

New Quantum Phenomena by Combining 2D Materials with Complex Oxides

August 2020

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Project background:

- Heterojunctions of electronic and magnetic materials have been the basis for many important scientific discoveries (quantum Hall effect, giant magnetoresistance) and technological innovations (high-speed transistors, laser diodes, photodiodes, GMR sensors).
- Very little has been done on heterojunctions of epitaxial oxides and 2D materials.

Project goals:

- To enhance the magnetic properties of isolated 2D materials by controlled synthesis.
- To explore of the magnetic & electronic properties of 2D materials upon interaction with magnetic oxides.
- To gain atomic-scale insight into 2D magnets by first-principles modeling.

Project team (complete list of participants)

- Xiaodong Xu, Jiun-Haw Chu, David Cobden, Daniel Gamelin, Xiaosong Li, Michael De Siena*, Ryan Beck*, Jiayi Zhu*, (UW -- *postdocs and graduate students).
- Scott Chambers, Peter Sushko, Tim Droubay (PNNL).

Research design and methodology:

- Colloidal nanoplatelet [CrI_3 , CrBr_3 , $\text{Cr}(\text{I}_{1-x}\text{Br}_x)_3$] and single-crystal (Fe_3GeTe_2) synthesis of 2D materials
- Molecular beam epitaxial (MBE) growth of single-crystal oxide films (NiO , $\alpha\text{-Cr}_2\text{O}_3$, Fe_3O_4)
- 2D material/oxide clean interface formation by storage and transfer in N_2
- Materials characterization by XPS, XRD, HRTEM.
- Magnetic characterization by reflective magnetic circular dichroism (RMCD), vibrating sample magnetometry (VSM) and electronic transport.
- First-principles modeling by density functional theory (DFT).

Results:

- First observation of robust ferromagnetism in a 2D material with nanometer lateral dimensions.
- Magnetic interactions in quasi-two-dimensional $\text{CrI}_{3-x}\text{Cl}_x$ from DFT.
- Establishment of 2D material/oxide electronic device fabrication capability.
- Observation of exchange bias at the interface of a 2D material ferromagnet and an oxide antiferromagnet.

Publications:

- De Siena, Creutz, Regan, Malinowski, Jiang, Kluherz, Zhu, Lin, De Yoreo, Xu, Chu, Gamelin, *Nano Lett.*, 2020, 20, 2100.
- Two other papers in preparation, but not likely to be done this FY.

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