Effect of Built in Polarization on Thermal Properties of InGaN/GaN Heterostructures

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Abstract : An important feature of InxGa1-xN/GaN heterostructures is strong built-in polarization (BIP) electric field at the hetero-interface due to spontaneous (sp) and piezoelectric (pz) polarizations. The intensity of this electric field reaches several MV/cm. This field has profound impact on optical, electrical and thermal properties. In this work, the effect of BIP field on thermal conductivity of In_xGa_{1-x}N/GaN heterostructure has been investigated theoretically. The interaction between the elastic strain and built in electric field induces additional electric polarization. This additional polarization contributes to the elastic constant of In_xGa_{1-x}N alloy. This in turn modifies material parameters of In_xGa_{1-x}N. The BIP mechanism enhances elastic constant, phonon velocity and Debye temperature and their bowing constants in In_xGa1-_xN alloy. These enhanced thermal parameters increase phonon mean free path which boost thermal conduction process. The thermal conductivity (k) of InxGa1xN alloy has been estimated for x=0, 0.1, 0.3 and 0.9. Computation finds that irrespective of In content, the room temperature k of In_xGa_{1-x}N/GaN heterostructure is enhanced by BIP mechanism. Our analysis shows that at a certain temperature both k with and without BIP show crossover. Below this temperature k with BIP field is lower than k without BIP; however, above this temperature k with BIP field is significantly contributed by BIP mechanism leading to k with BIP field become higher than k without BIP field. The crossover temperature is primary pyroelectric transition temperature. The pyroelectric transition temperature of In_xGa_{1-x}N alloy has been predicted for different x. This signature of pyroelectric nature suggests that thermal conductivity can reveal pyroelectricity in $In_xGa_{1-x}N$ alloy. The composition dependent room temperature k for x=0.1 and 0.3 are in line with prior experimental studies. The result can be used to minimize the self-heating effect in In_xGa_{1-x}N/GaN heterostructures.

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