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Phase Diagram and Crossover Phases of Topologically Ordered Graphene Zigzag Nanoribbons

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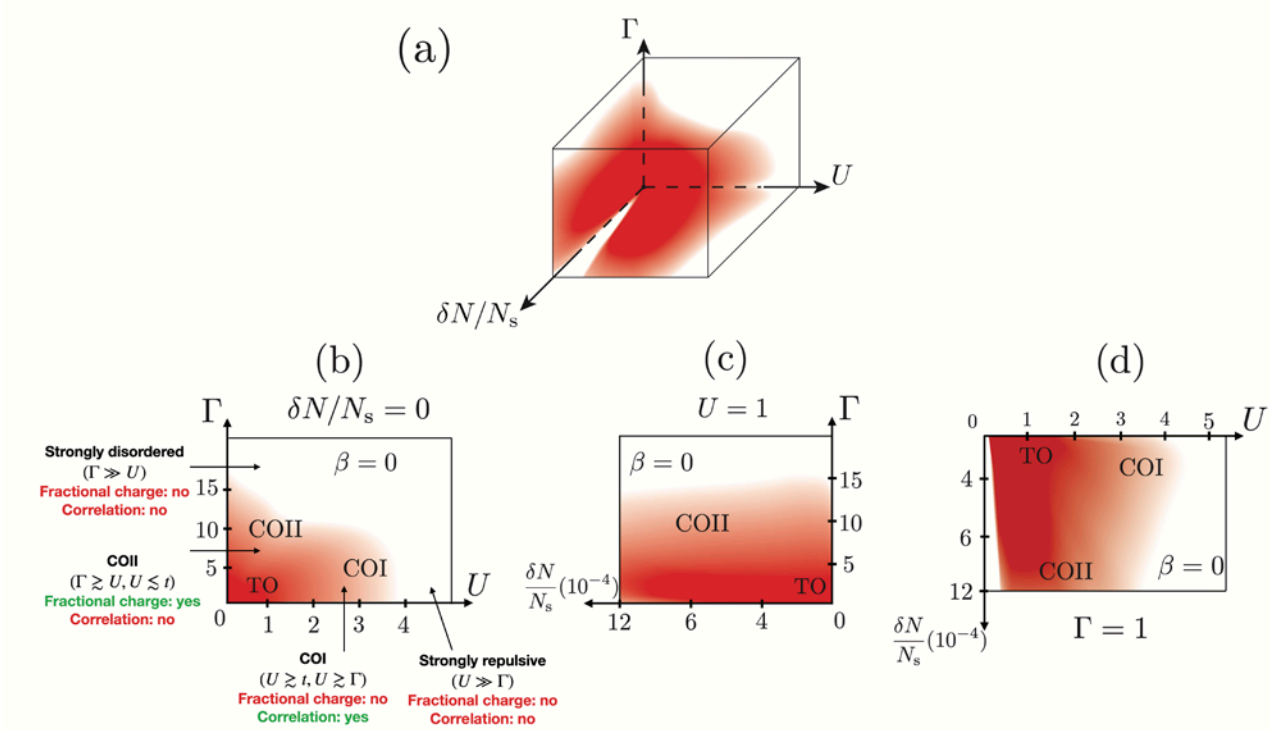
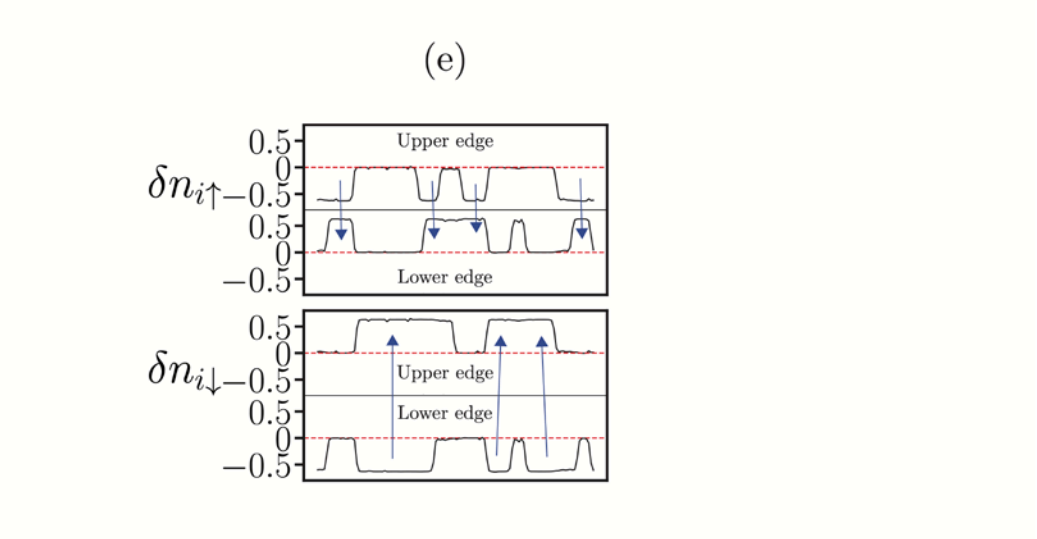
Topological order is a new phase of matter that goes beyond Landau symmetry-breaking theory [1]. Recent studies [2–4] show that disordered interacting zigzag graphene nanoribbons (ZGNRs) are topologically ordered Mott-Anderson insulators, displaying anyonic fractional charges residing on the opposite zigzag edges and a non-zero value of topological entanglement entropy (TEE). The topological order of ZGNRs results from interplay between topology of lattice, electron interaction and disorder. The prospects of experimental investigation of topologically ordered ZGNRs are excellent as fabrication of atomically precise graphene nanoribbons has become possible [5]. In this study, we construct, by computing the TEE, the phase diagram of ZGNRs as a function of on-site repulsion, doping concentration and disorder strength, see Fig. 1. We show that competition between disorder and on-site repulsion leads to nontrivial destruction of topological order, forming crossover phases. In crossover phase I (COI), there is no fractional charge and spin-charge separation, yet there exists charge transfer correlations between the zigzag edges (see Fig.1 (e)). Meanwhile in the other crossover phase (COII), fractional charges exist but no correlations between the opposite zigzag edges are found. The physical properties of these crossover phases as well as two non-topological phases, strongly disordered and strongly repulsive phases, are delineated. We also demonstrate that the obtained phase diagram is identical to that obtained by analyzing fractional charges and non-local correlations between the opposite zigzag edges.

FIG. 1. (a) Schematic phase diagram of ZGNRs as a function of on-site repulsion U, doping $\delta N/N_s$ and disorder strength Γ (δN and N_s are, respectively, the number of doped electrons and the number of carbon atoms). (b), (c), (d) are projections of the phase diagram onto 2D planes. Topologically ordered (TO) phase is represented by red color and crossover phases (COI and COII) are represented by degraded color. In the TO phase, the TEE has a universal value while in the COI and COII phases, the TEE is non-universal with large variances. (e) Disorder induced change of edge occupation numbers of spin σ, $\delta n_{i\sigma}$, is entirely transferred to the opposite edge in the the COI phase. Thus non-local charge correlations between upper and lower zigzag edges are present in the COI phase.

[1] X.-G. Wen, Rev. Mod. Phys. 89, 041004 (2017).
[2] S.-R. Eric Yang, Topologically Ordered Zigzag Nanoribbon: e/2 Fractionally Charged Anyons and Spin-Charge Separation
(World Scientific, 2023, (This is a graduate textbook)).
[3] Y. H. Kim, H. J. Lee, H.-Y. Lee, and S.-R. Eric Yang, Scientific Reports 12, 14551 (2022).
[4] A. Kitaev and J. Preskill, Phys. Rev. Lett. 96, 110404 (2006).
[5] M. Kolmer et al., Science 369, 571 (2020).





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