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【661】Topological electronic phases in graphene nanoribbons

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Among graphene related materials, graphene nanoribbons (GNRs) –narrow stripes of graphene –have emerged as promising building blocks for nanoelectronic devices. The lateral confinement in GNRs opens a bandgap that sensitively depends on the ribbon width, allowing in principle for the design of GNR-based structures with tunable properties. However, structuring with atomic precision is required to avoid detrimental effects induced by edge irregularities. A recently developed bottom-up fabrication route [1] allows for the required atomically precise synthesis of GNRs with different shapes and edge structures [2] as well as heterojunctions between dissimilar ribbon segments (e.g. doped/undoped [3], different widths [4]). In this presentation, the emergence of junction states at such hetero-interfaces will be discussed from a conceptual as well as experimental point of view.
Based on a topological classification of GNRs, S. Louie and coworkers have very recently predicted that topological junction states develop whenever two joining GNR segments belong to different topological classes [5]. I will discuss a first experimental realization of such situation, at the example of GNR quantum dot (GQD) heterostructures formed by cross-dehydrogenative coupling of armchair GNRs of width N = 7 (7-AGNRs) [4]. The so-formed intraribbon quantum dots reveal deterministically defined, atomically sharp interfaces between wide and narrow AGNR segments and host a pair of low-lying interface states. Scanning tunneling microscopy/spectroscopy measurements complemented by extensive simulations reveal that their energy splitting depends exponentially on the length of the central narrow bandgap segment. This allows tuning of the fundamental gap of the GQDs over one order of magnitude within a few nanometers length range.
Even more intriguing topological properties are predicted for a family of zigzag edge-extended AGNRs, of which we have synthesized and characterized a first member in some detail. I will show that variations of the AGNR backbone width and the zigzag edge segment spacing drive this family of GNR structures into trivial, metallic and topological insulating phases [6].

[1] J. Cai et al., Nature 466, 470 (2010).
[2] L. Talirz, P. Ruffieux, and R. Fasel, Adv. Mater. 28, 6222 (2016).
[3] J. Cai et al., Nature Nanotech. 9, 896 (2014).
[4] S. Wang et al., Nano Lett., in press (2017).
[5] T. Cao, F. Zhao, S. G. Louie, Topological Phases in Graphene Nanoribbons: Junction States, Spin Centers and Quantum Spin Chains; https://arxiv.org/abs/1702.02674.
[6] O. Gröning, S. Wang et al., in preparation.

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