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ORIGINAL PAPER - CROSS-DISCIPLINARY PHYSICS AND RELATED AREAS OF SCIENCE AND TECHNOLOGY

A theoretical approach to study the thermal impact of the DC and RF characteristics of a MgZnO/ZnO HEMT

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Abstract
In this work, a new current model of the MgZnO/ZnO high electron mobility transistors (HEMTs) has been developed considering the exact velocity-field characteristics of electrons in ZnO. The drain current of the device has been studied with reference to different applied potentials. The other device parameters, such as drain conductance, mutual conductance, cut-off frequency, and maximum operating frequency, are also calculated and their variations with different device parameters are studied. In addition, the variation of drain current with respect to ambient temperature and mole fraction of MgZnO have been studied and the results are reported. It has been noticed from our study that device characteristics depend significantly on the shift of temperature as well as the mole fraction of MgZnO. Finally, the theoretical results are compared with the experimental data reported earlier to crosscheck the validity of this model.

Keywords MgZnO/ZnO HEMT · Current model · DC characteristics · RF characteristics · Cut-off frequency · Maximum operating frequency

1 Introduction

High Electron Mobility Transistors (HEMTs) based on MgZnO/ZnO heterostructure have received considerable attention from the new generation researchers during the last few decades. ZnO is an emerging semiconductor material from II–VI group of the periodic table. It has some exciting material properties such as wide energy band gap (3.37 eV), high electron saturation velocity (3.2×10^5 m/s), high break down field (~3 MV/cm), high exciton binding energy (60 meV) etc. [1–6]. Further, its direct band gap enables it to be a good semiconductor material for optoelectronic applications [7–9]. In addition, it is a non-toxic, eco-friendly, and transparent material. Moreover, it is a radiation hard material and can be used in electronic devices extensively. Besides, the minimum lattice mismatch between MgZnO and ZnO supports itself in constructing a good heterojunction structure essential for optoelectronic applications [10–13].

Several works have been done earlier to study the performance of ZnO HEMT. Some researchers have developed ZnO-based HEMTs in the laboratory and performed different measurements [14, 15]. Some researchers have studied MgZnO/ZnO HEMTs theoretically developing various analytical models considering different issues of contemporary interests. For example, different analytical model of an HEMT based on MgZnO/ZnO heterojunction was developed by Verma et al. [16, 17]. Wang et al. theoretically investigated the impact of barrier thickness fluctuation scattering on the transport characteristic of undoped MgZnO/ZnO heterostructure [18]. Singh et al. have developed an analytical model in graded MgZnO/ZnO heterojunction having a cap layer [19]. Some theoretical works have also been done to study the ZnO HEMT for power switching [20]. Shinde et al. have studied the properties of fluorine-doped ZnO thin films at 673 K substrate temperature and demonstrated different parameters of ZnO like electrical conductivity and optical transmittance, etc. [21–24]. Khan et al. reported

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