Spin-orbit effects in ferroelectrics - electric control of spins in non-magnetic semiconductors

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Technological advances in future electronics and the design of next-generation devices strongly rely on the investigation of quantum degrees of freedom of electrons beside electron charge. Electron spin represents the most-studied case due to its obvious connection with magnetic information storage and to the possibility to design spintronic devices based on spin-splitting phenomena and spin-polarized transport[1]. Intrinsic spin-orbit interaction (SOI), which allows for spin-dependent electronic structures even in the absence of long-range magnetic ordering, lies at the origin of a rich variety of interesting phenomena in solid state physics, ranging from topological quantum phases of matter to Rashba- or Dresselhaus-like spin splitting effects. The latter phenomena, which in principle allow for an all-electric control of electron spins mediated by the SOI-induced spin-momentum locking, appear as a consequence of inversion-symmetry breaking. After reviewing spin-splitting effects and the recently proposed unified classification of spin polarization in nonmagnetic bulk materials[2], I will focus on ferroelectrics, a subclass of noncentrosymmetric materials which display, below a certain critical temperature, a long-range dipolar order with a permanent electric polarization switchable by an electric field. As such, they ideally offer intriguing perspectives to control and manipulate the spin polarization in a non-volatile fashion by acting on the ferroelectric switching[3]. By means of ab-initio Density Functional Theory complemented with effective models, I will discuss several types of mechanisms where ferroelectric polarization may be used to manipulate spin polarizations in nonmagnetic materials, ranging from Rashba/Dresselhaus spin-splitting[4,5] to spin-valley coupling[6,7], with possible links to topologically non-trivial behaviour[8,9].

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