The promise of anisotropic 2D materials: the Transition Metal Trichalcogenide (TMT)

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To develop new semiconductor technologies and, in fact, surpass silicon technology, the scaling of devices to transistor widths below 10 nm is essential. This poses problems for most materials, as few are perfect. Imperfections abound and in the limit of the very small scale can have disastrous effects, especially on device performance (in say a transistor). As transistor dimensions decrease, in principle, 2D semiconductor channel materials are highly desirable because this reduced the leakage currents, but edge effects become significant. In aiming for 2D semiconductor channel materials, here lies a challenge for materials science: *to engineer a 2D material in which edge effects are not detrimental to transport as the channel width shrinks below 20 nm.* Here, we discuss possible 2D materials, with highly anisotropic band structure. Transition metal trichalcogenide (TMT), like MX_3 (M=Ti, Zr, Hf; X=S, Se, Te), and In_4X_3 (X=Se, Te), are possible candidates for a semiconductor channel for a field effect transistor (FET) on the scale of a few nanometers. The band structure of titanium trisulfide (TiS_3) [1], ZrS_3 and In_4Se_3 [2] are all found to be highly anisotropic, consistent with transport measurements, and accompanied by few edge imperfections. TMT also have band gaps comparable to that of silicon (1.1 eV): ~ 1 eV for TiS_3, and ~ 1.9 eV for ZrS_3. In this presentation, we are going to show our experimental electronic structure measurement results (Figure) mainly on TiS_3 and ZrS_3 whisker materials.

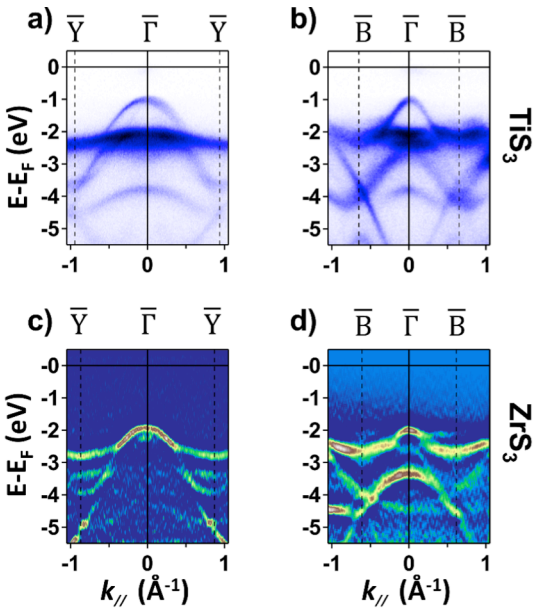

Figure: The experimental band structure of TiS_3(001) (a,b) and ZrS_3(001) (c,d) along the high symmetry directions of $\overline{\Gamma}$ to $\overline{Y}$ (a,c) and $\overline{\Gamma}$ to $\overline{B}$ (b,d), as derived from nano-spot Angle Resolved Photoemission Spectroscopy (nanoARPES). c) and d) are plots of the top of the valence band, after a taking the 2nd derivative of the experimental band structure, so as to illustrate the details of the band structure of ZrS_3(001).

[1] H. Yi, et al. *Applied Physics Letters* **112** (2018) 052102
[2] Ya. B. Losovyj, et al., *Applied Physics Letters* **92** (2008) 122107