Enhanced nanoscale heat dissipation in electronic and photonic device components by hBN

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Abstract

The rapid advancement of integrated circuits has made heat dissipation a critical bottleneck, particularly in high power density devices [1]. Hexagonal boron nitride (hBN) has emerged as a promising material for thermal management in chip components due to its high in-plane thermal conductivity and high thermal anisotropy [2]. Its large bandgap ensures both electrical insulation and wideband optical transparency, making it ideal for both electronic and photonic applications. However, conventional transfer method usually suffers from polymer residue and poor thermal contact [3]. Here, we employ the "hot pick-up" technique, which is a dry transfer technique that avoids polymer contamination at the interface [4]. The clean interface is confirmed by AFM topography. The nanoscale heat dissipation in gold and hSiGe nanowires —key building blocks of electronic and photonic integrated circuits, respectively, is significantly enhanced. For gold nanowires, encapsulation with hBN/Graphene/hBN stacks results in approximately a 40% increase in breakdown current density compared to bare gold nanowires, along with a significantly reduced temperature ramp rate. For hSiGe nanowires, hBN-covered hSiGe nanowires exhibit no blackbody radiation within the measured fluence range up to $8\,\mathrm{mJ\,cm^{-2}}$, unlike nanowires on SiO_2, where blackbody radiation emerges at a relatively low fluence. These results highlight the promise of clean-transferred hBN and hBN-based heterostructures as effective thermal management solutions for next-generation nanoscale chip components.

References

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