熱輸送のスペクトル学的理解と機能的制御
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実績報告書

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分極場工学による界面フォノン輸送の最適化

§1. 研究成果の概要

Due to the tremendous minimization and high-power requirement in the AlGaN/GaN high electron mobility transistors (HEMTs), efficient thermal management for the heat dissipation is becoming an urgent issue. The challenge lies in the poor physical understanding of the thermal transport through the solid-solid interface between HEMT and the heat spreader (typical diamond) due to their acoustic mismatch, leading to a large thermal boundary resistance (TBR) at the GaN/diamond interface. To enhance the phonon transport from GaN to diamond, we propose to utilize the piezoelectric effect inside the nitride materials through lattice mismatch. The low frequency phonons are significantly affected by the piezoelectric field, which can enhance the thermal transport at the heterojunctions. The AlN/GaN nano-laminated/superlattice structures with the large piezoelectric field are proposed as the transition layer between GaN and diamond to reduce the TBR.

The research progress in Y2019 is: 1) to experimentally demonstrate that the piezoelectric effect can reduce the TBR in the GaN-based materials; and 2) deposit the high-quality AlN/GaN superlattices by metal-organic chemical vapor deposition (MOCVD). From theoretical calculations, the phonon group velocity and mean free path can be enhanced due to the lattice distortion. The piezoelectric effect can be generated at the nitride hetero-interfaces due to the lattice mismatch. We firstly demonstrated the piezoelectric effect on the thermal properties of GaN from experiments. The mechanical stress was performed to the GaN films, and it was found that the TBR is decreased with increasing the stress. The results further confirm the feasibility of the proposed concept. By using MOCVD, the high-quality GaN/AlN superlattices with the ultra-flat nano-interface morphology was obtained. This achievement provides the solid basis for the fabrication of the high-quality interlayers using piezoelectric effect to enhance the phonon thermal conductivity.