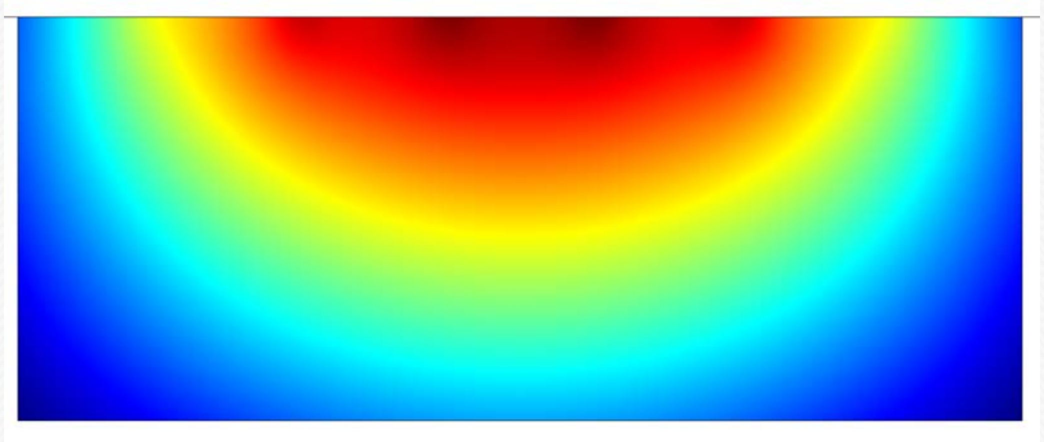
Numerical Simulation of Thermal Runaway in a THz GaAs Photoconductor

Shivam Sarodia[1,2], W. Zhang[2], E.R. Brown[2]
1. Centerville High School, Dayton, OH, USA
2. Wright State University, THz Sensors Group, Dayton, OH, USA



THz Sensors Group

WRIGHT STATE UNIVERSITY

COMSOL CONFERENCE 2014 BOSTON

Introduction

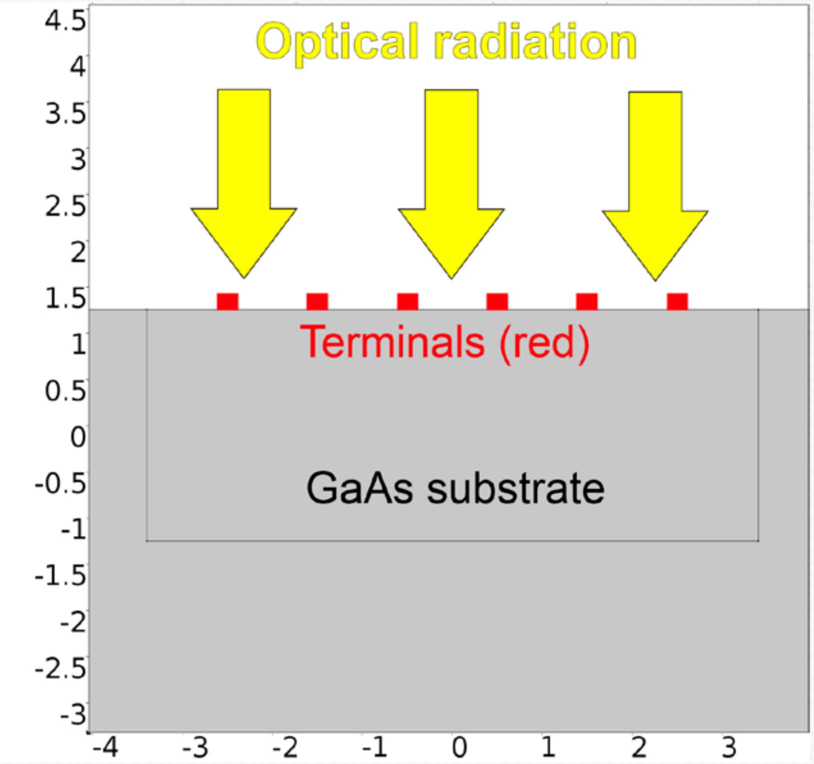
- Terahertz radiation applications:
  - Medical
  - Security
  - Academic
- Photomixers are a promising source of THz radiation
- Output power is thought to be limited by excessive device heating
- Breakdown properties are essential for understanding device reliability and failure

Hypothesis

- Sub-picosecond carrier lifetime required for THz generation
- High deep-level trap density enables sub-picosecond lifetimes
- **Breakdown occurs due to runaway from thermal ionization of deep-level traps**
- As temperature increases:
  - Valence carrier concentrations increase
  - Dark current increases
  - Device temperature further increases

Method: Geometric Model

Photograph of a 9x9 µm physical photomixer. The interdigitated electrodes are visible near the image center.



Our 2D model for the photomixer device. The GaAs outside the active region was modeled with a Scaled Geometry.

Method: Computational Models

- Heat transfer equation
  - Joule heating

$$Q/V = \mathbf{J} \cdot \mathbf{E}$$

  - Optical heating

$$Q/V = \alpha I e^{-\alpha y}$$

- Semiconductor and electrostatics
  - Solved with the COMSOL Multiphysics Semiconductor Module
  - Poisson’s equation
  - Drift-diffusion equation
  - Shockley-Read-Hall recombination

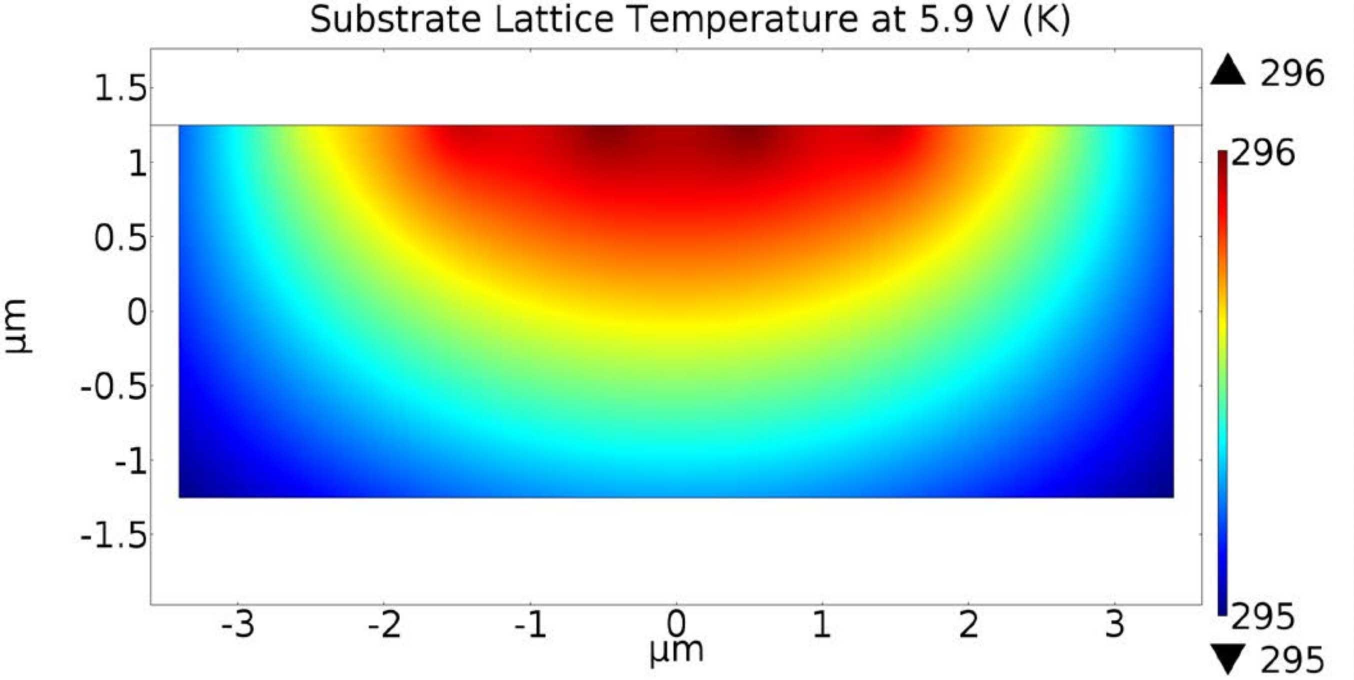
Method: Computational Models (cont.)

- Dopant ionization fraction was set manually

$$N_d^+/N_d = ce^{-1500/T}$$

  - Dopant ionization increases with increasing T, per hypothesis
  - Assumes a very high fraction of trapped carriers
- Optical absorption causes generation
  - Beer’s Law
  - User Defined Recombination

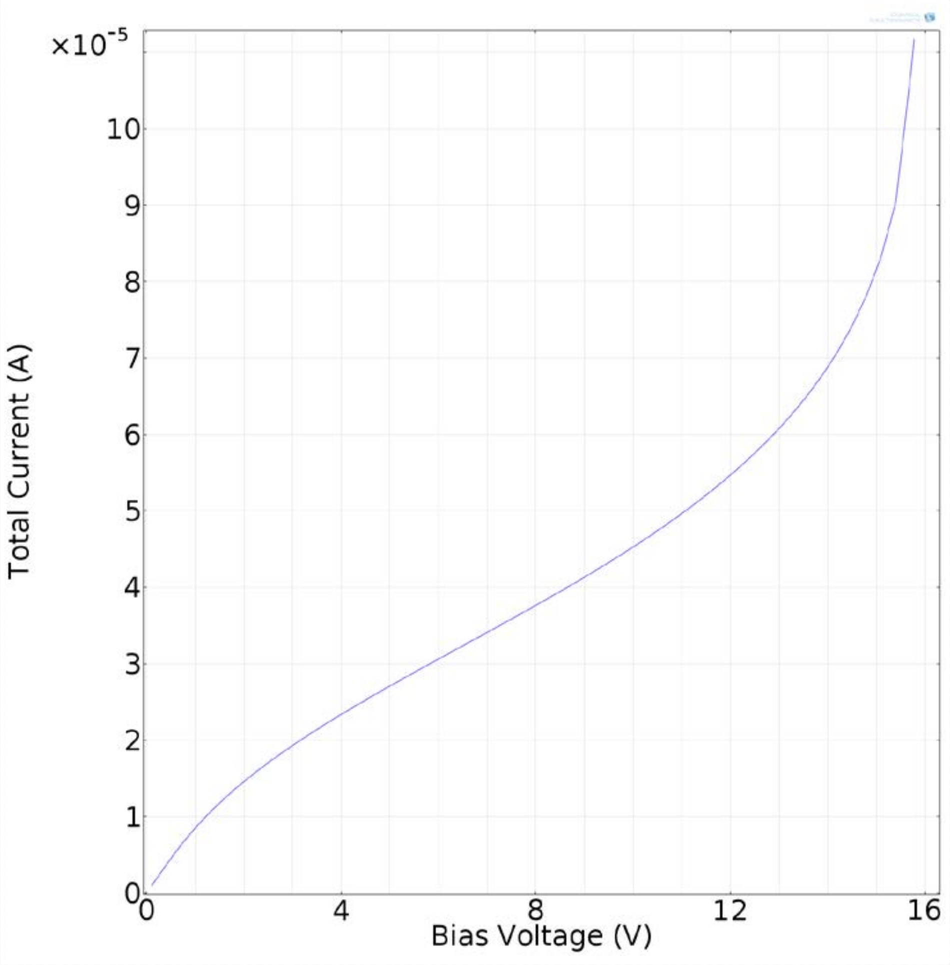
Results: Temperature Distribution



Device temperatures at 5.9 V bias. Note the elevated temperature near the electrodes, where the effect of Joule heating is greatest.

Results: I-V Plot

Total Current vs Bias Voltage of Photoconductor



Thermal runaway occurs near **15.7 V**

Conclusion

- Failure behavior of simulated device is characteristic of thermal breakdown
- Qualitative agreement exists between COMSOL results and breakdown behavior observed in real devices
- **Results support the hypothesis that thermal breakdown stems from ionization of deep-level traps**
- Future work:
  - Seek quantitative agreement between COMSOL results and experimental data
  - Investigate relationship between breakdown voltage and device parameters

Questions?