Non-local magnetolectric effects in diffusive conductors with spatially inhomogeneous spin-orbit coupling

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We present a theoretical study of non-local magnetoelectric effects [1] in diffusive hybrid structures with an intrinsic linear-in-momentum spin-orbit coupling (SOC) which is assumed to be spatially inhomogeneous. Our analysis is based on the SU(2)-covariant drift-diffusion equations [2,3] from which we derive the BC at hybrid interfaces. Within this formulation, the spin current is covariantly conserved when the spin relaxation is only due to the intrinsic SOC. This conservation leads to the absence of spin Hall (SH) [1] currents in homogeneous systems. We also consider extrinsic sources of relaxation (ESR), as magnetic impurities, which break the covariant spin conservation, and may lead to SH currents. We apply our model to describe non-local transport in a system with an interface separating two regions: one normal region without intrinsic SOC and one with a Rashba SOC. We first explore the inverse spin-galvanic effect, i.e., a spin polarization induced by an electric field [4,5]. We demonstrate how the spatial behavior of such spin density depends on both, the direction of the electric field and the strength of the ESR rate. We also study the spin-to-charge conversion [6], and compute the charge current and the distribution of electrochemical potential in the Rashba region induced by a spin current injected into the normal region. In systems with an inhomogeneous SOC varying in one spatial direction, we find an interesting non-local reciprocity between the spin density induced by a charge current at a given point in space, and the spatially integrated current induced by a spin density injected at the same point.

References

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