022

HEAT TRANSFER ANALYSIS OF THIN & ROUGH SILICON NANOWIRES

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SUMMARY: This study investigates the thermal behavior of a 22 nm silicon nanowire, whose thermal conductivity is proportional to T^1 unlike the Debye's T^3 law. To analyze heat transfer in the nanowire, each of LA (longitudinal acoustic) and TA (transverse acoustic) phonon band is divided into 6 sub-branches, and Cv_g of 12 sub-branches are theoretically calculated. By comparing Cv_g of 12 sub-branches with the total Cv_g extracted from experimental data, the contribution of each phonon branch to the total heat transfer rate is calculated. The results show that TA phonon is dominant at low temperature by up to 80%. On the other hand, LA phonon is plays a dominant role at high temperature by up to 93%. Higher energy phonons show much more contributions on the total heat transfer rate in the silicon nanowire than lower energy phonon branches do. The linear combination of 12 phonon branches shows good agreement with T^1 slop at low temperature. A nanowire with rough surface increases the boundary scattering so that the thermal conductivity decreases to the order of amorphous one. Comparison of Cv_g between a smooth 56 nm silicon nanowire and a rough 50 nm silicon nanowire shows that the surface roughness highly enhances the boundary scattering of higher energy phonons.