Spin-orbit interaction and g-tensor anisotropy of holes in nanowires of hexagonal germanium

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Hexagonal germanium (2H-Ge) offers strong spin–orbit interaction and optical activity, making it an appealing platform for semiconductor spin qubits. Recent progress in growing hexagonal Si_xGe_{1-x} nanowires enables controlled geometries suitable for quantum devices [1]. In contrast to cubic Si or Ge, 2H-Ge supports direct band-gap transitions, opening a pathway towards a novel spin-photon interface.

We study the electronic and spin properties of 2H-Ge nanowires using a multiband k·p Hamiltonian describing low-energy states near the Γ point [2]. We focus on nanowires oriented perpendicular to the c-axis and compute their band structure. We quantify confinement-induced gap variations and the influence of transverse electric fields, from which we extract Rashba coefficients. We find that the strength of the Rashba effect depends strongly on the electric-field direction, and for a y-directional electric field, the Rashba strength can exceed that in other strong spin-orbit semiconductors, e.g,. InSb. Magnetic fields are included via a Peierls substitution to investigate anisotropic spin responses. The resulting effective g-tensor is highly anisotropic, revealing regimes favourable for qubit operation in hexagonal Ge nanowires.

This study on hexagonal Germanium nanowires also serves as a convenient starting point for future investigations of electrically defined and/or optically active quantum dots, which promise advanced functionalities as spin-based quantum information processing devices or spin-photon interfaces.

References

[1] Lamon et al., Nano Letters 25, 14, 5741–5746 (2025).
[2] Pulcu et al., Phys. Rev. B 109, 245201 (2024)

Figures

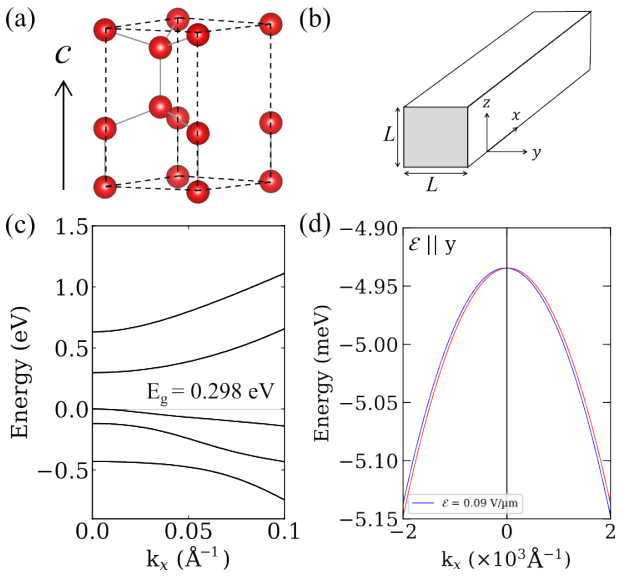

Figure 1: (a) Unit cell of 2H-Ge (b) Schematic diagram of the nanowire (c) Low energy bulk band structure with a band gap of E_g = 0.298 eV (d) Rashba splitting of the top valence subband due to the electric field of magnitude 0.09 V/μm along the y-direction.