The phonon–drag effect in low-mobility gallium nitride epilayers

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We have used phonon imaging to study the drag current induced by nonequilibrium acoustic phonons in low mobility n–type gallium nitride (GaN) epilayers. This material and related compounds are of great interest due to their potential applications in electronic and opto-electronic devices. The phonon–drag imaging technique, in connection with corresponding numerical simulations, provides direct information about the electron–phonon interaction and phonon and carrier dynamics.

The sample used in the experiments was a Si-doped GaN epilayer grown by molecular beam epitaxy on sapphire. Phonons were generated by illuminating a metal film on the back face of the substrate (opposite the GaN device) by a pulsed laser beam. The phonon pulses traveled ballistically from their local source to the GaN device and the drag currents induced by them were recorded as function of the phonon source position. Additionally, to distinguish between the contributions of the different phonon modes, the time evolution of the phonon induced signals was measured. We found the drag current was due mostly to transverse polarized phonons and its magnitude was much greater than predicted using the free electron gas model of the phonon drag [1].

The resulting experimental images are a superposition of the properties of phonon kinetic, electron–phonon coupling and electron transport in GaN. For that reason numerical calculations of the phonon–drag current including the effects of phonon focussing in the sapphire substrate, acoustic anisotropy in the GaN and acoustic mismatch between the different materials were performed. We discuss the deviations from the free electron gas model of phonon drag and present attempts to include the effects of electron localization in the theory.

[1] N.M. Stanton, A.V. Akimov, A.J. Kent, S.A. Cavill, T.S. Cheng and C.T. Foxon, *Appl. Phys. Lett.* **77**, 3403 (2000).