2D materials - from fundamentals to innovations

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Two-dimensional (2D) materials exhibit unique properties due to their atomically thin structure and weak van der Waals (vdW) coupling between layers. This vdW nature allows for the precise engineering of 2D quantum systems through stacking, twisting, hybrid integration and defect engineering. Those vdW stacks prepared from semiconducting, superconducting, magnetic, metallic or insulating layers can have properties individual layers or conventional 3D solids do not reveal. This includes but is not limited to (i) defect, strain or twist induced single photon emitter, (ii) twist-angle dependent moiré superstructure with periodic potential profiles and the formation of minibands hosting correlated quantum phases, and (iii) layer-dependent magnetic order with strong coupling between spin, charge and lattice degree of freedom. External stimuli, such as electric- or magnetic fields, strain, pressure and charge doping, enable in-situ control of these vdW systems. As such vdW materials are not only suitable for studying quantum phenomena and novel material for opto-/electronic applications but have also the potential to become building blocks for ultracompact opto-spintronic memories and neuromorphic hardware.

Following an introduction into the properties and promises of 2D materials and their heterostructures with special emphasize on the joint activities at the Institute of Physics, we focus on twisted transition metal dichalcogenides and layered magnetic semiconductors.

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