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Size effects on non-local heat transfer in one-dimensional and quasi-one-dimensional MOSFET channels

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Abstract
In the present study, the nonlocal dual phase lag phenomenological model is used to study heat transport in nanoscale MOSFET transistors. Also, the thermal properties of the studied materials, namely the phonon mean free path and the size-dependent thermal conductivity, are considered. Here, the quasi-one-dimensional materials of Titanium Trisulfide and Indium Selenide, which have recently been proposed as interesting replacements for the silicon channels in transistors, and carbon nanotubes are studied. The nonlocal heat transfer framework is also used to study the thermal behavior in silicon and the results obtained, are compared with those of the other materials. First, the thermal properties are assumed to be constant for all the materials and then, their size-dependency is taken into account. In the case of constant properties, for all the channels except the carbon nanotubes, the maximum temperature is almost the same, but the speed of propagation of hot spot effects and consequently the temperature increase along the length of the material is higher for silicon with higher thermal conductivity. This is also seen for carbon nanotubes, with the difference that this material experiences a lower maximum temperature. Only one-quarter and one-half of the length of the quasi-one-dimensional materials indium selenide and titanium trisulfide, respectively, have been affected through the heating zone. Therefore, the steady- state also occurs later for these two quasi-one-dimensional materials. In terms of thermal diffusion, these two materials are not superior to silicon, and thermal diffusers must be used in order to utilize these two materials instead of silicon channels**.**Considering the size-dependent properties, although the maximum temperature does not change significantly except in carbon nanotubes, the temperature and heat flux decrease throughout the channel length. This temperature decrease is more significant in carbon nanotubes and silicon materials, which have larger phonon mean free distance, respectively. The reason for this is the direct effect of increasing this parameter on the rate of change of the effective mean free distance and thermal conductivity. The obtained results show the importance of simultaneously considering non-local and phase lag effects alongside the size-dependent thermal properties to obtain accurate results for temperature and thermal distributions inside the transistors.

Keywords: Micro/nanoscale heat transport, Dual phase lag model, Thermal management,, Quasi-one-dimensional materials

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