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# Low-Dimensional Effect of Spin-Orbit Interaction

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## 1. Introduction

Spin field effect transistor (Spin-FET) has a main interest because of its potential uses in devices requiring high-speed switching such as logic devices. Previous reports [1-4] have shown the spin injection into a metal and a semiconductor channels. In a spin-FET, an electric field applied by a gate electrode controlls the spin-orbit interaction, and hence adjusts the amount of spin angle. Moving electrons ($k_x$) with a perpendicular electric field ($E_z$) induce an effective magnetic field ($H_R$) in the $y$-direction, a phenomenon known as the Rashba effect. This induced magnetic field in turn interacts with the magnetic moment of the electrons, resulting in spin orientation control. Generally, not only an electric field induces spin-orbit coupling, but also the structural asymmetry of a quantum well has the same effect. An interfacial electric field arising from the potential well asymmetry of a two-dimensional electron gas (2-DEG) system produces a Rashba term. The Rashba-effect-induced spin splitting energy between spin-up and -down electrons can be expressed as $\Delta=2\alpha k_F$, where $k_F$ is the Fermi wave number.

## 2. Experiments

We utilize an inverted high electron mobility transistor(HEMT) structure with InAs channel. In this system, the InAs channel is sandwiched by $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ double cladding layers. The thickness of the InAs active layer was chosen to be only 2 nm to reduce the structural stresses induced between the active layer and the InP substrate. The carrier concentration and mobility of the 2DEG before channel patterning were $n_S$ = $6.3\times10^{12}$ ($4.6\times10^{12}$) 1/1cm$^2$ and $\mu$ = 5,700 (34,700) cm$^2$/Vs at 295 K (20 K). The inset of Fig.1 shows the measurement geometry of the sample used in this experiment. We observed the node position of Shubnikov-de Haas (SdH) oscillation.

## 3. Results and Discussions

From SdH oscillation, we have determined the channel width dependence of the spin splitting energy which is functions of the spin-orbit interaction parameter and the charge concentration. As shown in Fig.1, the spin-orbit interaction parameter ($\alpha$) is inversely proportional to $w^{1/2}$, whereas the surface charge concentration is independent of the channel width. The reason is that in narrower channels the spin precession length is suppressed by the side wall of the channel. The spin precession length is inversely proportional to spin-orbit interaction strength, and therefore the spin-orbit interaction becomes stronger in a narrower channel. The large spin-orbit coupling parameter values of narrow channels are very advantageous for high density applications because the gate voltage can modulate the spin precession of the injected electrons, even for very short source-drain distances.

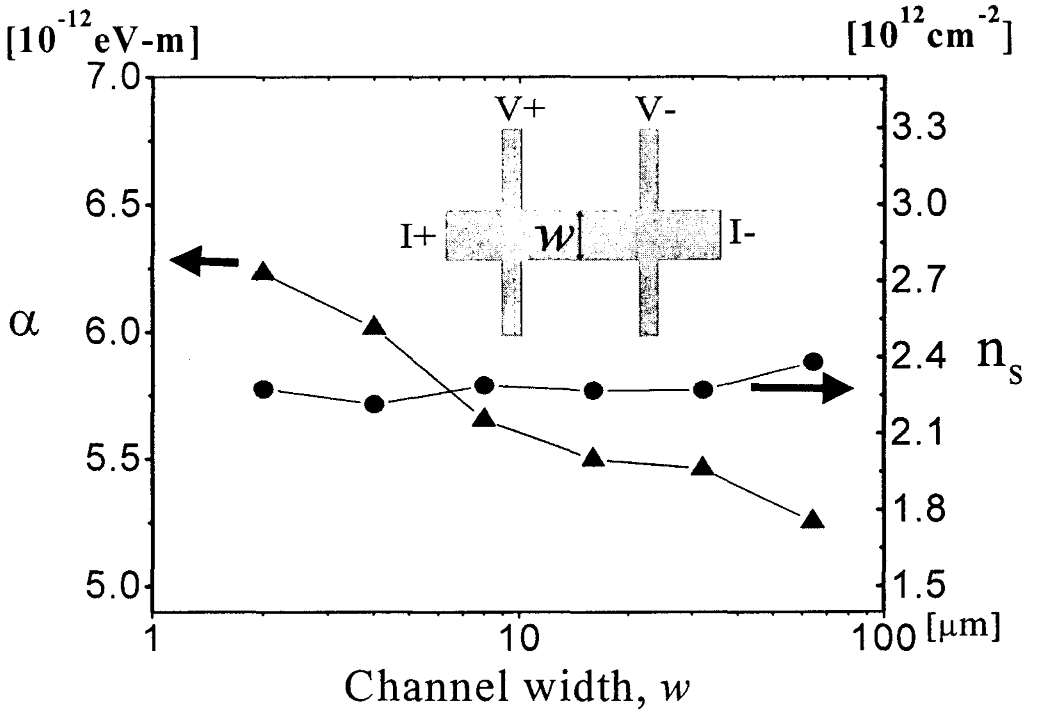

Fig. 1 Channel width dependence of spin-orbit interaction parameter and carrier concentration

## 4. References

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