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Nanoscale thermal management with newly proposed 2D MOSFETs

In nano-electronic technology, the overall thermal reliability is recognized by the temperature of the hottest zone on the die. Accordingly, the transistor with a lower maximum temperature is easier kept under the working threshold temperature. Thus, the material selection and also the heat spreader design, as the thermal management solutions for controlling the temperature of the hotspots, are always the issues of concern. While the attempts to find the proper methods for heat removal are being performed, looking for low-dimensional silicon replacement nominees, with the lowest peak temperature, is also developing as the easier and more feasible choice for the transistor industry. The present research investigates the thermal reliability of the 2D MOSFETs, tracking the achieved peak temperature under the influence of self-heating. The framework is the non-equilibrium Monte-Carlo simulation of the phonon Boltzmann equation. This formalism is used to comparative study of the well-known 2D replacements for silicon channels such as graphene, blue phosphorene, germanene, silicene, MoS_2, the 2D complex MA_2Z_4 structures of MoSi2N4 and WSi2N4, and the recently famous 2D silicon carbide. Our calculations establish that ambient stable WSi_2N_4 presents the lowest peak temperature rise in comparison to the other studied 2D channels with the peak temperature rise of 400 K in response to the heat source of Q=1×10 W/m^3. The 2D SiC with a very high melting point of 4050 K, stands in second place with the maximum temperature of 480 K, while MoSi2N4 and blue phosphorene occupy the next places. Consequently, we have obtained that WSi_2N_4, 2D SiC, $MoSi_2N_4$ and blue phosphorene are suitable for thermally efficient transistors. In other words, the limit of the energy and economic cost of producing the verified materials chips meets the value of the product for the enterprises.

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