Paper Title

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abstract

High-T_c superconductors have higher superconducting transition temperature and larger pairing gap in comparison with conventional superconductors. It is natural to make use of high-T_c superconductors to obtain effective topological superconductors (TSC) [1–3]. Very recently, much attention has been paid on the realization of the high order TSC state[4–30]. A two-dimensional (2D) high-order TSC is fully gapped at the one-dimensional edges, while hosts Majorana bound states at the corners. Recently many efforts have been made to realize Majorana corner states in 2D system with the high-T_c superconducting based heterostructures [9–19].

In a heterostructure system including a superconducting layer and a non-superconducting layer, the superconductivity will be induced to the non-superconducting layer, known as the proximity effect. Previously, when studying the high order topology, the proximity effect was usually phenomenologically considered with adding the effective pairing term to a non-superconducting system directly. While actually, for a hybrid system, a more microscopic model should include the original Hamiltonian describing different materials and consider their coupling [31–35]. The effective pairing term in the non-superconducting material is induced by the tunneling of the systems[36]. Previously, such microscopic model is indeed considered in some topological systems. Theoretically the induced pairing symmetry is not necessarily identical to the original one of the superconductor[33, 37, 38]. Moreover, some interesting properties emerge due to the mixing of the band structures[39]. Therefore, now it is timely and of importance to consider a microscopic model when studying the high order topology in a heterostructure system,

[1] N. Hao and J. Hu, Topological quantum states of matter in iron-based superconductors: from concept to material realization, National Science Review **6**, 213 (2018).
[2] X.-L. Qi and S.-C. Zhang, Topological insulators and superconductors, Rev. Mod. Phys. **83**, 1057 (2011).
[3] P. Zareapour, A. Hayat, S. Y. F. Zhao, M. Kreshchuk, A. Jain, D. C. Kwok, N. Lee, S.-W. Cheong, Z. Xu, A. Yang, G. D. Gu, S. Jia, R. J. Cava, and K. S. Burch, Proximity-induced high-temperature superconductivity in the topological insulators Bi_2Se_3 and Bi_2Te_3, Nat. Commun. **3**, 1056 (2012).
[4] W. A. Benalcazar, B. A. Bernevig, and T. L. Hughes, Electric multipole moments, topological multipole moment pumping, and chiral hinge states in crystalline insulators, Phys. Rev. B **96**, 245115 (2017).
[5] F. Schindler, A. M. Cook, M. G. Vergniory, Z. Wang, S. S. P. Parkin, B. A. Bernevig, and T. Neupert, Higher-order topological insulators, Science Advances **4**, 10.1126/sciadv.aat0346 (2018).
[6] E. Khalaf, Higher-order topological insulators and superconductors protected by inversion symmetry, Phys. Rev. B **97**, 205136 (2018).
[7] Z. Yan, Higher-order topological odd-parity superconductors, Phys. Rev. Lett. **123**, 177001 (2019).
[8] Z. Wu, Z. Yan, and W. Huang, Higher-order topological superconductivity: Possible realization in fermi gases and Sr_2RuO_4, Phys. Rev. B **99**, 020508 (2019).
[9] R. X. Zhang, W. S. Cole, X. Wu, and S. Das Sarma, Higher-order topology and nodal topological superconductivity in Fe(Se,Te) heterostructures, Phys. Rev. Lett. **123**, 167001 (2019).
[10] Z. Yan, F. Song, and Z. Wang, Majorana corner modes in a high-temperature platform, Phys. Rev. Lett. **121**, 096803 (2018).
[11] Q. Wang, C. C. Liu, Y. M. Lu, and F. Zhang, High-Temperature Majorana corner states, Phys. Rev. Lett. **121**, 186801 (2018).
[12] Z. Yan, Majorana corner and hinge modes in second-order topological insulator/superconductor heterostructures, Phys. Rev. B **100**, 205406 (2019).
[13] T. Liu, J. J. He, and F. Nori, Majorana corner states in a two-dimensional magnetic topological insulator on a high-temperature superconductor, Phys. Rev. B **98**, 245413 (2018).
[14] R.-X. Zhang, W. S. Cole, and S. Das Sarma, Helical hinge Majorana modes in iron-based superconductors, Phys. Rev. Lett. **122**, 187001 (2019).
[15] X. Wu, X. Liu, R. Thomale, and C.-X. Liu, High-T_c superconductor Fe(Se,Te) monolayer: an intrinsic, scalable and electrically-tunable Majorana platform (2019), arXiv:1905.10648.
[16] C.-H. Hsu, P. Stano, J. Klinovaja, and D. Loss, Majorana Kramers pairs in higher-order topological insulators,

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Phys. Rev. Lett. **121**, 196801 (2018).
[17] X. Zhu, Second-order topological superconductors with mixed pairing, Phys. Rev. Lett. **122**, 236401 (2019).
[18] M. Kheirkhah, Y. Nagai, C. Chen, and F. Marsiglio, Majorana corner flat bands in two-dimensional second-order topological superconductors, Phys. Rev. B **101**, 104502 (2020).
[19] M. Kheirkhah, Z. Yan, Y. Nagai, and F. Marsiglio, First- and second-order topological superconductivity and temperature-driven topological phase transitions in the extended hubbard model with spin-orbit coupling, Phys. Rev. Lett. **125**, 017001 (2020).
[20] C. H. Hsu, P. Stano, J. Klinovaja, and D. Loss, Majorana Kramers pairs in higher-order topological insulators, Phys. Rev. Lett. **121**, 196801 (2018).
[21] J. Langbehn, Y. Peng, L. Trifunovic, F. von Oppen, and P. W. Brouwer, Reflection-symmetric second-order topological insulators and superconductors, Phys. Rev. Lett. **119**, 246401 (2017).
[22] W. A. Benalcazar, B. A. Bernevig, and T. L. Hughes, Quantized electric multipole insulators, Science **357**, 61 (2017).
[23] Y. Wang, M. Lin, and T. L. Hughes, Weak-pairing higher order topological superconductors, Phys. Rev. B **98**, 165144 (2018).
[24] J. Ahn and B.-J. Yang, Higher-order topological superconductivity of spin-polarized fermions, Phys. Rev. Research **2**, 012060 (2020).
[25] Y. Volpez, D. Loss, and J. Klinovaja, Second-order topological superconductivity in π-junction layers, Phys. Rev. Lett. **122**, 126402 (2019).
[26] S. A. A. Ghorashi, X. Hu, T. L. Hughes, and E. Rossi, Second-order dirac superconductors and magnetic field induced Majorana hinge modes, Phys. Rev. B **100**, 020509 (2019).
[27] C. Zeng, T. D. Stanescu, C. Zhang, V. W. Scarola, and S. Tewari, Majorana corner modes with solitons in an attractive Hubbard-Hofstadter model of cold atom optical lattices, Phys. Rev. Lett. **123**, 060402 (2019).
[28] X.-H. Pan, K.-J. Yang, L. Chen, G. Xu, C.-X. Liu, and X. Liu, Lattice-symmetry-assisted second-order topological superconductors and Majorana patterns, Phys. Rev. Lett. **123**, 156801 (2019).
[29] S. Franca, D. V. Efremov, and I. C. Fulga, Phase-tunable second-order topological superconductor, Phys. Rev. B **100**, 075415 (2019).
[30] R.-X. Zhang, J. D. Sau, and S. D. Sarma, Kitaev building-block construction for higher-order topological superconductors (2020), arXiv:2003.02559.
[31] T. D. Stanescu, J. D. Sau, R. M. Lutchyn, and S. Das Sarma, Proximity effect at the superconductor–topological insulator interface, Phys. Rev. B **81**, 241310 (2010).
[32] F. Parhizgar and A. M. Black-Schaffer, Unconventional proximity-induced superconductivity in bilayer systems, Phys. Rev. B **90**, 184517 (2014).
[33] W.-J. Li, S.-P. Chao, and T.-K. Lee, Theoretical study of large proximity-induced s-wave-like pairing from a d-wave superconductor, Phys. Rev. B **93**, 035140 (2016).
[34] A. M. Black-Schaffer and A. V. Balatsky, Proximity-induced unconventional superconductivity in topological insulators, Phys. Rev. B **87**, 220506 (2013).
[35] A. M. Black-Schaffer and A. V. Balatsky, Odd-frequency superconducting pairing in topological insulators, Phys. Rev. B **86**, 144506 (2012).
[36] W. L. McMillan, Tunneling model of the superconducting proximity effect, Phys. Rev. **175**, 537 (1968).
[37] Z.-X. Li, C. Chan, and H. Yao, Realizing Majorana zero modes by proximity effect between topological insulators and d-wave high-temperature superconductors, Phys. Rev. B **91**, 235143 (2015).
[38] X. Lu and D. Sénéchal, Proximity effect in a heterostructure of a high-T_c superconductor with a topological insulator from dynamical mean field theory, Phys. Rev. B **101**, 054512 (2020).
[39] M. Khezerlou and H. Goudarzi, Mass-like gap creation by mixed singlet and triplet state in superconducting topological insulator (2019), arXiv:1903.01144.