Epitaxial van der Waals heterostructures for magnetism and spin-charge conversion

F. Bonell[1]
V. Polewczyk[1], Q. Guillet[1], K. Abdukayumov[1], J. Courtin[1], T. Guillet[2], F. Ibrahim[1], D. Dosenovic[3], C. Vergnaud[1], I. de Moraes[1], M. Chshiev[1], S.O. Valenzuela[2], H. Okuno[3], A. Marty[1], M. Jamet[1]

[1] University Grenoble Alpes, CNRS, CEA, SPINTEC, 38000 Grenoble, France
[2] Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and the Barcelona Institute of Science and Technology (BIST), Bellaterra, Barcelona, Spain
[3] University Grenoble Alpes, CEA, IRIG-MEM, 38000 Grenoble, France

frederic.bonell@cnrs.fr

Layered materials are a class of quantum materials with electronic properties of exceptional interest for several domains of solid-state physics. Their crystal structure with van der Waals bonding between unit layers makes it feasible to stabilize single 2D layers and to form a wide range of heterostructures without the constraint of lattice matching. In this family of materials, transition metal dichalcogenides and topological insulators hold great promise for spintronics owing to their large spin-orbit coupling and the locking between the electron spin and momentum [1]. The recent discovery of van der Waals 2D magnets has also opened exciting opportunities to explore low dimensionality magnetism, proximity phenomena in heterostructures and all-van der Waals spin devices [1]. While most research on these materials is currently performed with nanoflakes mechanically exfoliated from bulk crystals, molecular beam epitaxy is emerging as a powerful method to grow large-area 2D materials with fine tuning of the composition, control of the thickness down to the 2D limit and ability to fabricate heterostructures with sharp and clean interfaces. I will discuss the specificities and challenges of van der Waals epitaxy and review recent progress in the fabrication of van der Waals materials by this technique, including topological insulators [2], transition metal dichalcogenides [3,4] and 2D magnets [5-7]. I will then illustrate the potential of these materials for spintronics with examples of heterostructures in which spin-charge interconversion is implemented, leading to large spin-orbit torques and current-driven magnetization switching [8,9].

References

[1] R. Galceran et al., APL Mater. 9, 100901 (2021)
[2] Bonell et al., Cryst. Grow. Des. 17, 4655 (2017)
[3] Bonell et al., 2D Mater. 9, 015015 (2021)
[4] R. Salazar et al., Nano Lett. 22, 9260 (2022)
[5] E. Velez et al., ACS Appl. Elec. Mater. 4, 259 (2022)
[6] M. Ribeiro et al., npj 2D Mater. Appl. 6, 10 (2022)
[7] Q. Guillet et al., Phys. Rev. Mater. 7, 054005 (2023)
[8] Bonell et al., Nano Lett. 20, 5893 (2020)
[9] T. Guillet et al., Nano Lett. 24, 822 (2024)