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On the Electrical and Thermal Study of a MgZnO/ZnO HEMT for High Field Applications

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In this work, a simple current equation of a HEMT based on MgZnO and ZnO heterojunction is proposed in the framework of electron velocity saturation. The mathematical formulation of drain current is presented as a function of mole fraction and device temperature. It is observed that the effect of the mole fraction of MgZnO has a significant role to modulate the drain current of the device. For example, the drain current is shifted by almost 9% for a change in mole fraction from 0.2 (236.5mA) to 0.5 (257.2mA) when no gate voltage is applied. In addition to this, the impact of environmental thermal variation is included in our study and a noticeable shift of drain current and other device parameter has been observed for a temperature range 300K to 500K. This work has also been extended to study the switching characteristics of the device in terms of mole fraction of MgZnO and ambient temperature. It is observed that the threshold voltage is shifted by 0.36 V for a change in mole fraction by 0.2.

Keywords: ZnO MODFET; ZnO HEMT; Velocity saturation model; DC characteristics; RF characteristics; MgZnO/ZnO heterostructure

1 Introduction

High Electron Mobility Transistors (HEMTs) based on MgZnO-ZnO heterojunction becomes very popular to the new generation researchers. This is due to the exciting material properties of ZnO such as wide energy band gap (3.37 eV), high saturation electron velocity (3.2×10^7 cm/s), high critical electric field *etc.*[1-5]. Further its direct band gap enables itself to be a good semiconductor material for optoelectronic applications. It is non-toxic, eco-friendly and transparent material when it is in pure form. Moreover, it is radiation-hard material and hence it can be used in electronic devices to operate in satellites in low earth orbits. Besides the minimum lattice mismatch of MgO and ZnO and large tunable band gaps enable itself to provide a good heterojunction structure[6-10].

A number of works have been done earlier to study the performance of ZnO HEMT[11-15]. Verma *et al*. derived an expression of 2DEG density with respect to gate voltage at the hetero-interface by solving the 1D Schrodinger's equation in the triangular potential well[11]. In a very recent work they have also studied the electrical performance of the device using a physics based analytical model and calculated various device parameters[12]. In another work, they have simplified the expression for Fermi energy level to develop a 2D analytical model for 2DEG density and hence to develop the I-V characteristics of HEMT[13]. Singh *et al*. developed an analytical model of two dimensional electron gas density and threshold voltage for a fully strained graded MgZnO/ZnO heterostructure with cap layer[14]. Kumar *et al*. developed an analytical model to explain the power switching characteristics of ZnO based HEMTs[15]. In a very recent work we have developed a theoretical model of MgZnO/ZnO HEMT considering accurate velocity field relation of ZnO[16]. The theoretical works on ZnO HEMTs reported so far are limited and there is a good scope to work on it. For short channel devices when the gate length of the device is considerably small, the drain field becomes higher even if a low drain bias is applied. In such cases the device is subjected to high drain field and the velocity of the electrons is near to its saturation value. In this scenario, the velocity saturation model is appropriate to find out the device current. But, in the previous works reported so far, the issue of electron velocity

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