Ultracompliant Nanowire Array as High-Performance Thermal Interface Materials

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Thermal interface resistance which, as identified, constitutes more than 50% of the overall thermal resistance in thermal management, has posed a severe constraint on the further power density improvement of modern electronics. There is a drive towards developing high-performance thermal interface materials (TIMs). Currently, assorted TIMs including solders, polymers, and low-dimensional composites still show downsides either from the aspect of thermal conductive capability or mechanical ductility. Here, we demonstrate an innovative TIM based on copper nanowire array composite enabling to surmount the above difficulties. The vertically aligned copper nanowires significantly enhance the cross-plane thermal conductivity. Concurrently, the long aspect ratio of the copper nanowire meets the high mechanical compliance need for accommodating the stress and conforming to the mating surfaces, and therefore, highly improves its long-term reliability. On both the top and bottom sides of copper nanowire array structure, ultrathin tin layers are electroplated for bonding two mating surfaces. In a fully bonded configuration, this TIM exhibits extremely low thermal resistance of ~0.5 $mm^2 \cdot K/W$, which is about two times smaller than the state-of-the-art TIMs. Mechanically, it shows 2-3 orders of magnitude lower than bulk copper in compressive elastic modulus and shear modulus measurement. Such reduction on thermal resistance and increment on mechanical compliance contribute to its long-term operation reliability with >1200cycles when subjected to thermal power cycling. By leveraging this high-performance thermal interface material into electronic systems, regardless of microelectronics or massive data centers, they will be able to operate at lower temperature or at higher power density with higher performance.