MAR16-2015-006544

Abstract for an Invited Paper
for the MAR16 Meeting of
the American Physical Society

The road to superconducting spintronics[1]

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Energy efficient computing has become a major challenge, with the increasing importance of large data centres across the world, which already today have a power consumption comparable to that of Spain, with steeply increasing trend. Superconducting computing is progressively becoming an alternative for large-scale applications, with the costs for cooling being largely outweighed by the gain in energy efficiency. The combination of superconductivity and spintronics - "superspintronics" - has the potential and flexibility to develop into such a green technology. This young field is based on the observation that new phenomena emerge at interfaces between superconducting and other, competing, phases. The past 15 years have seen a series of pivotal predictions and experimental discoveries relating to the interplay between superconductivity and ferromagnetism. The building blocks of superspintronics are equal-spin Cooper pairs, which are generated at the interface between superconducting and a ferromagnetic materials in the presence of non-collinear magnetism. Such novel, spin-polarised Cooper pairs carry spin-supercurrents in ferromagnets and thus contribute to spin-transport and spin-control. Geometric Berry phases appear during the singlet-triplet conversion process in structures with non-coplanar magnetisation, enhancing functionality of devices, and non-locality introduced by superconducting order leads to long-range effects. With the successful generation and control of equal-spin Cooper pairs the hitherto notorious incompatibility of superconductivity and ferromagnetism has been not only overcome, but turned synergistic. I will discuss these developments and their extraordinary potential. I also will present open questions posed by recent experiments and point out implications for theory.

[1]This work is supported by the Engineering and Physical Science Research Council (EPSRC Grant No. EP/J010618/1).