Heavy Ion Transport in SiC-Based Power Devices

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Abstract

Single-event burnout (SEB) phenomenon is studied using a unified physics model between radiation transport and device response. The charge carrier distribution is modeled using a double Gaussian function to include ion and delta-ray contributions. 3D TCAD electro-thermal simulations were performed on a high voltage SiC JBS diode which agree with experimental results of SEB in SiC power devices.

Motivation

• SiC-based power devices are susceptible to heavy ions with relatively low LETs
• Triggering and failure mechanisms of SEB are not yet fully understood
• Modeling techniques are needed to understand SEB triggers and behaviors

Heavy Ion Transport

• Monte Carlo radiation transport code MCNP6.2 is used for modeling 1289 MeV silver (Ag) ion strike process in SiC
• Heavy ions are highly ionizing and create free electrons (delta-rays)

Charge Carrier Distribution

• High fidelity radiation transport physics model and device physics simulator are linked
• Data from the radiation transport physics model is fitted to a linear combination of Gaussian functions
  \[ \varphi(x) = A \exp\left(\frac{x^2}{a^2}\right) + B \exp\left(\frac{x^2}{b^2}\right) \]
  where \( a, b, A, \) and \( B \) are fitting parameters, \( x \) is radius, and \( \varphi(x) \) is charge carrier density

3D Device Simulations

• Sentaurus from Synopsys is used for full 3D transient electro-thermal simulations
• Notional JBS diode similar to 1200V commercially available devices is modeled

Results

• Device peak temperature was predicted based on three charge carrier distribution models: double Gaussian fit, simplistic, and ion core models
• Simplistic model uses a constant width and LET while ion core model uses a Gaussian only for heavy ion contributions
• All models reach temperatures over 3000 Kelvin where simulations are terminated upon achieving burnout condition

Conclusions

• Significant difference in device response to heavy ion strikes using simple approximations and those backed by high fidelity radiation simulations
• Heavy ion transport model is critical in modeling device response

References


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