第 112 回トポロジカル物質科学セミナー
Topological Materials Science Seminar (112)

Geometrically tunable platforms for spin-orbitronics and superconducting spintronics

Paola Gentile

CNR-SPIN, c/o Università di Salerno, Fisciano (SA), 84084 Italy

Date: **January 15 (Wednesday), 2020**

Time: **13:00-14:30**

Place: **Room 401, Department of Physics, Kyoto University**

Abstract: Low-dimensional semiconducting nanomaterials have proven to be an ideal playground for the generation and manipulation of topological quantum states, which are at present at the centre of an intensive investigation. Apart from the conventional geometries, the most recent advances in nanotechnology have demonstrated the possibility to create flexible semiconductor nanomaterials which are bent into curved, deformable objects ranging from semiconductor nanotubes, to nanohelices, etc. Motivated by the excitement in both topological states of matter and novel shape deformed nanostructures, we have explored the impact that nanoscale geometry [1] has on electronic, topological and superconducting properties of low-dimensional materials, showing the possibility to exploit the interplay between geometry, Rashba spin-obit coupling (RSOC) and superconductivity as a tool for the realization of novel platforms for spintronics and superconducting spintronics. By considering the paradigmatic example of quantum wires with RSOC, which are periodically corrugated at the nanometer scale, we show that geometric effects in low-dimensional nanomaterials can lead to metal-insulator transition and promote the generation of insulating and semimetallic topological phases of matter [2,3]. Relevantly, semiconducting nanowires with such a serpentine shape, under the application of a rotating magnetic field, can realize the Thouless topological pumping protocol in an entirely novel fashion [4]. We also found that, through a suitable geometric design, it is possible to reach an independent tuning of spin transport and charge transport characteristics in metallic nanochannels [5], a holonomic manipulation of the spin-orbital degenerate states of the Kramers doublet in narrow semiconducting channels with RSOC [6], as well as the control of quantum geometric

Host: Youichi Yanase [Kyoto Univ. / Solicitation Project D02]
（075-753-3771, yanase@scphys.kyoto-u.ac.jp）

phases in deformed quantum rings, with an interesting potential deployment for the design of new spin interferometers [7].
In the presence of superconductivity, the interplay between RSOC and shape deformations can lead to novel paths for an all-geometric manipulation of the superconducting state, both for spin-singlet and spin-triplet quantum configurations [8], as well as of the supercurrent in weak links between Rashba coupled superconducting nanowires with geometric misalignment [9] or non-trivial geometric curvature [10]. All these findings lead to a conceptual departure in the different fields of spintronics, topological states of matter, and superconductivity by successfully demonstrating that the curved geometry of a nanosystem can be used as an effective knob to trigger unique electronic and transport phenomena.

[Acknowledgements: EU-FET OPEN project “CNTQC”, grant agreement N. 618083 (http://www.nano2qc.eu/)]

References

[1] P. G., M. Cuoco, C. Ortix, SPIN, Vol. 3, No. 2, 1340002 (2013).
[2] P. Gentile, M. Cuoco, C. Ortix, Physical Review Letters 115, 256801 (2015).
[3] P. Gentile, V. Benvenuto, C. Ortix, C. Noce and M. Cuoco, Condens. Matter 4 (1), 25 (2019).
[4] S. Pandey, N. Scopigno, P. Gentile, M. Cuoco, C. Ortix, , Physical Review B 97, 241103(R) (2018).
[5] K. S. Das, D. Makarov, P. Gentile, M. Cuoco, B. J. van Wees, C. Ortix, I. J. Vera-Marun, Nano Letters 19, 6839 (2019).
[6] G. Francica, P. Gentile, M. Cuoco, Europhysics Letters 127, 30001 (2019)
[7] Z.-J. Ying, P. Gentile, C. Ortix, M. Cuoco, Physical Review B 94, 081406(R) (2016).
[8] Z.-J. Ying, M. Cuoco, C. Ortix, P. Gentile, Physical Review B 96, 100506(R) (2017).
[9] Z.-J. Ying, M. Cuoco, P. Gentile, C. Ortix, 2017 16th International Superconductive Electronics Conference (ISEC), IEEE Xplore (2018).
[10] G. Francica, M. Cuoco, P. Gentile, arXiv:1912.03279