Advanced quasi-self-consistent Monte Carlo simulations of non-stationary-state electron and phonon transport in nanometer-scale Gallium Nitride High Electron Mobility Transistors (HEMTs)

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As a means of investigating both the electrical and thermal properties of nanometer-scale electron devices within a reasonable computing time, we previously proposed a quasi-self-consistent Monte Carlo simulation method that used two new procedures: (i) a local temperature determination using the simulated phonon spatial distribution and feedback to update the electron-phonon scattering rates and (ii) a new algorithm which enable us to calculate long-time phonon transport by introducing different time increments for the electron and phonon transport and a replica technique for phonon generation map [1, 2]. In order to improve the quantitative accuracy and self-consistency of the simulation, we introduced (i) spatially dependent electron-phonon scattering rates that are calculated directly using a simulated phonon distribution (not the local temperature) taking into account (ii) the energy dependence of the phonon group velocity and phonon-phonon scattering rate and (iii) positive polarization charges due to piezoelectricity at the AlGaN/GaN interface [3]. Using this advanced Monte Carlo method, we succeeded in simulating the current-voltage characteristics and thermal resistance of nanometer-scale GaN High Electron Mobility Transistors (HEMTs), with which a quantitative evaluation could be made using actual devices [3]. We also examined the convergence of this self-consistent Monte Carlo model.

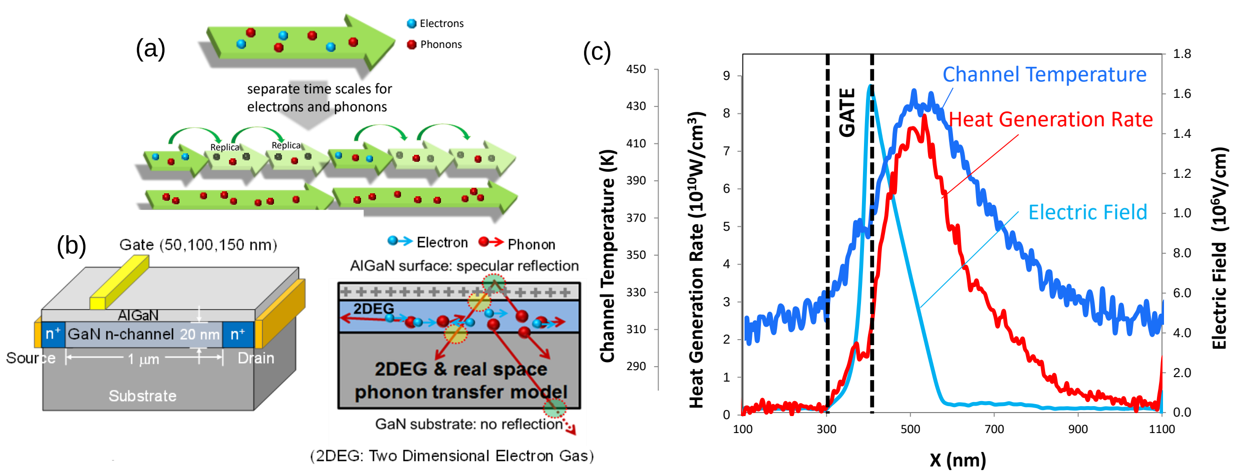

Fig. 1: (a) Schematic diagram of quasi self-consistent simulation procedure for electron and phonon transport, (b) two-dimensional AlGaN/GaN HEMT model and boundary-reflection models for electrons and phonons, and (c) profiles of local channel temperature, heat generation rate, and electric field in the channel (Vgs=1 V, Vds=20 V) [3] .

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[2] T. Misawa, S. Oki and Y. Awano, *Proceedings of IEEE The International Conference on Simulation of Semiconductor Processes and Devices (SISPAD)*, 2013, pp. 308-311, (2013)
[3] N. Ito, T. Misawa and Y. Awano, *Proceedings of IEEE The International Conference on Simulation of Semiconductor Processes and Devices (SISPAD)*, 2016, pp. 349-352, (2016)