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Low Frequency Noise in Tunneling Field Effect Transistors

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A B S T R A C T

An analytical model is developed for the fluctuation of the electrostatic potential induced by a charged trap in the gate oxide in tunneling field effect transistor (TFET). The model is applied to get the fluctuation of the drain current induced by an interface trap in TFET. A low frequency noise model based on the current transportation through the tunneling and the channel is proposed. The dependency of the normalized power spectra S_{Id}/I_d^2 on the frequency f and the gate bias V_g for TFET is obtained. The noise spectra in TFET are found to be very different from those of conventional MOSFETs, and have the superposition of Lorentzian and $1/f$ lineshapes with the former associated with tunneling and the later with channel transportation. The potential and current models are compared with TCAD simulation. The calculated I_dV_g and the noise spectra are also compared with our experimental observations. The results show that the normalized spectra of the current noise due to the tunneling are more significantly affected by V_g than that due to the transportation through the channel. The results also show that the noise from the channel is dominated by the mobility fluctuation rather than the carrier number fluctuation.

Keywords: Tunneling field effect transistor (TFET), interface trap, potential model, low frequency noise.

1. Introduction

Due to the low power application in modern VLSI circuits, tunneling field effect transistor (TFET) becomes a very promising candidate because of its ability to reduce the sub-threshold swing below 60mV/dec [1-6]. Instead of carrier drift in a single band in conventional MOSFETs, band-to-band (BTB) tunneling dominates the drive current of TFET. The exponential dependence of the tunneling probability on tunneling field makes the IV characteristics very sensitive to the materials, geometry, as well as the traps near the source/channel (tunneling) junction. With scaling of the device dimensions, the effect of traps and its induced current fluctuation have emerged as crucial concerns and may affect the reliability of TFET [7-11].

The power spectra of low frequency noise from electronic devices are of great interest [12-14]. The noise characteristic itself should affect many aspects of device applications in integrated circuit. Noise spectra are also a powerful tool for the device characterization, especially for the effect of defects in the nanometer devices, in which the conventional techniques such as CV and charge pumping may fail. While the noise spectra have been widely reported for conventional Si MOSFETs, very limited investigations are reported for TFETs [9, 15-19].

In this paper, we systematically investigate the properties of the low frequency noise in TFET. We establish a potential model in section II, starting by developing an analytical model for the fluctuation of the electrostatic potential induced by a single charged trap in the gate oxide in TFET. We then apply this model to calculate the fluctuation of the tunneling probability and the drain current induced by an interface trap located near the tunneling junction in section III. In section IV, we propose a low frequency noise model for TFET by considering the current fluctuation through tunneling and channel transportation. Finally we calculate the noise spectra for TFETs using the model and compare the results with our experimental observations.

2. Potential Model

2.1 Device Structure and Potential Equations

Fig. 1 schematically shows the cross section of a TFET structure with interface traps and the coordinate axes used in the text. A symmetric double gate structure is used as a n-type device. The z axis is not shown and its origin (z = 0) is chosen to be far from the edges of the structure. Source and drain are p+ and n+ doped Si. The channel is intrinsic (i-Si). The gate dielectric is SiO_2 with a thickness of t_{ox}. The channel length and width are L and W respectively. The interface traps may distribute uniformly or non-uniformly in the channel/gate oxide interface. These traps are divided into two types. One, with a small number, is near the tunneling junction (solid dots) and is expected to have a significant effect on tunneling. The second type, with a much large number, distributes in the

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