Spin filtering in germanium/silicon core/shell nanowires with pseudo-helical gap

Appl. Phys. Lett. **117**, 052403 (2020); https://doi.org/10.1063/5.0014148

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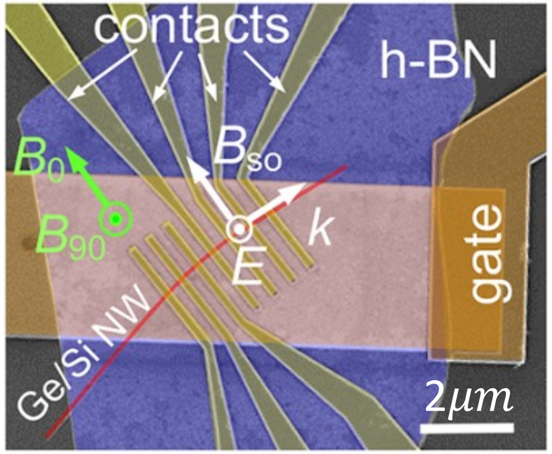
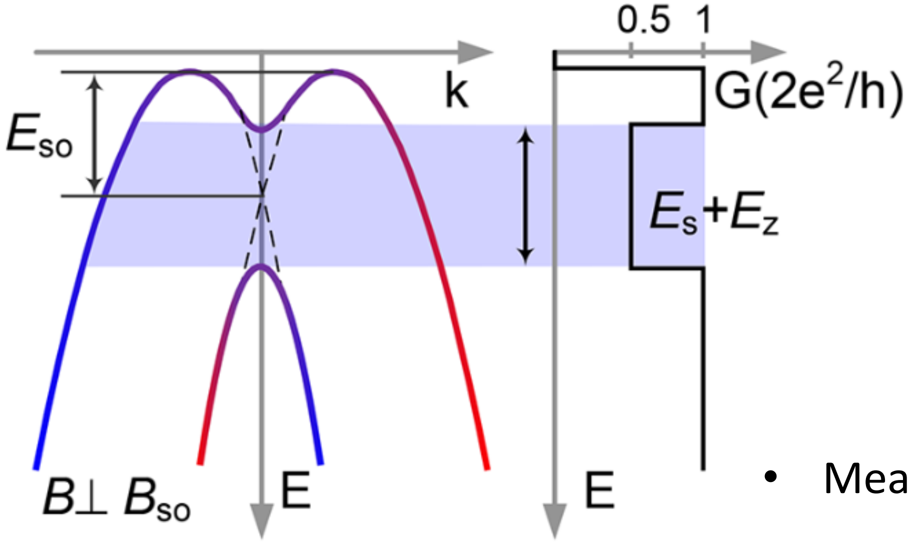
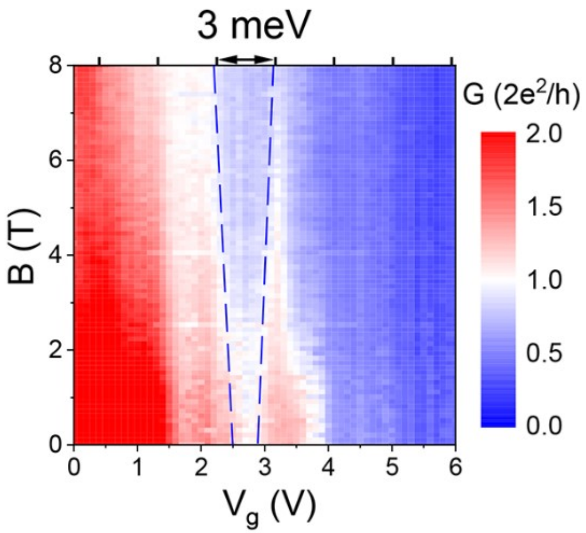
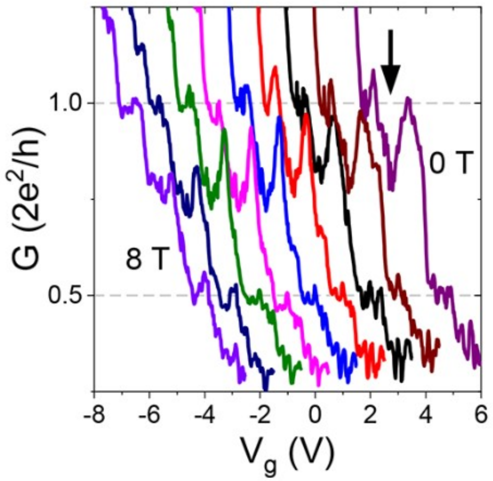
Preface : Helical hole state in Ge/Si NWs









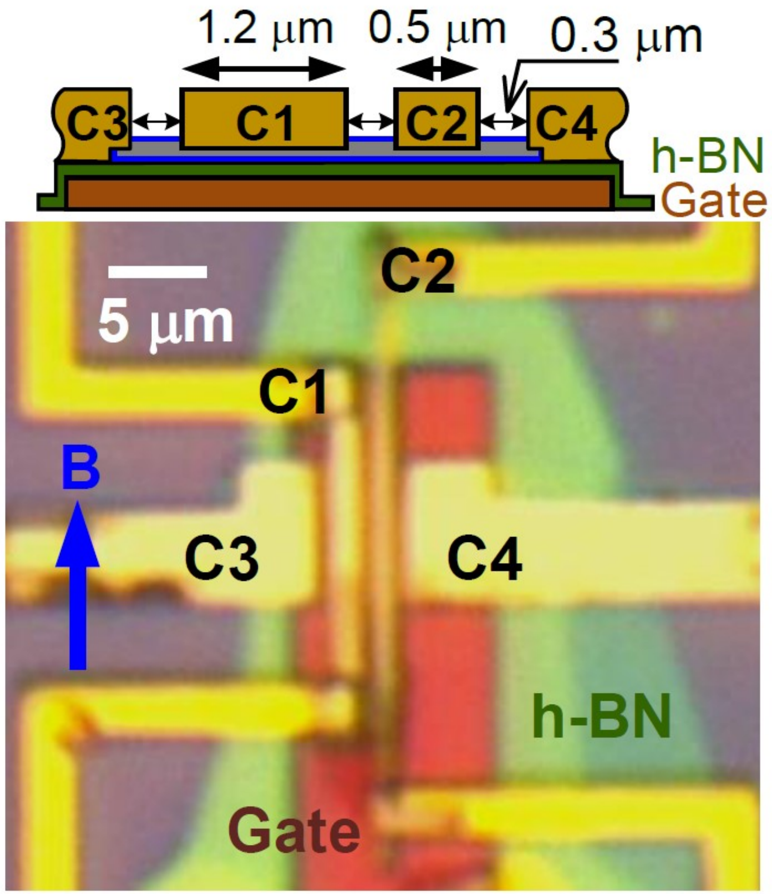
- Measurable as a reentrant conductance feature

- Even in absence of magnetic field, a “pseudo-helical” gap might emerge due to an interplay of a two-particle backscattering process and Rashba SOI [2]

From Ref. [1]

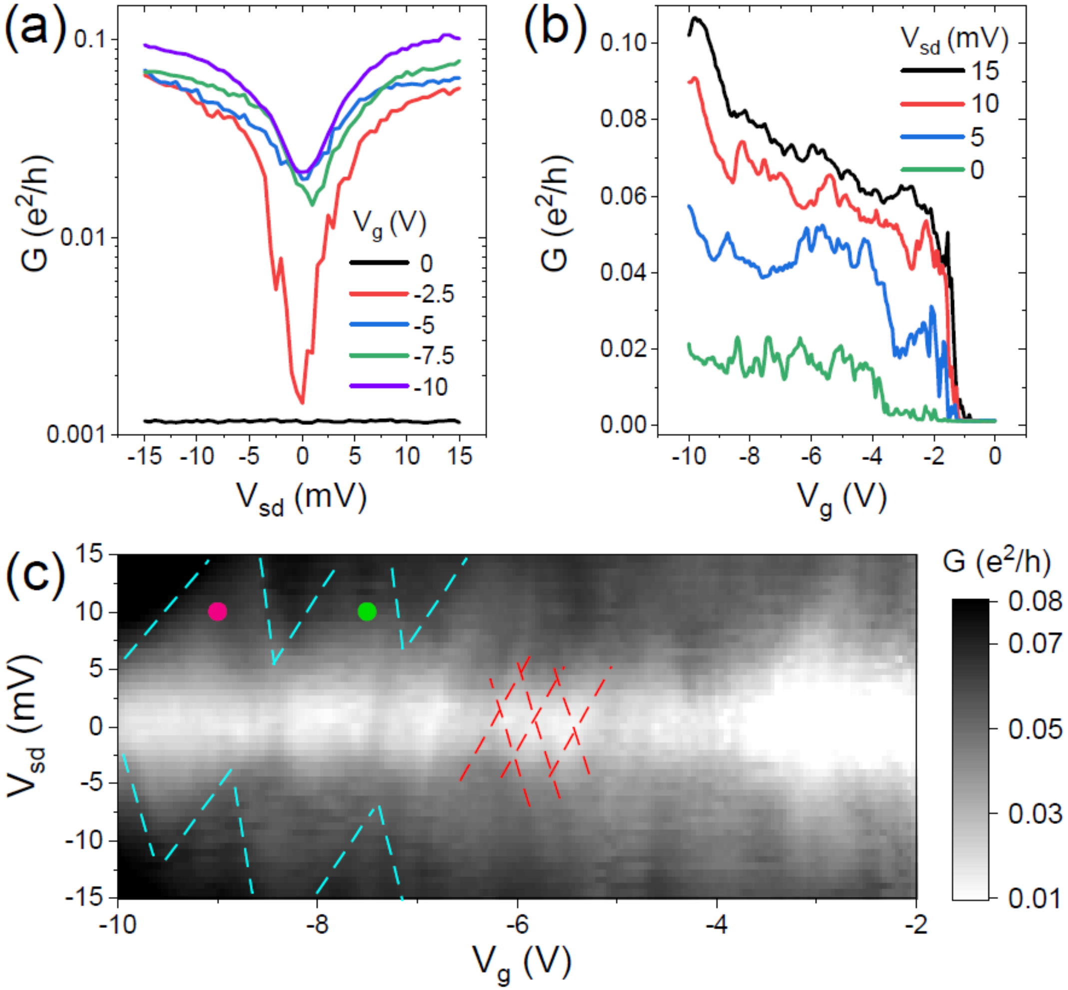
[1] J. Sun et al., Nano Letters 2018
[2] C. Pedder et al., PRB 2016

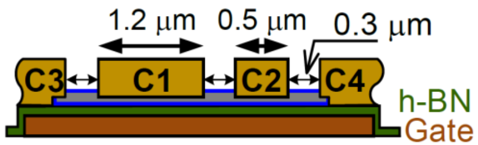
Device



- Au gate on SiO_2/Si substrate, separated from wire by ~30 nm hBN flake
- Ferromagnetic (Schottky) cobalt contacts C1-C4 of different widths, such that they have different coercive fields
- Schottky contacts: Increased spin injection efficiency at the “cost” of high resistance background, realized by controlled air exposure after HF dip
- C1: Spin injection, C2: Spin detection

Differential conductance between C1 and C2

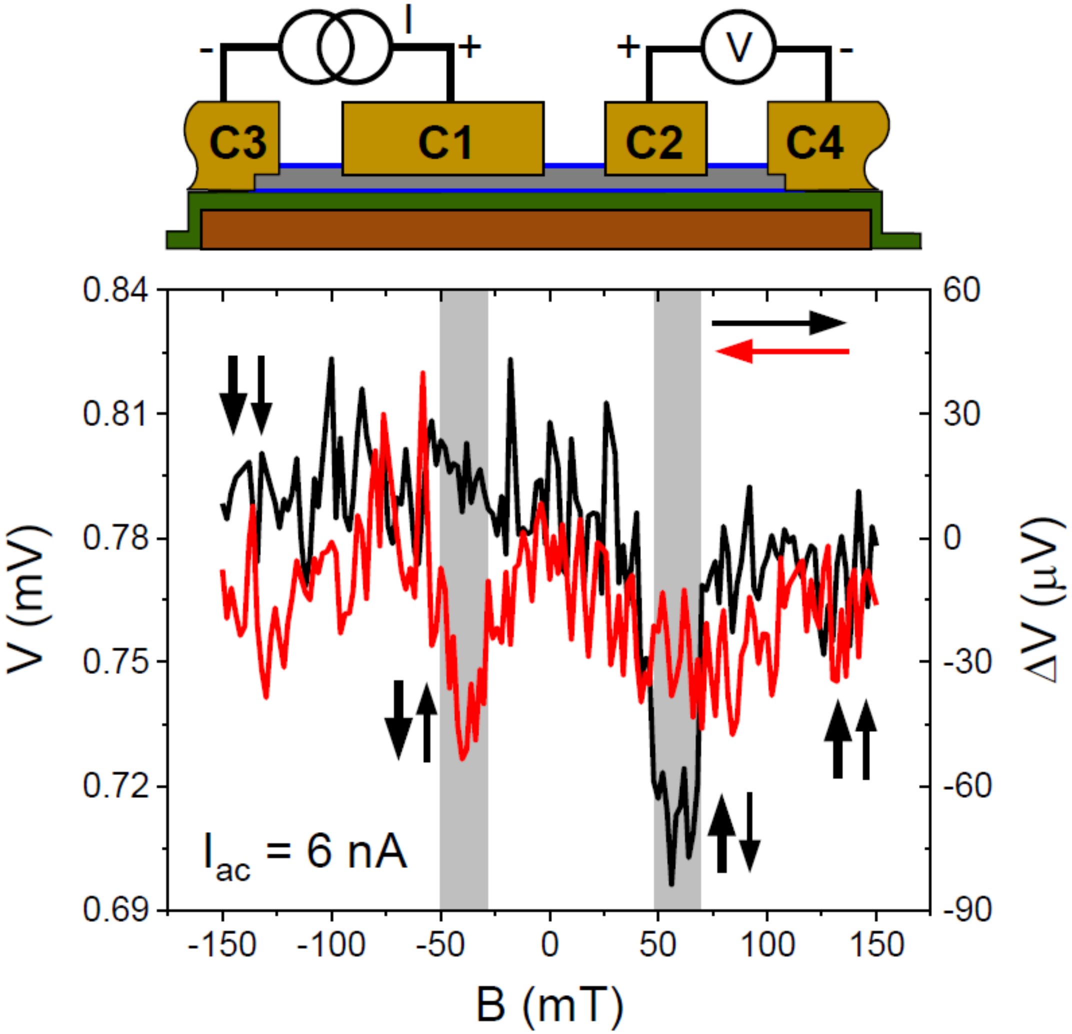




- Decreased conductance compared to previous work, due to suboptimal tunnel barriers
- Charge stability diagram in (c):
  - ➢ Red dashed lines near zero bias: Fabry-Pérot interferences due to partial reflections at contacts
  - ➢ Blue dashed lines: Conductance “diamonds”, here ascribed to a trivial quantized conduction mode (red dot) and a pseudo-gap (green dot)
  - ➢ Knowledge from [1]: Voltage separation of ~5-8 V between first Conduction mode and pinch-off, hence speculate that also here there is only one conduction mode and helical gap in this range

[1] J. Sun et al., Nano Letters 2018

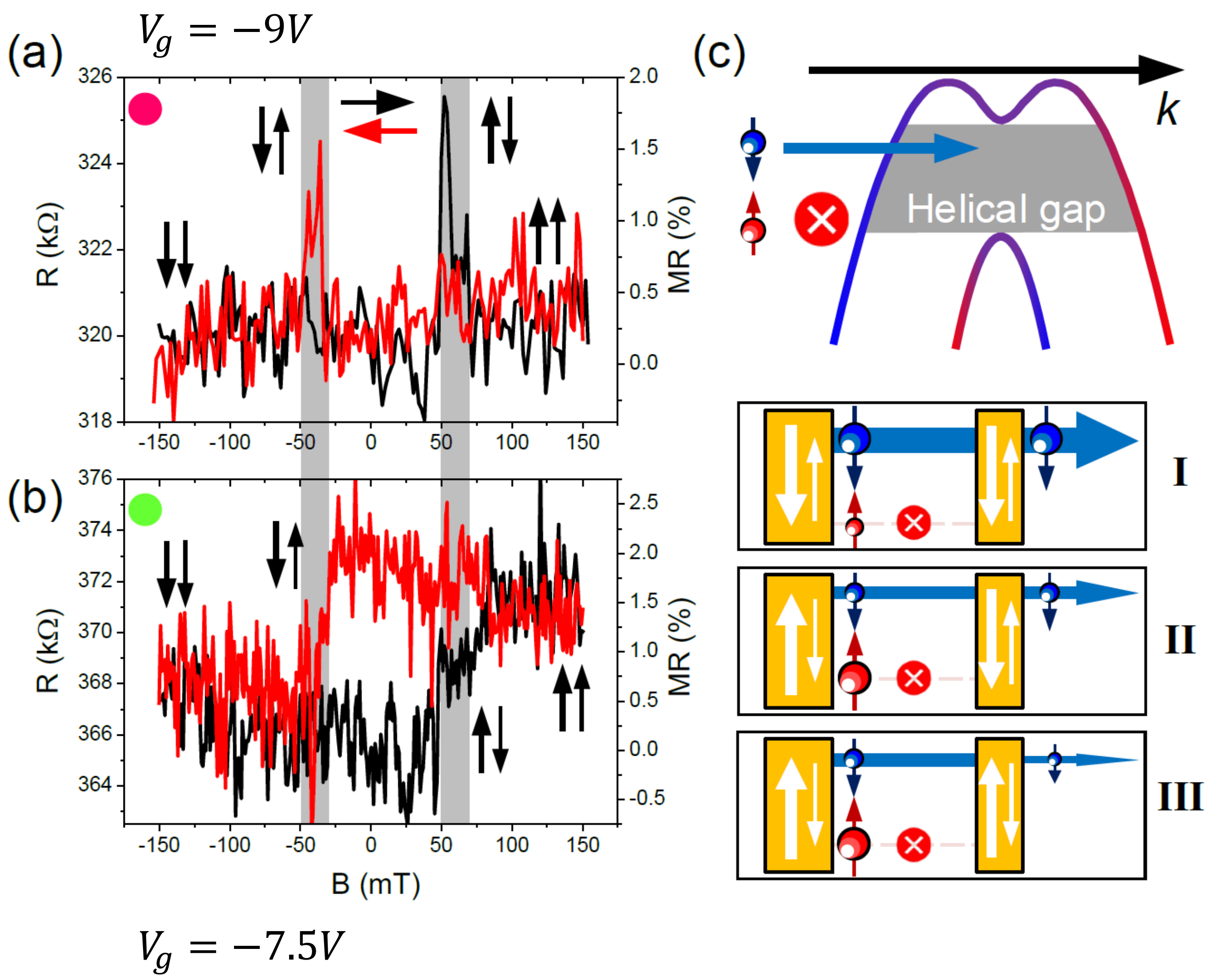
Spin valve effect



- Confirm injection of polarized spins by measuring spin valve effect
- Four-terminal configuration: ac excitation between C1-C3, V measured between C2-C4; spin injection C1, spin detection C2

1. (-150 mT -> ~50 mT): all FM contacts magnetized in negative direction
2. ~50 mT : magnetization in C1 flips, causing voltage drop as C2 hasn't flipped
3. ~70 mT : all FM contacts have flipped, output returns to background
4. When sweeping B back, voltage dip occurs at ~-30-50 mV

Spin filtering in the helical gap



- Two-terminal configuration between C1-C2
- dc bias of 10 mV fixes momentum direction
- $V_g = -9V$ (a): spin valve behavior
- $V_g = -7.5V$ (b): Hysteresis loop with three resistance states
  - I. (-150 mT -> ~50 mT): primarily down-spins injected (allowed to transport in the NW)
  - II. ~50 mT: C1 flips, down-spins become minority
  - III. ~70 mT: C2 flips, resistance further increases
- Spin filtering effect is only observed in this two-terminal configuration with applied bias

Summary

- Experimental demonstration of spin filtering effect originating from helical state in Ge/Si NW
- Limitations: Low spin injection efficiency, high resistance background; could be improved through interface engineering of the FM contacts, which is a technical challenge on NWs