DESIGN OPTIMIZATION OF THE GALLIUM NITRIDE HETEROSTRUCTURE FIELD-EFFECT TRANSISTOR WITH A GRAPHENE HEAT-REMOVAL SYSTEM

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I. INTRODUCTION

The self-heating effect has a considerable influence on the characteristics of the heterostructure field-effect transistor (HFET) based on gallium nitride (GaN) [1,2]. To reduce the maximum temperature in GaN HFETs, a variety of thermal solutions has been attempted. These include diamond substrate [3], flip-chip bonding [4], backside metal deposition [5] and heat-eliminating element [6]. We have recently investigated [1] the dc and small signal performance of the HFETs with a graphene heat-removal system closely resembling that used by Yan *et al.* [6]. The graphene heat-eliminating element is connected with a heat sink outside the device structure and is designed specifically for removing the heat immediately from the maximum temperature region, thus providing an additional heat-escape route. To enhance the graphene heat-removal system, we have proposed [2] the formation of a trench in the passivation layer in which a high thermal conductivity material, such as boron nitride, boron arsenide or synthetic diamond is deposited.

This paper is dedicated to the design optimization of the GaN HFET with a graphene heat-removal system enhanced by a trench in the passivation layer filled by diamond.

II. DEVICE STRUCTURE

The main object of the research is a GaN HFET with a graphene heat-removal system shown in Figure 1. After the solidus signs, the region thicknesses are indicated. The source-to-gate and gate-to-drain distances equal to 2 and 3 μm, respectively. The length and the width of the gate are 0.5 μm and 1 mm. The lengths of the diamond layer and the graphene heat-eliminating element equal to 2.8 and 3.9 μm.

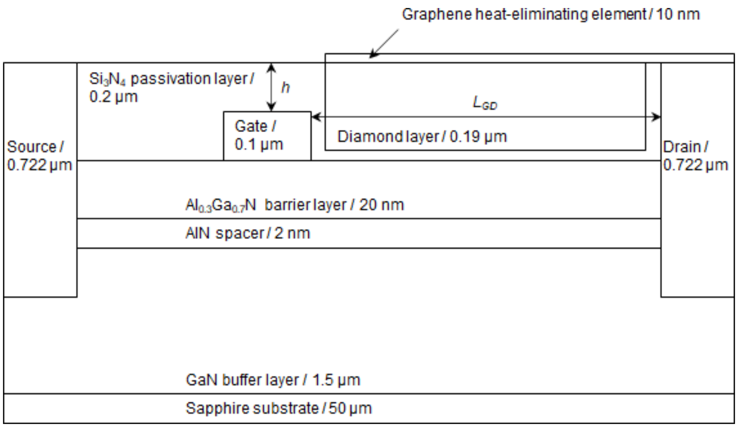

Figure 1. GaN HFET with a graphene heat-removal system

III. RESULTS

In Figure 1, the parameter h denotes the distance between the gate and the top surface of the GaN HFET uncovered by the graphene heat-eliminating element. If the top surface of the device is lowered by 0.05 and 0.1 µm, which corresponds to h values of 0.05 and 0 µm, the cut-off frequency increases by 1.2 and 3.3%, from 33.0 to 33.4 and 34.1 GHz, respectively. The maximum frequency of oscillation grows by 3.0 and 9.0%, from 114.0 to 117.4 and 124.2 GHz, respectively.

Figure 2 shows the dependence of the cut-off frequency and the maximum frequency of oscillation on the gate-to-drain distance (L_{GD}). If the parameter L_{GD} is raised from 3 to 6 µm, leading to an increase in the lengths of the diamond layer and the graphene heat-eliminating element, the cut-off frequency and the maximum frequency of oscillation decrease by 11.0 and 10.0%, to 29.4 and 102.6 GHz, respectively.

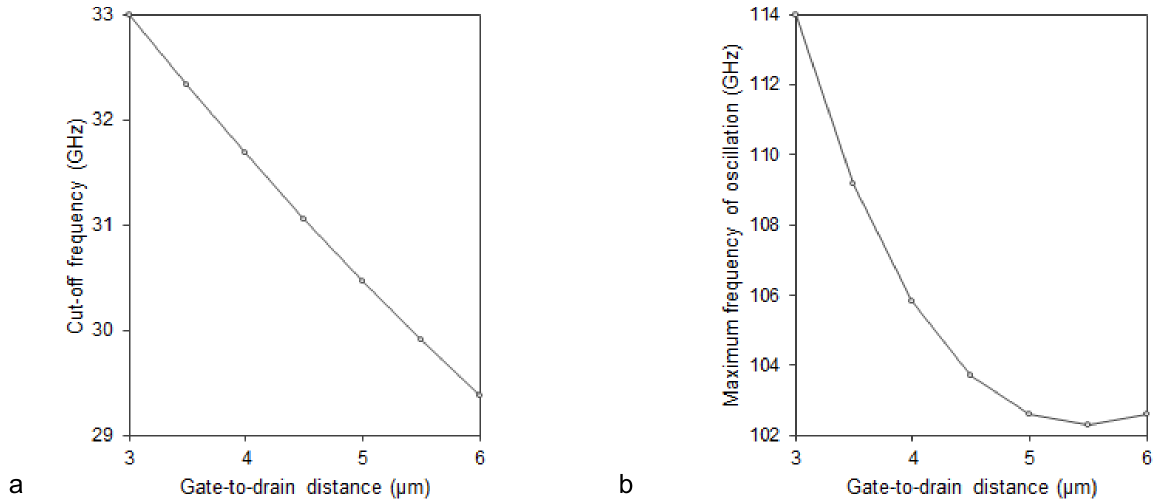

Figure 2. Cut-off frequency (a) and maximum frequency of oscillation (b) as functions of the gate-to-drain distance

IV. CONCLUSIONS

We have conducted the design optimization of the GaN HFET with a graphene heat-removal system enhanced by a trench in the passivation layer filled by diamond. A reduction in the parameter h leads to a relatively small improvement in the small-signal performance quanitites, since the heat-eliminating element approaches the maximum temperature region.

ACKNOWLEGMENTS

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