ABSTRACT

Natural convection gas flows in vertical microchannels with isothermal wall condition along with velocity slip and temperature jump are numerically investigated, in order to analyze the influence of the entrance (developing) region on the overall heat transfer characteristics. A large channel aspect ratio is considered to achieve both hydrodynamically and thermally fully developed flow conditions at the channel exit. A wide range of Rayleigh number is covered to analyze very short and relatively large entrance lengths in a unified mathematical framework. Within slip flow regimes ($Kn < 0.1$), local and average value of Nusselt number are computed, by invoking the Navier-Stokes equations and energy conservation equation. The numerical predictions are compared with published literature for fully developed flow field. Contrasting features in the heat transfer rate predictions with and without the considerations of the entrance region effects are delineated.

Forced convection liquid flows in microchannel heat sink are investigated by a comprehensive and systematic semi-analytical methodology for characterization of thermal and hydrodynamic performance of single-phase liquid cooled microchannel heat sink using both developing and fully developed laminar flow and heat transfer correlations. Effect of various design parameters such as eccentricity and footprint of heat source or device, thickness of heat sink base, channel aspect ratio, number of microchannels or fins, coolant flow rate, and thermal conductivity of heat sink material are enumerated. Finally, analytical results are compared with experimental data and found to be in good agreement. It is demonstrated that the classical Navier-Stokes and energy equations can adequately predict the fluid flow and heat transfer characteristics of microchannel heat sink. The methodology proposed in this study would help to design and optimize the microchannel heat sinks that exhibit superior thermal performance with low pressure drop systems.

Thin film evaporation in a microchannel is characterized using a semi-analytical formalism developed in this part of the study. The mathematical model is based on the conservation equations for momentum, mass and heat transport in the liquid phase linked to the vapor phase through the interfacial equilibrium constraints. Augmented Young-Laplace equation is used for predicting the pressure difference, due to capillary and disjoining pressure, between vapor and liquid at the liquid-vapor interface. Mass transfer across the liquid-vapor interface is governed by the interfacial thermo-kinetic constraints. Equilibrium vapor pressure corresponding to the liquid-vapor interface temperature is calculated accounting the effect of disjoining and capillary pressure. In the first of the study, traditional disjoining pressure formulation with no-slip boundary condition is employed for evaluating transport characteristics for various channel sizes and degrees of superheat. The predicted results are compared with published literature and found to be in good agreement. Also, high heat transfer ability of the evaporating thin film is demonstrated. In the second part of the study, slope- and curvature-dependent disjoining pressure with no-slip boundary condition is employed for evaluating transport characteristic for various degrees of superheat and dispersion constants. In the third part of the study, implications of apparent slip stems from the continuum and rarefied depleted gas layers adhering to the wall, on evaporation transport characteristic are studied along with the traditional disjoining pressure formulation for different thickness of depleted gas layers, superheats and dispersion constants. In fourth part of the study, implication of real slip at the liquid-wall interface is studied along with the traditional disjoining pressure for different values of superheats and dispersion constants. Contrasting results are presented for film thickness profiles and heat or mass fluxes.

Key Words: natural, forced, convective, velocity slip, temperature jump, entrance region, developing flow, developed flow, Nusselt number, Rayleigh number, microchannel, characterization, single-phase, thermal conductivity, optimize, methodology, thin film, evaporation, disjoining pressure, capillary pressure, vapor pressure, interface, apparent slip, real slip, superheat, dispersion constant, continuum, rarefied, depleted layer, transport.