Design and analysis of electric-field-assisted four-terminal nonlocal Si-channel MOS devices

°Daiki Kitagata[1], Taiju Akushichi[1], Yota Takamura[2] , Yusuke Shuto[1] , Satoshi Sugahara[1]

1.Imaging Science and Engineering Laboratory, Tokyo institute of Technology

2.Department of Physical Electronics, Tokyo institute of Technology

E-mail: kitagata.d@isl.titech.ac.jp

Si-channel spin-transistors, such as a spin-MOSFET, have attracted considerable attention as a key device for low-standby-power integrated circuits. To realize spin-MOSFETs, understanding of spin dynamics in the Si channel is indispensable. In particular, analysis technique for spin lifetime in MOS inversion channels needs to be developed. The Hanle effect is known to be powerful tool for evaluating spin lifetime. Recently, we have developed a new analysis technique of spin dynamics for Si channels based on a four-terminal nonlocal (4TNL) technique, called the electric-field assisted (EFA) 4T-NL method (Fig. 1). This technique enables us to evaluate accurate spin lifetime using an application of a specific electric field (E_{acc}^{X}) to the channel [1, 2]. Although the electric field enhances the intensity of Hanle-effect oscillation signals, the width (*d*) of the electrodes strongly affects the waveform of the signals. In this study, we developed the design scheme of EFA-4TNL MOS devices.

Figure 2 shows calculated Hanle-effect signals using LILD and DIDD models, in which LILD and DIDD represent line injection / line detection and domain injection / domain detection models, respectively [2]. The peak intensities of the Hanle-effect signals decrease with increasing *d* except *B*=0. Figure 3 shows 2nd peak intensity of the signals as a function of *d*, in which E_{acc}^{X} is applied to the channel. The deviation (denoted by δ in the figure) of the 2nd peak intensity of the DIDD model is widened with increasing *d*. This deviation is uniquely determined by the ratio of $d/L_{\rm eff}$ for the condition of the E_{acc}^{X} application. Therefore, when $L_{\rm eff}$ is sufficiently long (which could be supposed at low temperatures owing to long spin lifetime), narrower *d* is not required. For instance, a few microns of $L_{\rm eff}$ with its half for *d* are acceptable for the design of EFA-4TNL MOS devices, as shown in Fig.4. Even for these robust designs, spin lifetime can be accurately determined as long as E_{acc}^{X} is applied to the channel.

[1] D.Kitagata, et al, Silicon Nanoelectronics Workshop 2015.

[2] Y. Takamura, et al, J. Appl. Phys., **117**, 17D919 (2015).

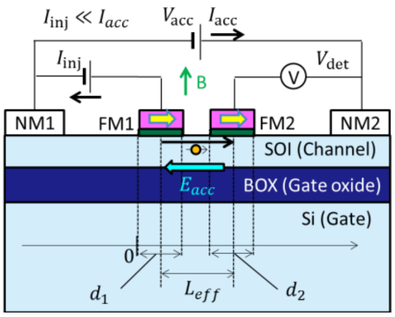

Figure 1 Schematic of EFA-4TNL MOS device

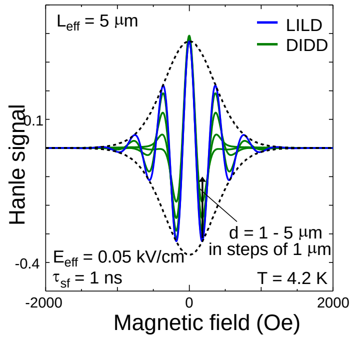

Figure 2 Hanle-effect signals for the LILD and DIDD models.

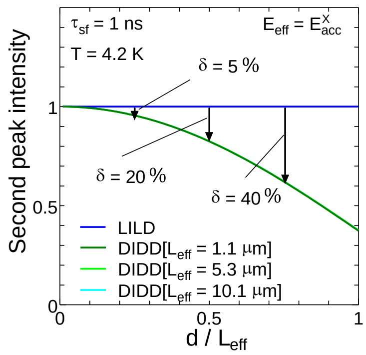

Figure 3 Second peak intensity as a function of $d/L_{\rm eff}$. δ represents the deviation for the DIDD-model intensity from the LILD-model intensity .

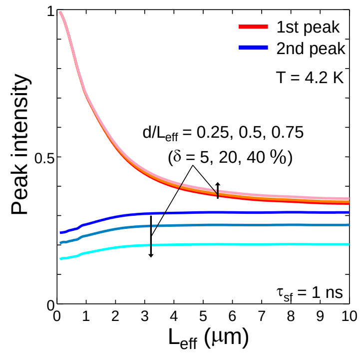

Figure 4 1st and 2nd peak intensities of Hanle-effect signals as a function of $L_{\rm eff}$.