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Tuning van der Waals heterostructures by pressure

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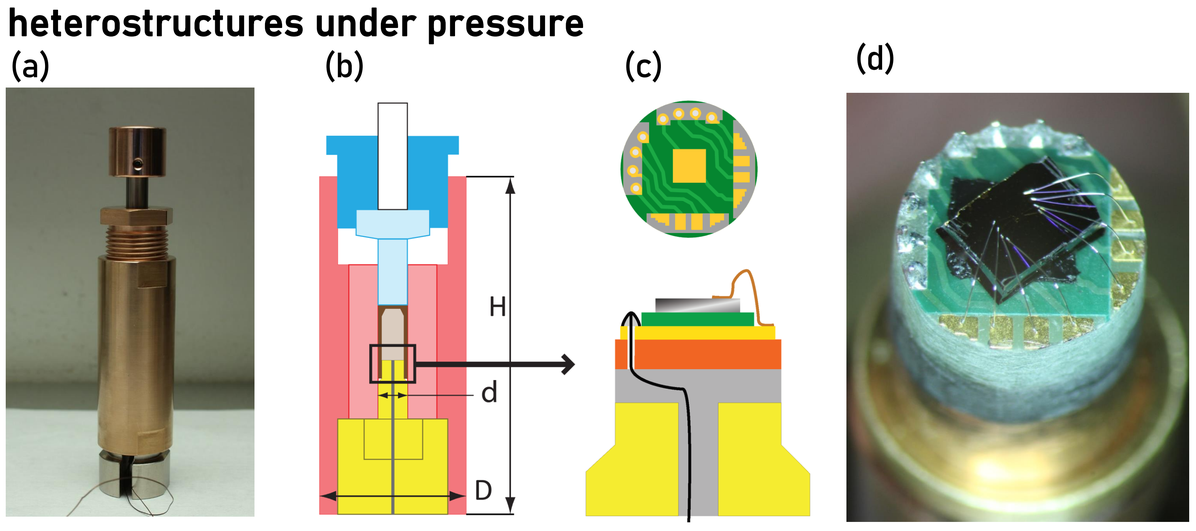
Abstract

In van der Waals heterostructures the layer distance strongly affects the interaction between the layers. Therefore, pressure is an ideal tool to engineer the band structure of van der Waal materials [1]. On this poster two examples are shown for the versatility of this method. First, it is shown here that in WSe_2/Gr structures spin-orbit coupling can be induced in graphene using proximity effects, which can be boosted using hydrostatic pressure [2]. The enhancement is confirmed using weak anti- localization measurements. Moreover, I will also demonstrate the band structure tuning of magic-angle twisted double bilayer graphene [3]. We have performed thermal activation and magneto-transport measurements to reveal changes in the bandgaps of the system. We have observed a strong tuneability with pressure, which is confirmed by our theoretical calculations. Finally, we have also observed changes in the strength of electron-electron interactions and in the topological phases at the charge neutrality point in magnetic fields.

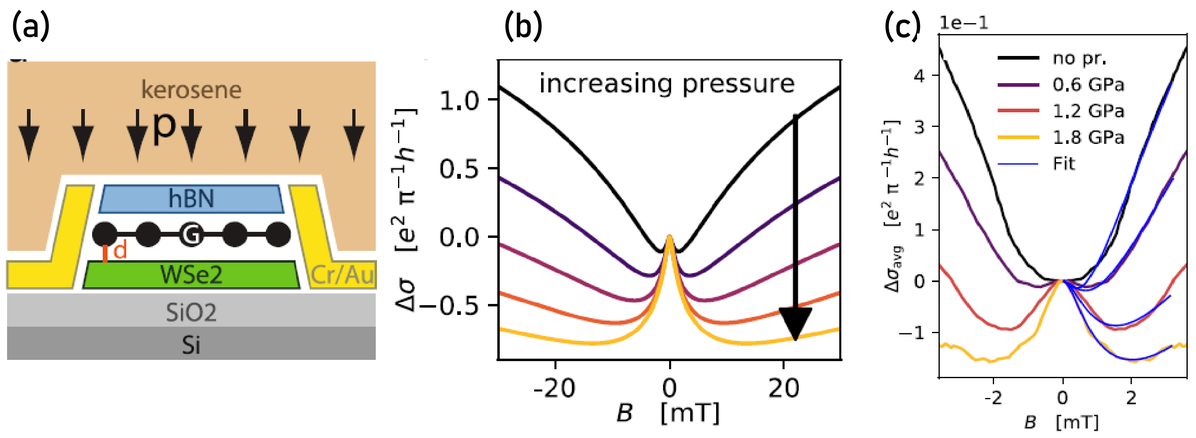
A new method of transport measurements on van der Waals heterostructures under pressure



(a) Side view of a clamp-type two-layer pressure cell. (b) Schematic side view of a clamp-type two-layer pressure cell without the detailed sample holder head. The cell dimensions are H = 62mm, D = 25mm, and d = 6.5mm. (c) Detailed schematic side view of the sample holder head, as marked by the black rectangle on panel a, and the schematic top view of the PCB design. (d) Corresponding bird's-eye view of the top of the sample holder head with a chip attached on it and bonded to the electric contacts. [1]

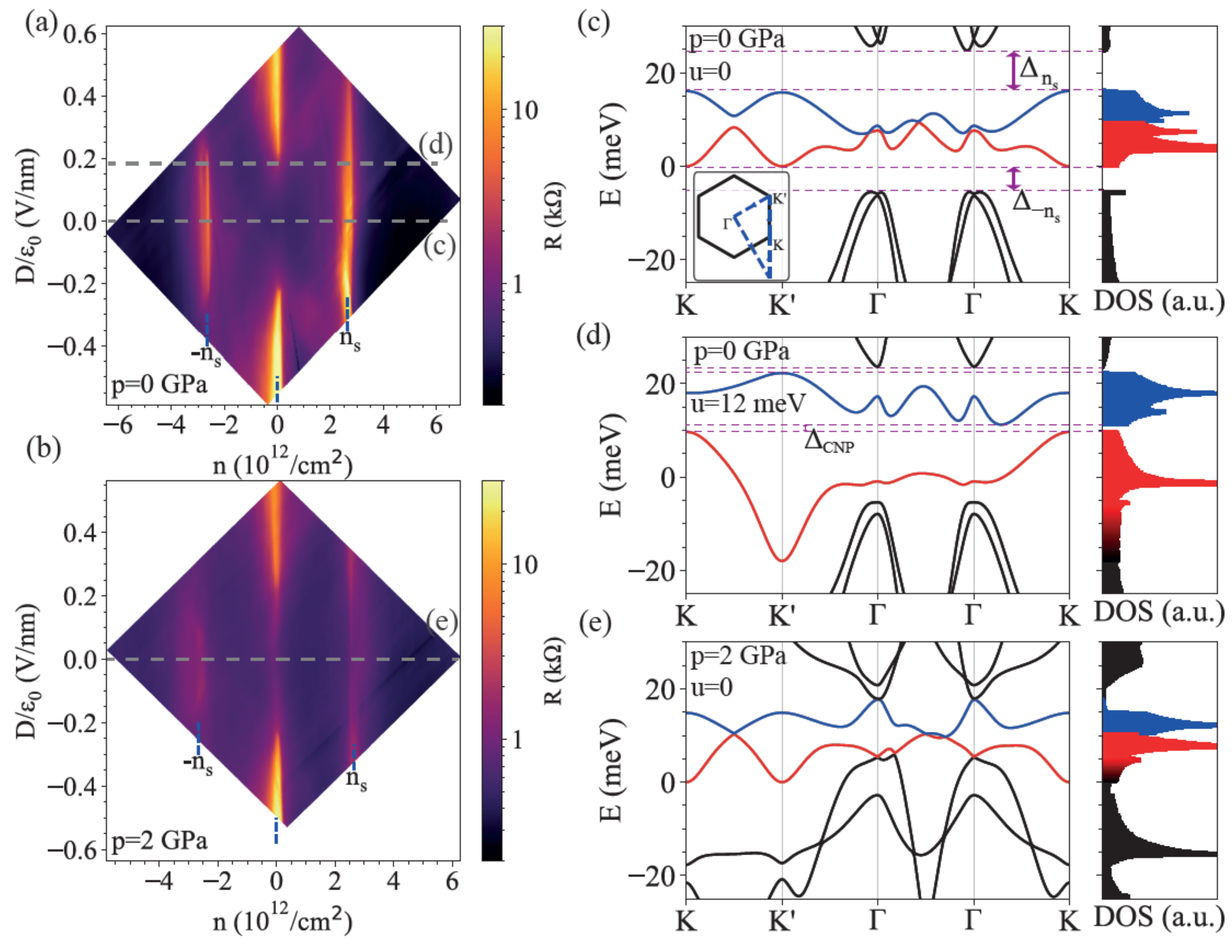
Boosting proximity spin–orbit coupling in graphene/WSe2 heterostructures

Van der Waals heterostructures composed of multiple few layer crystals allow the engineering of novel materials with predefined properties. As an example, coupling graphene weakly to materials with large spin–orbit coupling (SOC) allows to engineer a sizeable SOC in graphene via proximity effects.

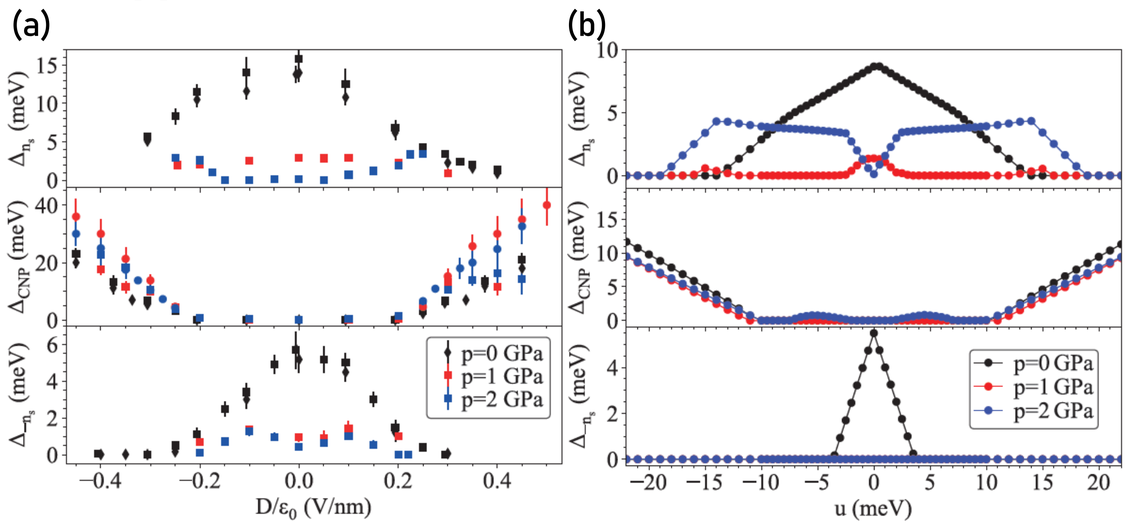


(a) Schematic side view of a hBN/graphene/WSe2 heterostructure in kerosene pressure transfer medium. Hydrostatic pressure reduces the distance d between the graphene and the WSe2 layers (among others), which leads to an enhancement of the proximity-induced SOC in graphene. (b) Simulated weak antilocalization curves using realistic parameters to demonstrate the potential effect of the application of ca. 2 GPa pressure on the heterostructure. The increased SOC leads to a more pronounced WAL peak in the magneto-conductivity curve. See Supplementary Note 1 for the simulation details. (c) Comparison of averaged $\Delta\sigma_{avg}(B)$ measurement curves for each pressure. Clear signature of the Weak Localization (WL)→Weak Anti-Localization (WAL) evolution is visible. Solid blue lines for B > 0: fits. [2]

Tailoring the band structure of twisted double bilayer graphene



(a) and (b) Four-probe resistance of the TDBG as a function of the charge density (n) and electric displacement field (D) measured in (a) at ambient pressure and in (b) at p = 2GPa. (c-e) Calculated band structure and DOS of the TDBG at ϑ = 1.067° twist angle, roughly corresponding to the dashed ines in panels (a) and (b). The flat bands are highlighted with red and blue colors. The spectra in (c) and (d) are calculated at ambient pressure for displacement fields D = 0 and D/ε_0 = 0.18 V/nm. The band structure in (e) is calculated for D = 0, p = 2GPa. [3]



(a) The measured gaps with respect to D. The different colors show the gaps at different pressures. The gaps obtained from different methods are shown with different markers: the squares and diamonds show gaps obtained from four-probe and two-probe thermal activation measurements, respectively, and the circles are gaps obtained from bias measurements. (b) Corresponding theoretically calculated single-particle gaps at three different pressures with respect to the on-site energy difference (u) of the layers. [3]

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