

Quenching the band gap of 2D semiconductors with an electric field

Daniil Domaretskiy*,^{1,2} Marc Philippi*,^{1,2} Marco Gibertini,^{1,3} Nicolas Ubrig,^{1,2} Ignacio Gutiérrez-Lezama,^{1,2} and Alberto Morpurgo^{1,2}

¹ *Department of Quantum Matter Physics, University of Geneva, 24 Quai E. Ansermet, CH 1211 Geneva, Switzerland*

² *Group of Applied Physics, University of Geneva, 24 Quai E. Ansermet, CH 1211 Geneva, Switzerland*

³ *Dipartimento di Scienze Fisiche, Informatiche e Matematiche, University of Modena and Reggio Emilia, IT-41125 Modena, Italy*

The electronic band structure of atomically thin semiconductors can be tuned continuously by the application of a perpendicular electric field. Shortly after the discovery of graphene, this principle was demonstrated experimentally by opening a finite band gap in graphene bilayers which naturally are zero-gap semiconductors [1, 2]. So far, however, the same principle could not be employed to control a broader class of materials because the required electric fields are too large. Indeed, whereas top gates with high capacitance were readily available in the form of ionic liquids, the lack of high capacitance back gate restricted the maximum electric field that could be applied. A solution to this problem was brought by our recent study where we used Li-ion conducting glass ceramics for electrostatic gating [3]. In it, we showed that these ionic ceramics had a capacitance similar to that of ionic liquids and could therefore be used in conjunction with them in double gating measurements. As such, we present in this work an experimental strategy using double ionic gated devices, which enables very large electric fields to be applied perpendicularly to atomically thin crystals. Using these devices, we show that the band gap of few-layer semiconducting transition metal dichalcogenides can be continuously suppressed from 1.5 eV to zero. This unprecedented level of control of the band structures has important implications for both future research and applications of atomically thin crystals.

* Both authors contributed equally

[1] Oostinga et al., *Nature Materials* 7, 151 (2008).

[2] Zhang et al., *Nature* 459, 820 (2009).

[3] Philippi et al., *APL* 113, 033502 (2018).