Controlling magnetism in van der Waals ferromagnets

Hidekazu Kurebayashi

London Centre for Nanotechnology, UCL, UK

Two-dimensional (2D) van der Waals (vdW) materials have been intensively and extensively studied in the last two decades. Interesting enough, there exist many magnetic versions of these 2D vdW materials, known for decades in bulk form but only in 2017, a few mono-layers of exfoliated ones were reported to show magnetism [1.2]. Since then, scientists started to seriously explore the physics and materials science of this new class of materials by applying their own research ideas and growth/measurement techniques. The ultimate answer of "are there any unique properties of 2D magnets?" is yet to be answered, if any.

We started to work on one of magnetic 2D vdW materials, $Cr_2Ge_2Te_6$ (CGT), to study its spin dynamics and how to control the magnetism by any external stimuli. In this presentation, I will start with a brief introduction of magnetic 2D vdW materials and then move on to our latest work of controlling magnetism (Curie temperatures and magnetic anisotropies) in CGT by electric field [3] and chemical doping [4]. Both doping techniques show the change of carrier density in CGT by orders of magnitude (from insulator to metallic). As a result, the exchange coupling strength has been greatly enhanced, leading to Curie temperature enhancement. The carrier doping also modifies the spin-orbit interaction within CGT which is measured by a significant change of the magnetic anisotropy parameters. These have been characterized by magneto-transport as well as spin dynamics techniques [5].

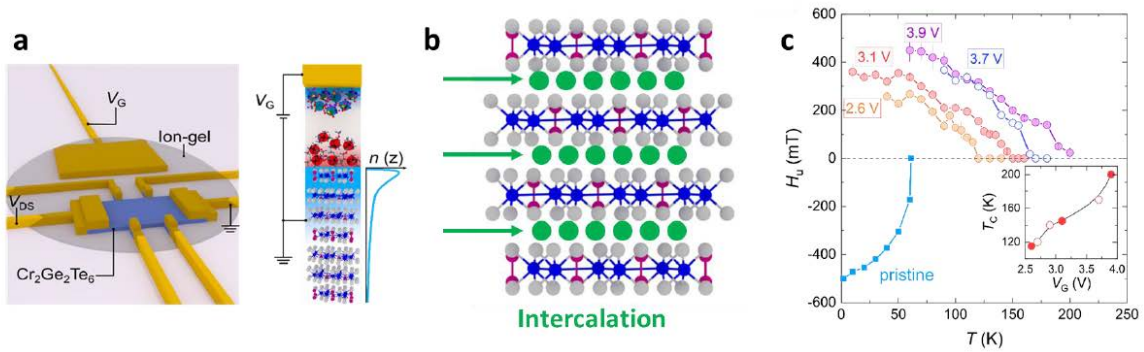

Fig: **a** Schematics of ionic gating of CGT and its charge concentration *n*. Interestingly, the screening effect can make a 2D electron gas within 20 nm CGT flake. **b** Schematic of chemical modification of CGT by intercalating atoms (in green), c the magnetic anisotropic field *H*u as a function of gating voltage and temperature. Further details can be explained in this talk as well as in Ref. [3].

[1] Gong et al. Nature 546 265 (2017).
[2] Huang et al., Nature 546, 270 (2017).
[3] Verzhbitskiy et al., Nature Electronics AOP (2020).
[4] Khan et al., in preparation.
[5] For example, for undoped CGT, Khan et al., Phys. Rev. B 100, 134437 (2019); arXiv:1903.00584.