P-3-1 (Invited)

Extended Abstracts of the 2014 International Conference on Solid State Devices and Materials, Tsukuba, 2014, pp1034-1035

Signatures of Majorana Fermions in Topological Superconductor Nanowires

Hongqi Xu[1,2]

[1] Lund University
Division of Solid State Physics,
Box 118, S-22100 Lund, Sweden
Phone: +46-46-2227759; E-mail: hongqi.xu@ftf.lth.se
[2] Peking University
Key Laboratory for the Physics and Chemistry of Nanodevices and Department of Electronics,
Beijing 100871, China
Phone: +86-10-62751761; E-mail: hqxu@pku.edu.cn

Abstract

The search for Majorana Fermions [1] in solid state systems is one of paramount research tasks in physics today [2–5]. Here we report on experimental observations of the signatures of Majorana fermions in topological superconductor nanowire quantum devices made from high crystal-quality InSb nanowires and superconductor Nb contacts.

1. Introduction

Majorana fermions are an elusive class of fermions that are their own antiparticles. Although an extensive effort has been made worldwide in particle physics, Majorana fermions have so far not been convincingly discovered in free space. In recent years, numerous proposals for probing Majorana fermions in solid state systems have been suggested. The most recent ones are to explore a topological superconductor phase of a strong spin−orbit coupled semiconductor nanowire in the proximity of an s-wave superconductor. These proposals have stimulated a new wave of searches for Majorana fermions in solid state systems. Here we report on experimental observations of the signatures of Majorana fermions in topological superconductor nanowire quantum devices made from high crystal-quality InSb nanowires and superconductor Nb contacts.

2. Experiment and Results

The InSb nanowires are known to have excellent physical properties [6-8] and have therefore been considered as one of the most promising material systems for realizing topological superconductor nanowire systems in which Majorana fermions can be created. In a fabricated device, an InSb nanowire quantum dot is formed between the two Nb contacts by Schottky barriers. Due to the proximity effect, the InSb nanowire segments covered by superconductor Nb contacts turn to superconductors with a superconducting energy gap Δ^* [9]. Under an applied magnetic field larger than a critical value for which the Zeeman energy in the InSb nanowire is $E_z \sim \Delta^*$, the entire InSb nanowire is found to be in a nontrivial topological superconductor phase, supporting a pair of Majorana fermions, and Cooper pairs can transport between the superconductor Nb contacts via the Majorana fermion states. This transport process will be suppressed when the applied magnetic field becomes larger than a second critical value at which the transition to a trivial topological superconductor phase occurs in the system. This physical scenario has been observed in our experiment [9,10]. We have also found that the measured zero-bias conductance for our hybrid devices shows a conductance plateau in a range of applied magnetic fields in quasi-particle Coulomb blockade regions [9] and that the zero-bias conductance peak is present in many consecutive Coulomb diamonds, irrespective of the even-odd parity of the quasi-particle occupation number in the quantum dots [10]. Our work provides a solid evidence of detecting Majorana fermions in solid state systems and should greatly stimulate Majorana fermion research and applications.

Acknowledgements

The author acknowledges collaborations with Mingtang Deng, Chunlin Yu, Guangyao Huang, Marcus Larsson, and Philippe Caroff for this work.

References

[1] E. Majorana, Teoria simmetrica dell'elettronee del positrone. NUOVO CIMENTO 14, 171-184 (1937).
[2] F.Wilczek, Majorana Returns. Nature Phys. 5, 614-618 (2009).
[3] M. Franz, Race for Majorana Fermions, Physics 3, 24 (2010).
[4] Service, R. F. Search for Majorana Fermions nearing success at last? Science 332, 193-195 (2011).
[5] Alicea, J. New directions in the pursuit of Majorana Fermions in solid state systems. Rep. Prog. Phys. 75, 076501 (2012).
[6] H. A. Nilsson, P. Caroff, C. Thelander, M. Larsson, J. B. Wagner, L.-E. Wernersson, L. Samuelson, and H. Q. Xu. Nano Lett. 9, 3151–3156 (2009).
[7] H. A. Nilsson, O. Karlström, M. Larsson, P. Caroff, J. N. Pedersen, L. Samuelson, A. Wacker, L.-E. Wernersson, and H. Q. Xu. Phys. Rev. Lett. 104, 186804 (2010).
[8] H. A. Nilsson, P. Samuelsson, P. Caroff, and H. Q. Xu, Nano Lett.12, 228-233 (2012).
[9] M. T. Deng, C. L. Yu, G. Y. Huang, M. Larsson, P. Caroff, and H. Q. Xu, Nano Lett. 12, 6414−6419 (2012); arXiv: 1204.4130 (2012).
[10]M. T. Deng, C. L. Yu, G. Y. Huang, M. Larsson, P. Caroff, and H. Q. Xu, arXiv:1406.4435 (2014).