Thermal transport in heterogeneous nanoscale interfaces

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Thermal transport across material-fluid interfaces is crucial in several technologies, such as smart nanoparticle fluid suspensions for thermal management, medical applications using therapeutic nanoparticles, electronic and photonic devices, or thermal management in electronic components in phones and electric vehicles. A current challenge in thermal transport is achieving spatial control at the nanoscale. Such control could bring benefits and expand the scope of thermal transport solutions in technological applications and materials science. Here, we will discuss novel strategies to control heat transport in nanoscale material-fluid interfaces, involving plasmonic and dielectric materials. We use non-equilibrium molecular dynamics simulations, a unique tool that allows us to interrogate the relevant heat transport mechanisms at the atomic level, to guide the design of heterogeneous interfaces with contrasting chemical compositions. These interfaces provide a route to sustain and modulate very large thermal gradients across nanometer length scales, expanding the scope of nanomaterials as e.g. nanoheaters in nanomedicine applications. We will discuss the implications of this work on the applicability of the continuum classical theory of thermal transport to nanoscale systems, as well as on the development of theories to investigate the motion of colloids in suspensions under the influence of thermal fields.