Finite Element Modeling of an AlGaN/GaN Based VOC Sensor Using COMSOL

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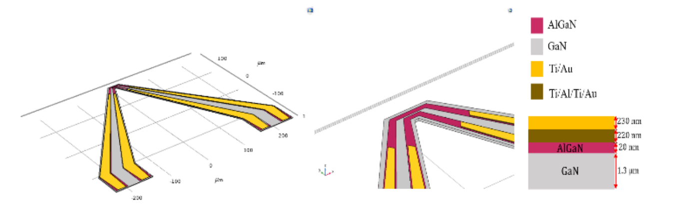
INTRODUCTION: An AlGaN-GaN-AlGaN based dual channel microcantilever has been simulated to compute the temperature profiles in the absence of volatile organic compounds (VOC) at different bias voltages.

- Simulations are performed by varying the bias voltages from 5 V to 30 V with a step size of 5 V
- Using the electric currents (ec) module, the electric field intensity, current density and the electromagnetic loss profiles of the cantilever are computed
- By coupling the ec module with heat transfer (ht) module, the temperature profiles are computed



(a) (b)

Figure 1. **(a)** 3D Geometry of GaN$-Al_xGa_{1-x}N-$GaN ultraviolet photodetector, **(b)** Longitudinal cross section at the tip region of the cantilever

COMPUTATIONAL METHODS: In this model, for the given 3D geometry, the temperature profiles at different bias voltages are computed using the electric currents (ec) and heat transfer (ht) modules in the COMSOL. The electric potential boundary conditions are used to apply the bias voltages to the cantilever device. From the electric potential (V), the electric field intensity (E), current density (J), and electromagnetic losses (Q_e) are computed.

$$E = -\nabla V, \qquad (1)$$

$$J = \sigma . E, \qquad (2)$$

$$\nabla . J = Q_e. \qquad (3)$$

The electromagnetic loss data obtained from the *ec* module is given as input to the *ht* module to solve the heat equation which can be written as

$$\left(\rho \cdot c_p \cdot \vec{u}\right) \cdot \nabla T = \nabla \cdot (\vec{q}) + Q_e, \qquad (4)$$

where $$\vec{q} = k \cdot \nabla T. \qquad (5)$$

In Eq. (4) $\vec{u}$ is the fluid velocity vector, T is the temperature and $\vec{q}$ is the conductive heat flux. Convective and radiative heat losses are also considered in the simulation. The equation to represent the convective heat loss can be written as

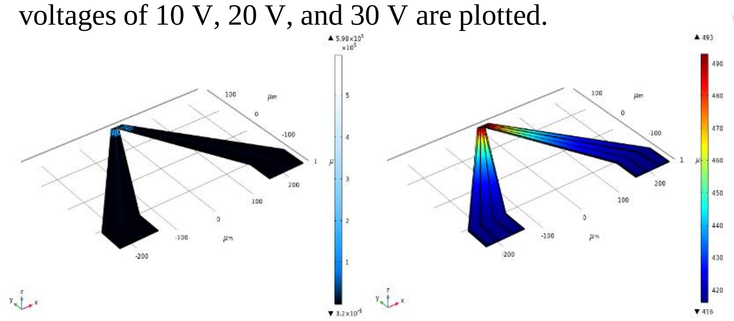
$$-\vec{n} \cdot \vec{q} = q_0, \qquad (6)$$

where $$q_0 = h \cdot (T_{ext} - T). \qquad (7)$$

The equation to compute the radiative heat loss can be written as

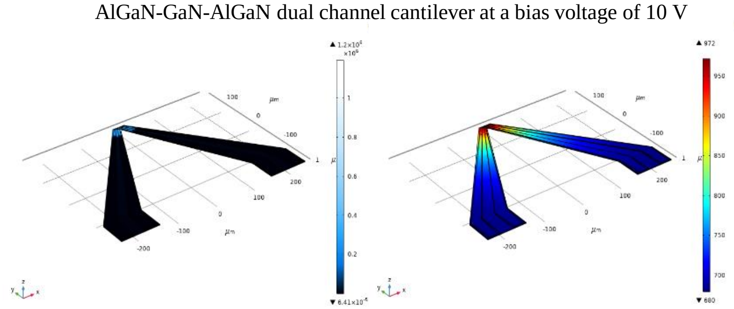
$$-\vec{n} \cdot \vec{q} = \varepsilon \cdot \sigma \cdot \left(T_{amb}^4 - T^4\right), \qquad (8)$$

RESULTS: The electric field intensity, and temperature profiles of the dual channel cantilever at different bias voltages. The bias voltages are varied from 5 V to 30 V with a step size of 5 V. The computed results for bias voltages of 10 V, 20 V, and 30 V are plotted.



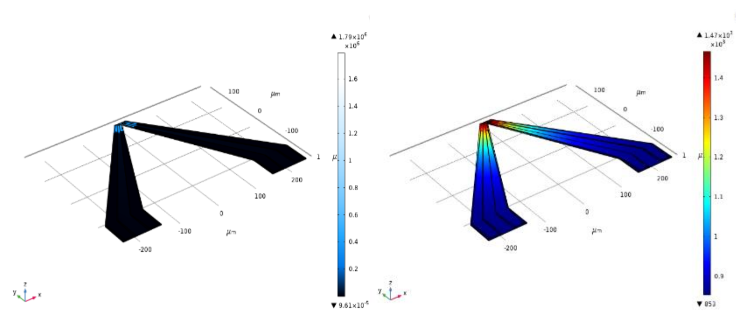
(a) (b)

Figure 2. **(a)** Electric field intensity, and **(b)** temperature profile of an AlGaN-GaN-AlGaN dual channel cantilever at a bias voltage of 10 V



(a) (b)

Figure 3. **(a)** Electric field intensity, and **(b)** temperature profile of an AlGaN-GaN-AlGaN dual channel cantilever at a bias voltage of 20 V



(a) (b)

Figure 4. **(a)** Electric field intensity, and **(b)** temperature profile of an AlGaN-GaN-AlGaN dual channel cantilever at a bias voltage of 30 V

CONCLUSIONS: From the computed results, it can be concluded that at every bias voltage the magnitude of electric field intensity and temperature is maximum at the tip region of the cantilever. Also, as the applied bias voltage increases, the electric field intensity and temperature also increases.

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