Growth-microstructure-thermal Property Relations in AlN Thin Films

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AlN thin films are enabling significant progress in modern optoelectronics, power electronics, and microelectromechanical systems. The various AlN growth methods and conditions lead to different film microstructures. In this report, phonon scattering mechanisms that impact the cross-plane (κz; along the c-axis) and in-plane (κr; parallel to the c-plane) thermal conductivities of AlN thin films prepared by
various synthesis techniques are investigated. In contrast to bulk single crystal AlN with an isotropic thermal conductivity of ∼330 W/m K, a strong anisotropy in the thermal conductivity is observed in the thin films. The κz shows a strong film thickness dependence due to phonon-boundary scattering. Electron microscopy reveals the presence of grain boundaries and dislocations that limit the κr. For instance,
oriented films prepared by reactive sputtering possess lateral crystalline grain sizes ranging from 20 to 40 nm that significantly lower the κr to ∼30 W/m K. Simulation results suggest that the self-heating in AlN film bulk acoustic resonators can significantly impact the power handling capability of RF filters. A device employing an oriented film as the active piezoelectric layer shows an ∼2.5Å~ higher device peak temperature as compared to a device based on an epitaxial film.