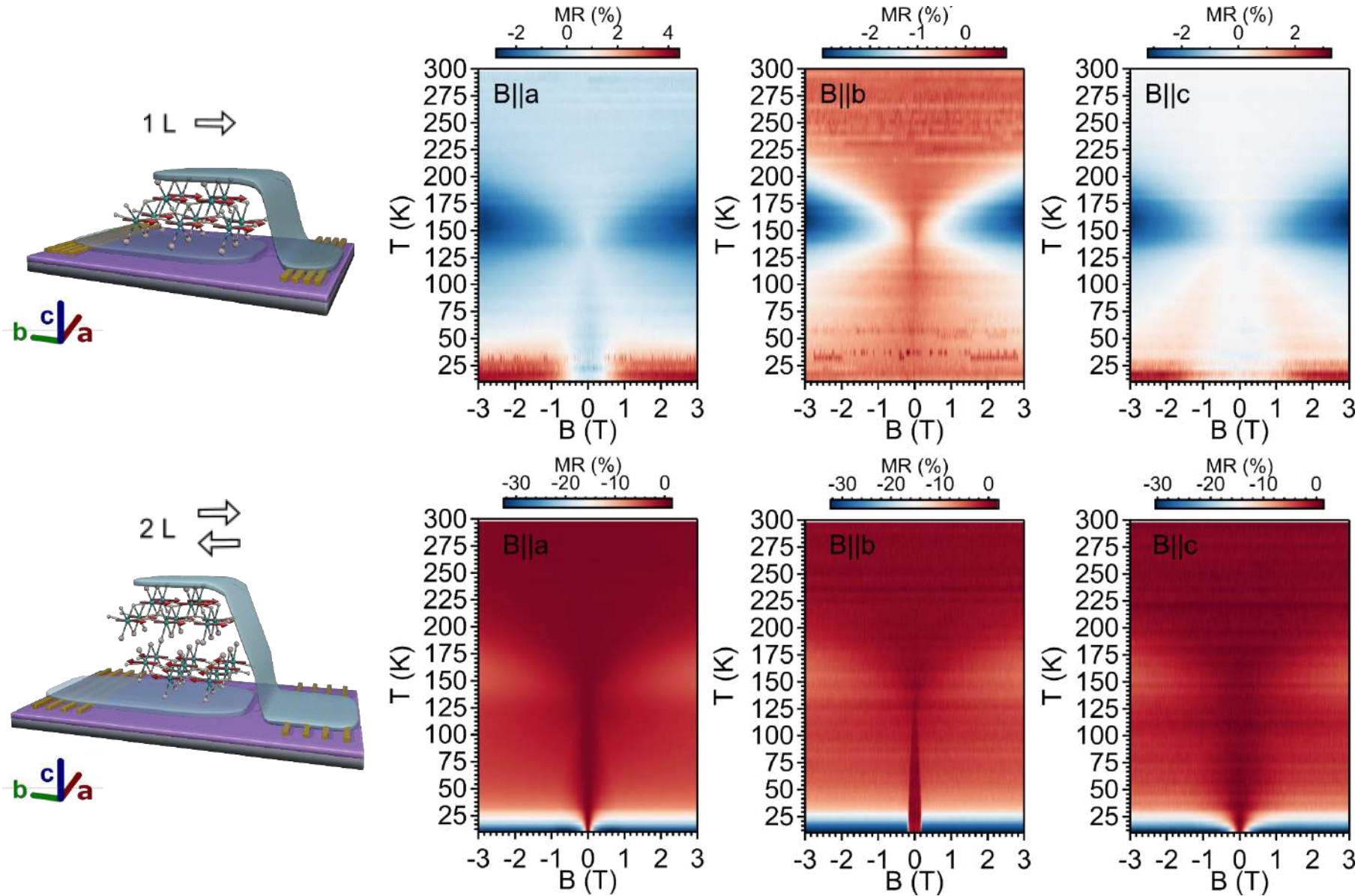
# CrSBr with a *twist*: different number of layers.

Adv. Mater. 37, 2415774 (2025).



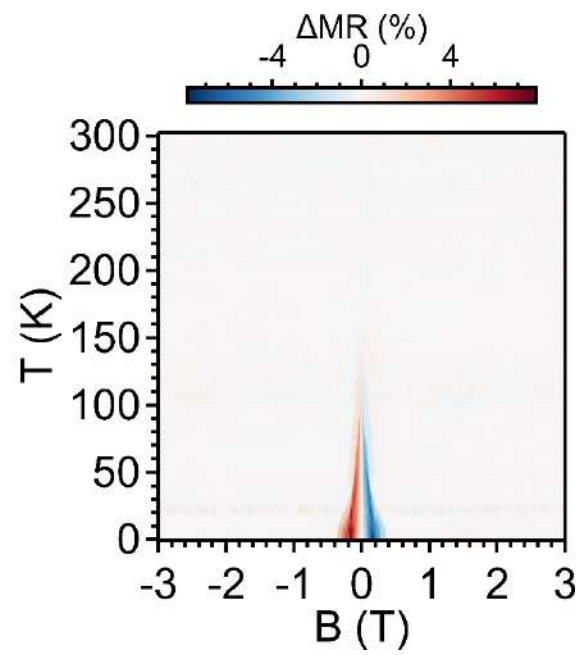
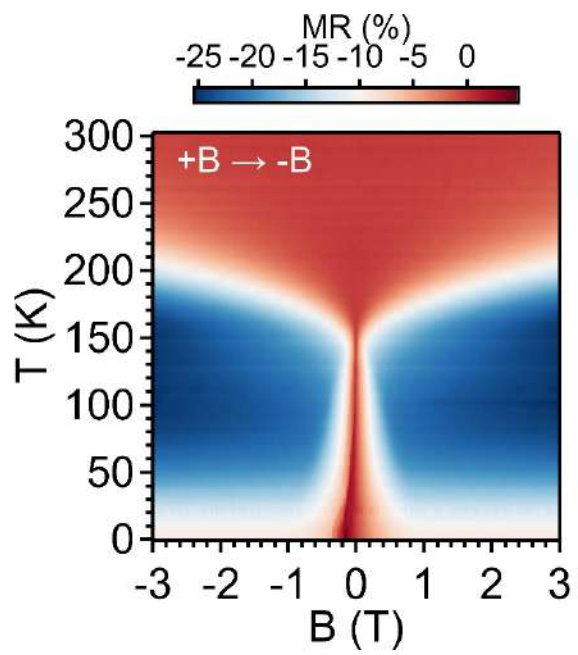
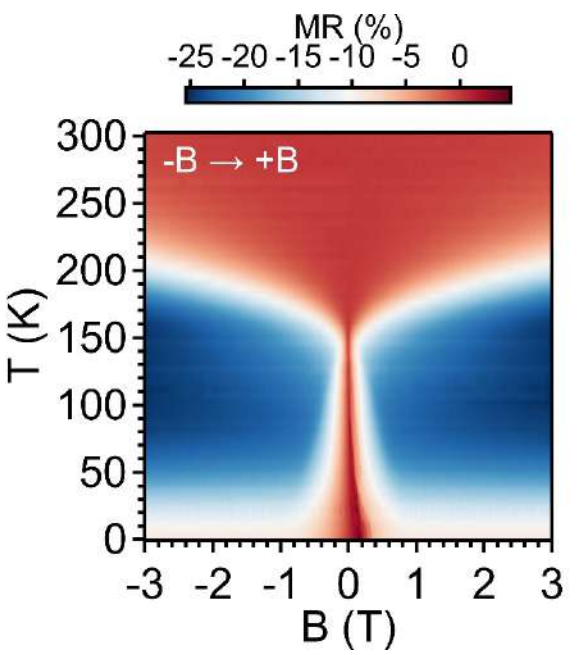
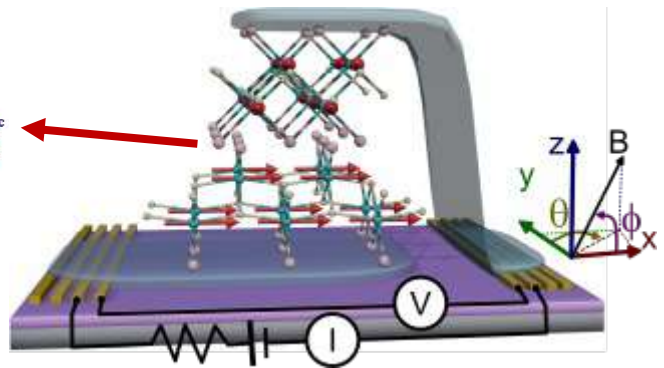
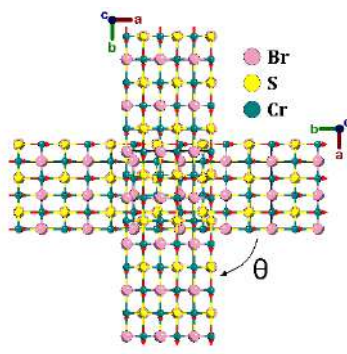
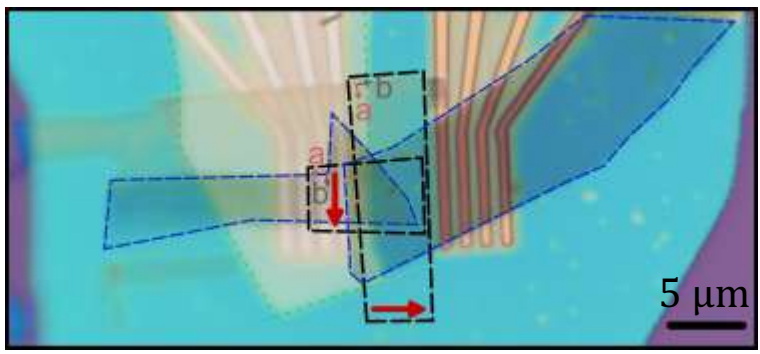
# Temperature dependence (pristine case)

Adv. Mater. 34, 2204940 (2022).



# Temperature dependence (orthogonally-twisted bilayer case)

*Nat. Mater.* **23**, 212-218 (2024).



# Temperature dependence (orthogonally-twisted $n$ -layer case)

*Adv. Mater.* **37**, 2415774 (2025).

