Effective Thermal Properties of Multilayered Systems with Interface Thermal Resistance in a Hyperbolic Heat Transfer Model

José Ordóñez-Miranda C, S and Juan José Alvarado-Gil
CINVESTAV Mérida, Mérida, Yucatán, México

The one-dimensional thermal wave transport in multilayered systems with interface thermal resistance is studied using the Cattaneo-Vernotte hyperbolic heat conduction equation [1], considering a modulated heat source for both Dirichlet and Neumann boundary conditions. In the thermally thin regime, with Dirichlet boundary condition, the well known effective thermal resistance formula is obtained; while for Neumann problem only the heat capacity identity is found, due to the fact that in this case this boundary condition cannot become asymptotically steady when modulation frequency goes to zero. In contrast in the thermally thick case, an analytical expression, for both Dirichlet and Neumann conditions are obtained for the effective thermal diffusivity of the whole system in terms of the thermal properties of the individual layers and their interface thermal resistance. It is shown that a strong enhancement on the effective thermal diffusivity is remarkable when the thermalization time and the thermal relaxation time are comparable. The limits of applicability of our equation, in the thermally thick regime are shown to provide useful and simple results in the characterization of layered systems. It is shown that when the thermal relaxation times of the component layers tend to zero, our equation reduces to the results obtained using the Fourier law [2]. The role of the thermal relaxation time and the interface thermal resistance, and the implications of our results in the enhancement of heat transport observed in recently reported experimental data [3] are discussed.

[1] D.D. Joseph, L. Preziosi, Heat waves, Rev. Mod. Phys. 61 (1) (1989) 41-73.
[2] J.L. Lucio, J.J. Alvarado-Gil, O. Zelaya-Angel and H. Vargas, On the thermal properties of a two-layer system, Phys. Stat. Sol. (a) 150 (2) (1995) 695-704.
[3] J.A. Eastman, S.U.S. Choi, S. Li, W. Yu, L.J. Thompson, Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing copper nanoparticles Appl. Phys. Lett. 78 (6) (2001) 718–720.