7th International Workshop on 2D Materials

Title of the Presentation: Symmetry engineering and bulk photovoltaic effect in WSe_2/black phosphorus heterostructure

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Abstract:

Symmetry plays a crucial role in condensed matter physics. In bulk crystals, symmetry is determined by the crystal structure, whereas symmetry of nano systems can be artificially controlled. For instance, bulk crystal of 2H type transition metal dichalcogenide (TMDC) has the inversion symmetry, but it is well known that once it is exfoliated to the monolayer form, the inversion symmetry is broken, resulting in peculiar optical and transport properties, which give rise to the concept of valleytronics [1]. Another recent example is the TMDC nanotubes. When TMDC is rolled into a tubular structure, the tube becomes chiral and polar, despite the nonpolar nature of two-dimensional (2D) TMDCs. As a result, we have observed a relatively large bulk photovoltaic effect, which is missing in nonpolar carbon nanotubes [2]. These examples exhibit that the linear (former) and nonlinear (latter) properties can be controlled by the artificial manipulation of structural symmetry in nanostructures. In other words, nanomaterials are a fruitful platform of symmetry engineering, which might bring about novel functionalities [3].

In this presentation, we report symmetry engineering in van der Waals heterostructures. Specifically, we focus on the emergence of in-plane polar structure at the heterointerfaces of nonpolar 2D materials. The combination we have chosen is the monolayer WSe_2 and multilayer black phosphorus. Both materials are nonpolar, but polarization is created in their heterointerface. The emergence of polarity is intuitively understood as breaking rotational symmetry by combination of two lattice with three-fold and two-fold rotational symmetry. The polarity was probed by the observation of bulk photovoltaic effect [4]. Interestingly, the polar direction is rotated by twisting the alignment angle between WSe_2 and black phosphorus. We will explain detailed experimental results in the talk.

[1] J. R. Schaibrey, *et al., Nat. Rev. Mater*. **1**, 160555 (2016).
[2] Y. J. Zhang, *et al.*, *Nature.* **570**, 349 (2019).
[3] T. Ideue and Y. Iwasa, *Annu. Rev. Condens. Matter Phys*., in press.
[4] T. Akamatsu, *et al*., submitted for publication.