Spintronic devices using spin injection into semiconductor

The injection of spin polarized carriers from a ferromagnetic electrode inside semiconductors (spin injection) is one of the hottest topics in the research field of spintronics, because spin injection is the first step towards creating viable semiconductor spintronic devices featuring non-volatile, reconfigurable logic functions and ultralow power consumption. We recently achieved an efficient spin injection into a GaAs channel from a spin source of Co-based Heusler alloy Co2MnSi electrode. (Click here for detail)

Furthermore, we successfully demonstrated an efficient nuclear spin polarization of Ga and As atoms inside a GaAs channel by using the spin injection. Nuclear spins in semiconductors are an ideal system for implementing quantum bits (qubits) for quantum computation because they have an extremely long coherence time. Our results will be applicable to the manipulation and detection of qubits in semiconductor nanostructures for future semiconductor quantum information technologies.

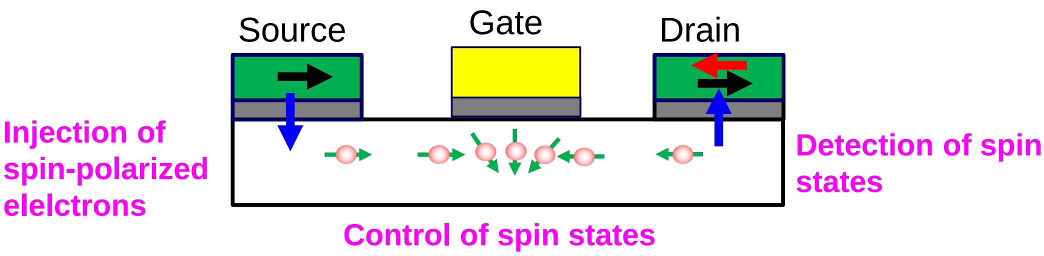

FIG. 1

Nonlocal detection technique

We used a nonlocal detection to demonstrate spin injection and detection of spin-polarized electrons which transport through a semiconductor channel. This technique enables to isolate a pure spin injection signal from other spin-related signals, such as those coming from anisotropic magnetoresistance (AMR) or Hall effects by separating the current and the voltage circuit. Spin-polarized electrons are injected into a semiconductor channel at contact 2 and flow towards contact 1, while the nonlocal voltage, V_{NL}, is measured between contacts 3 and 4. Although no net current flows between contacts 3 and 4, the nonequilibrium spin polarization in semiconductor can diffuse in either direction from contact 2. The spin polarization results in an electrochemical potential difference for the two spin states in the channel, leading to a change in V_{NL} when the relative orientations of the magnetization of contacts 2 and 3 is switched from parallel to antiparallel configuration. The spin-valve measurement is carried out by sweeping the inplane magnetic field along the magnetic easy axis to switch the relative orientations of the magnetization of contacts 2 and 3, and measures a change in V_{NL}. The Hanle effect measurements, on the other hand, demonstrate that the spin polarization can be modulated by an out-of-plane magnetic field which causes the spin-polarized electrons to precess and dephase in the channel. Observation of both spin-valve signal and Hanle signal is the most rigorous evidence of spin injection.

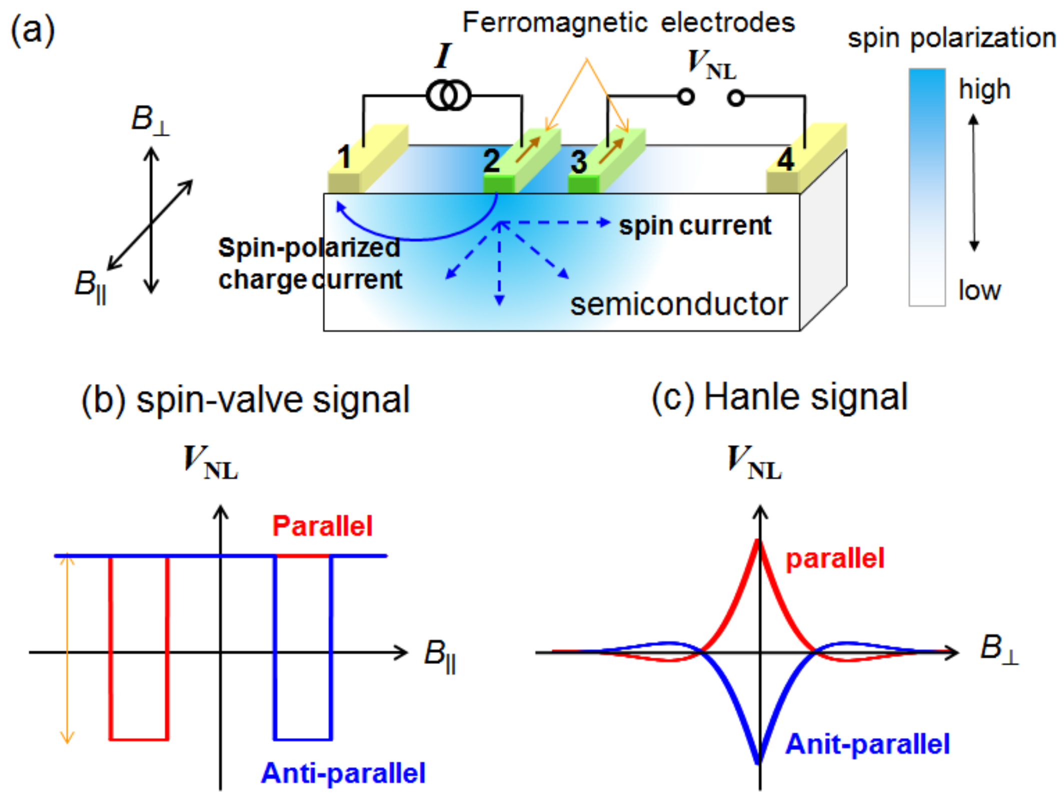

FIG. 2 Non-local detection techniques using a four-terminal lateral spin transport device

Highly efficient spin injection using Co-based Heusler alloy electrodes

We observed a clear spin-valve signal and Hanle signal in the four-terminal nonlocal geometry in Co_2MnSi/CoFe/n-GaAs Schottoky tunnel junctions, indicating a spin injection from Co2MnSi spin source into a GaAs channel through an ultrathin CoFe insertion layer. The magnitude of spin signal is more than one order of magnitude higher than those obtained in samples with conventional Fe or CoFe electrodes, indicating a high spin polarization arising from the half-metallic character for Co_2MnSi.

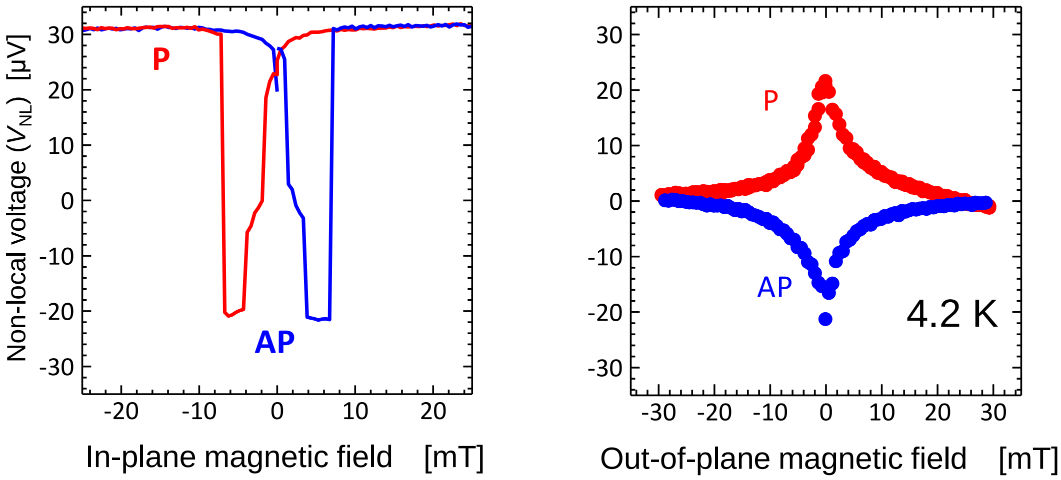

FIG. 3 Signals for spin injection from a Co_2MnSi spin source into GaAs