

Master's Thesis Defense Announcement
Mechanical and Aerospace Engineering Department
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Analytical and simulation modelling of the thermal runaway phenomenon in MOSFET semiconductors

By

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Abstract

MOSFETS (Metal Oxide Semiconductor Field Effect Transistors) are a popular type of active current carrying device. The need for higher performance and faster switching times has led to designs which use low gate source voltage where heat conduction is dominated by charge carriers. The concentration of charge carriers increases with an increase in temperature, causing more current to flow as the temperature increases. As a result, the device draws more current as temperature increases, causing further temperature rise. As the device temperature increased, it would draw more current and cause further temperature rise. This is a positive feedback loop which may eventually result in thermal runaway. This work attempts to capture the physics of the thermal runaway phenomenon using a one-dimensional heat transfer model. The heat-generating channel region of the device occupies around 90% of the physical area of the device. This allows the heat transfer to be considered as one-dimensional for the purpose of analysis. The Laplace transform technique is used to solve the temperature field in the channel. For any given MOSFET, manufacturers typically provide a (SOA) safe operating area chart which shows the maximum tolerable currents for a range of voltages. The one-dimensional model is validated by using it to try and match the maximum current predictions given in the SOA chart for 4 different devices. The model showed good agreement with the SOA data. It shows the correct trend of reducing currents for increasing voltages as well as the same slope for the current-voltage curve.

The one-dimensional heat transfer approximation is predicated on the fact that the heat generating channel occupies 90% of the area of the device. To check the validity of this assumption, a simulation of the MOSFET was set up. The simulation accounts for heat transfer in all 3 spatial dimensions. In particular, the influence of the channel width on the maximum tolerable current was investigated. Results for a channel width of 90% of the device area showed better agreement with the one-dimensional model than the channel width of 50%. In summary, this mathematical model automates the process of generating the safe operating area (SOA) charts and provides a fast and convenient alternative to the manual testing of MOSFETs