Semi-Empirical Model for the Thermal Conductivity of Amorphous Polymers Thin-films

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Amorphous thin-films are integral components in all integrated circuits. As devices are miniaturized, they routinely encounter heat dissipation problems. For amorphous thin-films, a robust model – beyond the Cahill-Pohl or Einstein models – for predicting their thermal conductivity is needed. More generally, little is understood about the fundamental microscale physics that underpins thermal conductivity in amorphous materials and much can be learned about the vibrations in amorphous materials. With this goal in mind, we developed an empirical model based on Allen-Feldman's classification of vibrational modes – vibrons, which are divided into propagon, diffusons, and locons. In the presented work we investigate the low temperature (~10-30 K) thermal conductivity of amorphous polymer films, to better understand the nature of the propagating modes, using the well-established 3-omega technique. This technique was selected because of its accuracy at low temperature. Using these results, we establish cut-off frequencies and temperatures that correspond to modal transitions. We then extend this empirical model to understand vibrational modes that are more diffusive in nature, and vibrational modes that are more localized in nature. Using this model we are able to extract characteristic thermal length-scales, which then provide us with the engineering tools to control the thermal conductivity in these materials.