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Noise Characteristics of SOI MOSFET for Single-Photon Detection

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Introduction

It has been reported that the silicon-on-insulator (SOI) metal-oxide-semiconductor field-effect transistor (MOSFET) can operate as a single-photon detector [1]. However, the noise behavior of the SOI MOSFET, which is closely related to the noise equivalent power [2] and the operation speed of the single-photon detection, has not been analyzed well. In this paper, we will present detailed analysis of the drain current noise in SOI MOSFET under different substrate biases for higher performance as a single-photon detector.

Device structure and measurement setup

An n^+ poly-Si-gate n-channel SOI MOSFET with p^- channel dopant concentration less than 10^{15} cm^{-3}. Thicknesses of buried oxide, SOI and gate oxide are 145, 50 and 5 nm, respectively. The gate length are fixed at 300 nm, and the channel width is varied among 90, 95 and 110 nm. In this experiment, we changed V_{sub}, and keep drain current at the constant level of 1 nA by adjusting the front gate voltage V_g. For different V_{sub}, we analyzed the drain current noise in dark condition at 300 K.

Experimental results and discussion

Figure 1 shows noise power and threshold voltage V_{th} at the drain current of 1 nA plotted against the substrate voltage for various channel widths. The deflection point 1 corresponds to the transition point between front- and back-channel operations, and the deflection point 2 to the transition between inversion and accumulation conditions at the buried oxide/substrate interface [3]. The noise levels show horseshoe shape, and become low at around the deflection point 1 and in the back-channel region between deflection points 1 and 2. Figure 2(a) shows the drain current noise spectra in $-10 \le V_{sub} \le -3$V. It can be seen that, as the V_{sub} decreased, the Lorentzian noise at high frequency increases only in the plateau level at first (α), after that the noise spectra asymptotically approaches a single $1/f^2$ line (β), indicating that the plateau level increases and the cut-off frequency decreases simultaneously [4]. Figure 2(b) shows the noise spectra in $-3 \le V_{sub} \le 4$V. The similar behavior of the evolution of the generation-recombination (GR) noise can be observed (β), but the initial incrase only in the plateau level (α) cannot be seen.

Conclusions

It was found that the noise in the SOI MOSFET became low at the transition point between the front- and back-channel operations, and in the back-channel region near the transition point. On both sides, the noise spectra asymptotically approached a single $1/f^2$ line, indicating that the active trap density and carrier lifetime increased simultaneously. The understanding of the noise behavior is beneficial for high-sensitivity and high-speed SOI MOSFET single-photon detector.

References

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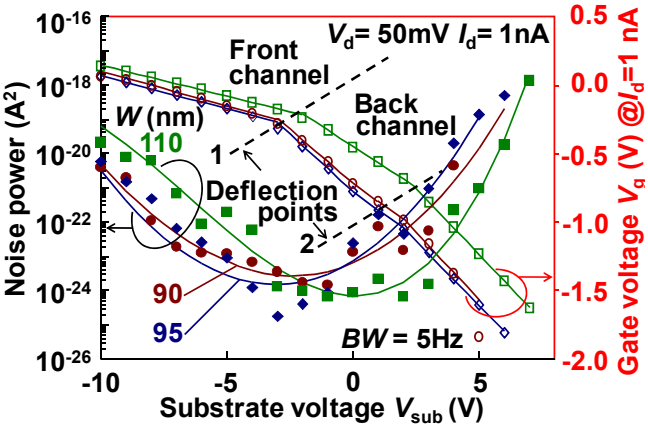
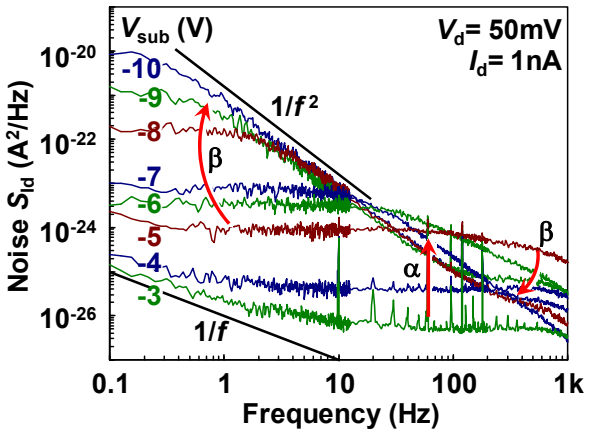
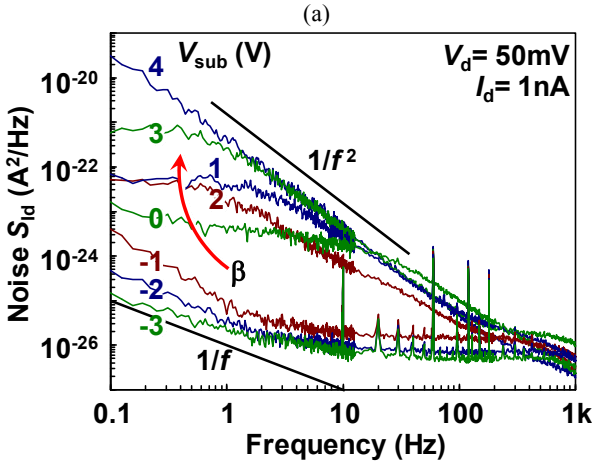


Fig.1 Noise power and threshold voltage V_{th} at I_d=1 nA as a function V_{sub}. The gate length is fixed at 300 nm, channel width is varied among 90, 95 and 110 nm.



(a)



(b)

Fig. 2 Drain current noise spectra for (a) front-channel ($-10 \le V_{sub} \le -3$V), and (b) back-channel ($-3 \le V_{sub} \le 4$ V) operations. Device sizes are L = 300 nm and W = 95 nm.