SELF-ALIGNED SiGe MOS-GATE FET WITH MODULATION-DOPED QUANTUM WIRE CHANNEL FOR MILLIMETER WAVE APPLICATION

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Received May 11, 2000

Abstract

This paper describes a self-aligned SiGe MOS-gate field-effect transistor (FET) having a modulation-doped (MOD) quantum wire channel. An analytical model based on modified charge control equations accounting for the quantum wire channel, is presented predicting the transport characteristics of the MOS-gate MODFET structure. In particular, transport characteristics of devices having strained SiGe layers, realized on Si or Ge substrates, are computed. The transconductance g_m and unity-current gain cutoff frequency (f_T) are also computed as a function of the gate voltage V_G. The calculated values of f_T suggest the operation of one-dimensional SiGe MODFETs to be around 200 GHz range at 77 °K, and 120 GHz at 300 °K.

Key words: MODFET, MOSFET, two-dimensional electron gas (2 DEG), unity-current gain cutoff frequency (f_T), Quantum Well Wire (QWW)

I. Introduction

SiGe heteroepitaxial technology has been used to fabricate high performance heterojunction bipolar transistors (HBTs) [1,2] and
modulation-doped field-effect transistors in SiGe strained layers [3]. Novel Field-Effect transistors combining self-aligned MOS-gate with a modulation-doped channel, using SiGe strained layers, have been proposed by Jain et al. [4]. Verdonck-Vanderbroeck et al. [5] reported the experimental demonstration of MOS-gate MODFETs in Si. Subsequently, these devices have been modeled to extend the use of SiGe FETs to over 80 GHz range for a 0.25 μm gate length at 77°K [6,7]. Enhanced performances of PMOS and CMOS circuits using self-aligned MOS-gate MODFETs have also been reported [8].

This paper presents simulation on self-aligned SiGe MOSFETs with modulation-doped Quantum Wire Channel. The proposed device incorporates quantum well wire (QWW) channel and self-aligned feature of Si MOSFETs. Modulation doping is well known to provide a separation of mobile charge carriers from ionized donors resulting in very high carrier mobility. A quantum wire channel provides two-dimensional carrier confinement and is expected to result in even higher carrier mobilities [9].

II. Device Structure

Figure 1 shows the schematic illustration of the proposed Quantum Well Wire (QWW) MOS gate n-channel MODFET structure. The proposed device structure is shown in figure 1. The device consists of a Metal-SiO2-nSi (MOS) section, an n-Si0.5Ge0.5 supply layer, undoped n-Si0.5Ge0.5 spacer layer, a quantum well transport channel (NID, not intentionally doped), and SiGe buffer layer(s) grown on a Si substrate. The channel is formed on the surface of unintentionally doped p'-Si layer, similar to conventional MODFETs as shown in figure 1(b). The quantum wire is obtained by further confining the electron gas in the lateral direction, as shown in figure 1 (b). The potential barriers are represented by shaded regions and can be achieved by etching and regrowth and by ion-implantation. The resulting rectangular potential well is about 150 °A wide. The Schottky gate of a conventional one-dimensional MODFET is replaced by a MOS-gate in this device. The SiO2 layer is about 50-100 nm and can be grown by a low-temperature process described in the literature [10]. The doping concentrations and thickness of various layers are selected to provide adequate channel charge density.