# Numerical Simulation of Thermal Runaway in a THz GaAs Photoconductor

S. Sarodia[1], W. Zhang[2], E. Brown[2]

[1]Centerville High School, Dayton, OH, USA; Wright State University, Dayton, OH, USA
[2]Wright State University, Dayton, OH, USA

## Abstract

Ultrafast photoconductor devices provide promising solutions for the generation of terahertz (THz) radiation (300 GHz - 10 THz) for spectroscopic sensing studies at frequencies that have not yet been well-explored. THz photoconductive devices, especially photomixers, are usually limited in output power by device failure thought to be caused by excessive temperatures induced by the laser drive power, the Joule heating from the electrical bias, or both. Therefore, accurate estimation of thermal breakdown point is essential to the understanding of device reliability and failure of photoconductors. We performed a series of simulations with COMSOL Multiphysics® software to determine the electronic and thermal thresholds that are responsible for device failures.

The COMSOL Multiphysics® software was used to establish the electrical and thermal properties of a GaAs photoconductor with a sub-picosecond photocarrier lifetime (0.6 ps) through simulation of the photoconductive device under varying bias voltages. These sources elevated the temperature of the device, as heat was not removed at a sufficient rate by thermal conduction. A photoconductor with interdigitated electrodes was modeled and meshed as a two-dimensional rectangular substrate of length 8 µm with electrodes of width 0.4 µm and separation of 0.8 µm (Figure 1). A position-dependent generation rate, analytically calculated from Beer's Law, was added to the simulation to realistically model carrier generation by illumination. Joule heating from the photocurrent and dark current and optical heating from incident light served as the two primary heat sources inputted into the Heat Transfer Module. By taking advantage of the powerful multiphysics capabilities in COMSOL Multiphysics® software, we coupled the Semiconductor Module with the Heat Transfer Module to compute the steady-state temperature distributions for a variety of bias voltages.

Using a sweep through various bias voltages, the steady state simulation converged for low bias. However, beyond a maximum voltage, device properties indicated the presence of a positive-feedback thermal runaway effect which is fundamentally non-steady state. The I-V plot of the device was linear for low bias voltages, but exhibited deviation from its previously linear form above that, indicating a corresponding sharp rise in photocurrent. Additionally, the average electron concentration in the device rapidly increased near the breakdown voltage. It was found that the root cause of the thermal runaway is thermal ionization of the deep levels required for ultrafast recombination. Furthermore, the simulation results revealed a strongly quadratic

relationship between applied bias voltage and average device temperature for low biases, as was expected, confirming the validity of our module coupling. In this manner, COMSOL Multiphysics® software can be used to accurately and cheaply determine device thresholds for thermal runaway and breakdown.

## Figures used in the abstract

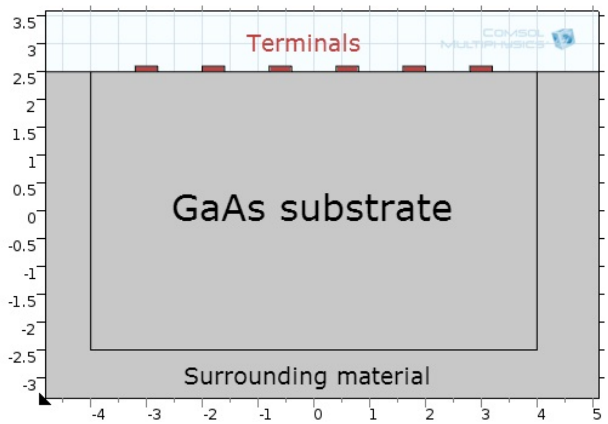


**Figure 1**: The photoconductor geometry model.