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Quantum Oscillations in Topological Insulator Bi_2Te_2Se Microwires Contacted with Superconducting In_2Bi Leads

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Abstract

We studied the magnetoresistance (MR) of polycrystal Bi_2Te_2Se topological insulator (TI) microwires contacted with superconducting In2Bi leads. Bi_2Te_2Se has a simple band structure with a single Dirac cone on the surface and a large non-trivial bulk gap of 300 meV. To study the TI/SC interface, the Bi_2Te_2Se glass-coated microwire with a diameter of d = 17 μm was connected to copper leads on one side using superconducting alloy In_2Bi (Tc = 5.6 K), and on the other side using gallium. The topologically nontrivial 3D superconductor (SC) In2Bi has proximity-induced superconductivity of topological surface states. To eliminate conventional contribution to superconductivity from the bulk, the resulting edge states of the TI/SC contact area were studied in magnetic fields above H_{c2} in In_2Bi. The *h/2e* oscillations of magnetoresistance (MR) in longitudinal and transverse magnetic fields (up to 1 T) at the TI/SC interface were observed at various temperatures (4.2 k–1.5 K). To explain the observed oscillations, we used magnetic flux quantization, which requires a multiply connected geometry where flux can penetrate into normal regions surrounded by a superconductor. The effective width of the closed superconducting area of the TI/SC interface is determined to be 15 nm from an analysis of FFT spectra and the beats of the MR oscillations for two different directions of magnetic field.

Keywords: topological insulators, superconductivity, thin microwires, proximity effect, magnetoresistance, oscillations of magnetoresistance

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References

1. Zhang, Y., Liu, C., Qi, X., et al.: Topological insulators in Bi2Se3, Bi2Te3 and Sb2Te3 with a single Dirac cone on the surface. Nat. Phys. **5**, 438–442 (2009). https://doi.org/10.1038/nphys1270
2. Hasan, M.Z.,Kane, C.L.: Colloquium: topological insulators.Rev.Mod. Phys. **82**, 3045–3067 (2010). https://doi.org/10.1103/RevModPhys.82.3045
3. Schmid, C.P., Weigl, L., Grössing, P., et al.: Tunable non-integer high-harmonic generation in a topological insulator. Nature **593**, 385–390 (2021). https://doi.org/10.1038/s41586-021-03466-7
4. Schmitt, T.W., Connolly, M.R., Schleenvoigt, M., et al.: Integration of topological insulator Josephson junctions in superconducting qubit circuits. Nano Lett. **22**, 2595–2602 (2022). https://doi.org/10.1021/acs.nanolett.1c04055
5. He, M., Sun, H., He, Q.L.: Topological insulator: spintronics and quantum computations. Front. Phys. **14**(4), 1–16 (2019). https://doi.org/10.1007/s11467-019-0893-4
6. DiSalvo, F.J.: Thermoelectric cooling and power generation. Science **285**(5428), 703–706 (1999). https://doi.org/10.1126/science.285.5428.703
7. Hong, M., Chen, Z., Zou, J.: Fundamental and progress of Bi2Te3-based thermoelectric materials. Chinese Phys. B **27**, 048403 (2018). https://doi.org/10.1088/1674-1056/27/4/048403
8. Wang, G., Zhu, X., Sun, Y., et al.: Topological insulator thin films of Bi2Te3 with controlled electronic structure. Adv. Mater. **23**, 2929–2932 (2011). https://doi.org/10.1002/adma.201100678
9. Tian, M., Ning, W., Qu, Z., et al.: Dual evidence of surface Dirac states in thin cylindrical topological insulator Bi2Te3 nanowires. Sci. Rep. **3**, 1212 (2013). https://doi.org/10.1038/srep01212
10. Peng, H., Lai, K., Kong, D., et al.: Aharonov-Bohm interference in topological insulator nanoribbons. Nature Mater. **9**, 225–229 (2010). https://doi.org/10.1038/nmat2609
11. Alicea, J.: New directions in the pursuit of Majorana fermions in solid state systems. Rep. Prog. Phys. **75**, 076501 (2012). https://doi.org/10.1088/0034-4885/75/7/076501
12. Mourik, V., Zuo, K., Frolov, S.M., et al.: Signatures of Majorana fermions in hybrid superconductor-semiconductor nanowire devices. Science **336**(6084), 1003–1007 (2012). https://doi.org/10.1126/science.1222360
13. Cook, A., Franz, M.: Majorana fermions in a topological-insulator nanowire proximitycoupled to an s-wave superconductor. Phys. Rev. B **84**, 201105(R) (2011). https://doi.org/10.1103/PhysRevB.84.201105

14. Xu, J., Wang, M., Liu, Z., et al.: Experimental detection of a Majorana mode in the core of a magnetic vortex inside a topological insulator-superconductorBi2Te3/NbSe2 heterostructure. Phys. Rev. Lett. **114**, 017001 (2015). https://doi.org/10.1103/PhysRevLett.114.017001

15. Konopko, L.A., Nikolaeva, A.A., Huber, T.E., Meglei, D.F.: Thermoelectric properties of Bi2Te3 microwires. Phys. Status Solidi C **11**, 1377–1381 (2014). https://doi.org/10.1002/pssc.201300202

16. Jones, R., Ittner, W.: Superconductivity of In2Bi. Phys. Rev. **113**, 1520 (1959). https://doi.org/10.1103/PhysRev.113.1520

17. Mori,K., Saito,Y., Sato,K.: Resistivity saturation of superconducting intermetallic compound In2 Bi. Physica B+C 107, 477 (1981). https://doi.org/10.1016/0378-4363(81)90542-8

18. Lin, P., Gandhi,A.,Wu, S.: Size effect of strong-coupled superconducting In2Bi nanoparticles: an investigation of short-range electron phonon coupling. J. Appl. Phys. **117**, 17E316 (2015). https://doi.org/10.1063/1.4916106

19. Kuang, W., Lopez-Polin, G., Lee, H., et al.: Magnetization signature of topological surface states in a non-symmorphic superconductor. Adv. Mater. **33**, 2103257 (2021). https://doi.org/10.1002/adma.202103257

20. Konopko, L.A., Nikolaeva, A.A., Huber, T.E., et al.: Magnetoresistance oscillations in topological insulator microwires contacted with normal and superconducting leads. Physica B Condens. Matter **536**, 259–261 (2018). https://doi.org/10.1016/j.physb.2017.09.082