2N-rule: Searching topological phases and robust edge modes in carbon nanotubes

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Carbon nanotubes (CNTs) can be generally classified to two phases, metal or insulator, depending on their tube indexes. So far, the insulating CNTs are considered identical apart for some quantitative gap difference. However, here we show that the insulating phases may be topologically non-equivalent. We theoretically report an explicit and robust scheme, 2N-rule, for systematically searching topological phases in CNTs of all diameters. By investigating the topological Zak phase based on both analytical model and first-principles approaches, such a 2N-rule of insulating CNT(n,0) is generally established: when n = 2N where N is an integer, it is a topological insulator; otherwise, it is a normal insulator. For finite-length topological CNTs, topologically protected quantum modes naturally occur at the tube ends, which hold significant robustness against external environment perturbations, taking advantage over fragile edge states in conventional systems.

REFERENCES

[1] Chen Hu and Hong Guo, Applied Physics Letters, 117 (2020) 083101

FIGURES

CNT$(n,0)$	⋯	7	8	9	10	11	12	13	14	15	16	17	⋯
Phase	⋯	NI	TI	M	TI	NI	M	NI	TI	M	TI	NI	⋯

Figure 1: Complete phase table of CNT(n,0). Green, red, and blue regions denote the metal (M), topological insulator (TI), and normal insulator (NI), respectively