A review on channels for cooling applications

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Abstract**—**Continuous miniaturization and high-end demand for digital devices and appliances have contributed to a dramatic rise in heat flux generation. As a result, traditional coolants and cooling methods are increasingly falling short of meeting the ever-increasing cooling requirements and challenges of these electronic devices that produce high heat. In this article, the recent studies performed on the use of channels in microelectronic devices, electronic devices, and refrigeration cooling applications are reviewed. Another intention behind this review is to explain the challenges of different design for channels for electronic cooling. Many researchers have reported on micro/mini channel heat sinks for cooling electronics for the past 5 years. Furthermore, the prospects for future study and the issues emerging in this field are introduced and explored.

Keyword: ***Microelectronics, Electronics, Refrigration.***

I. Introduction

The electronics industry has substantial growth in recent years, though there are still some important problems for the cooling of their high performance and high heat flux products. Therefore, it is necessary to discover efficient heat removal arrangements from electrical devices. Traditional cooling methods using air as a coolant do not satisfy the cooling demands because of the rise in power density and the scaling down of electronic packages. There has been a constant demand for the components and compactness of the systems to be scaled down over the last few decades. The engineering community has been focusing on scaling down the components and raising the functionality to feed this demand.

In this survey, the research investigation carried out on the cooling application of channels in microelectronic devices, electronic devices, and refrigeration is reviewed. Also, problems that arrases in this area are listened to and addressed in this study, and several directions for future study are proposed. The biggest step towards compactness is the implementation of the Mini / Microchannel in the field of refrigeration and cooling. With less refrigerant quantity and thus less effort, the Mini / Microchannel allows a high cooling effect and pressure to be produced and can work with all forms of refrigerant. It is possible to compact the size of the parts with the help of Mini / Microchannel. The worldwide warming effect can be minimized by using this in refrigerant and air conditioning systems.

II. COOLING APPLICATION OF CHANNELS IN MICROELECTRONICS

Thermal-hydraulic properties of liquid flowing water in micro-channels with super-hydrophobic surfaces for various shear-free fractions and Reynolds numbers have been numerically investigated. Super-hydrophobic surfaces with longitudinal grooves display the most reduced and transverse grooves show the highest thermal-hydraulic characteristics[1].A microchannel heat drop (MHSS) coordinating with an internal vertical Y-shaped bifurcation plate has been experimentally verified in thermal-hydraulic efficiency. Y-shaped plates with large lengths show high heat transfer and the large length will increase pressure drop, which affects pumping power. This modification is a good option for better cooling performance[2].

Associated with traditional rectangular microchannel heat sinks, the thermal and fluid flow properties of the complex slatted heat pipe (CMS) were evaluated. For CMCHS, both pressure drop and also the heat transfer coefficients are more cost-effective for cooling applications[3].With greater tapering, the Poiseuille number increases, although the needed pumping power decreases.MCHS with a width tapering ratio of 0.5 shows better heat transfer performance. The expanding quantity of branches decreases temperature and pressure drop[4].At a volumetric flow rate of .5 l/m, SPSM contributes to a 35 percent improvement in the overall Nussult number and a 19 percent decrease in overall thermal resistance relative to the traditional SRM heat pump[5].

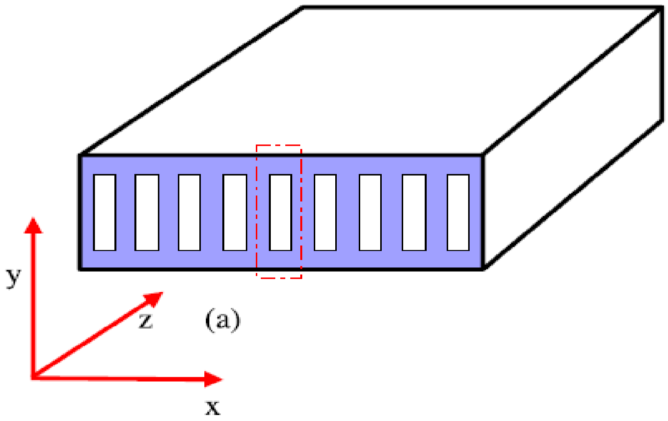

Figure 1 : Rectangular micro-channel heat sink

For their use in micro-electronics, the mathematically examined thermal-hydraulic efficiency of dual-layered micro-channel heat sinks (DL-MCHS) is contrasted with single-layer micro-channel heat sinks with the same configuration. Compared to individual layers, double layers have improved temperature difference and pressure loss features. DL-MCHS with re-entrant Ω-shaped micro-channels is the best option when the pressure drop is the only concern[6].The elongation trend is primarily influenced by water flow rate in the micro-channels for greater AR, whereas in the micro-channels with aspect ratio near to 1, the extension trend is largely caused by the thermal stress intake[7].

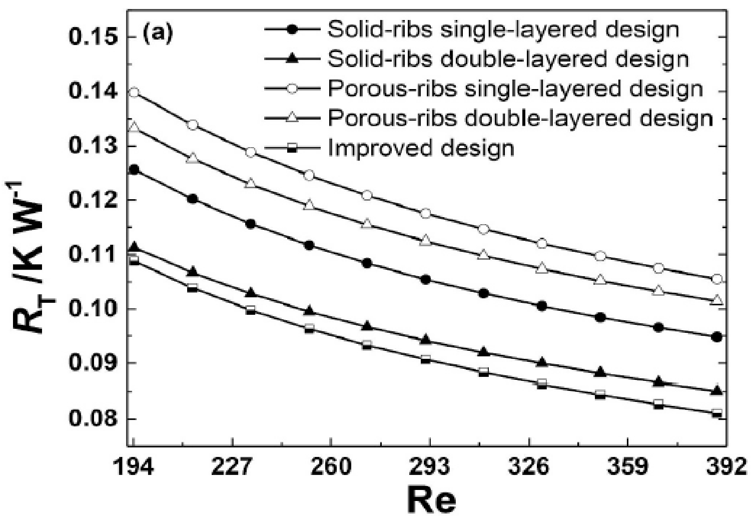

Figure 2: Overall thermal resistance for the five heat sink designs at different Reynolds numbers.

To ensure excellent temperature difference of the high power laser diode arrays, a combination micro-channel, and slot jet array heat pipe was developed and manufactured. Thermal conductivity decreases by more than 15%, suggesting that such a hybrid heat pump is a good option for optimizing the high-power laser diode array freezing[8].The superior heat efficiency and low-temperature drop are seen by the dual-layer microchannel heat sink implemented mostly by flexible ribs configuration. Combined impact of strong perpendicular ribs and upper porous ribs is due to this improved efficiency[9].On a linear microchannel heat sink, hydrodynamic and thermal nature was analyzed numerically including water, al-Al_2O_3-water, and TiO_2-water nano-fluids as base fluid. There had been a greater increase in the rate of the temperature difference and no excess reduction in pressure was observed. Even as volume of the thermal boundary layer fell within the very fine size of the path, the rise in heat transfer rate was attributed and decreasing in overall heat transfer tolerance[10].

Double layer microchannel heat sink with multiple alternations structures hasgreater thermal performance as compared to a traditional straight one and shows a minor increase of pressure drop. Regarding the maximum temperature on the surface and the pressure loss, the singular distributed DMHS with crossflow configuration has the strongest adjective thermal features. The irrevocability of heat transfer can be minimized by expanding the quantity of phased flow differentiation systems[11].The right option to have the maximum total heat transfer is to put the phased flow differentiation configuration in the centre of the DMHSs. Shifting the place often does not contribute to a rise in the temperature drop. Including several rectangular shape fractal-like units, the micro-channel heat pump has very little hydraulic capacity than those of the regular one[12].

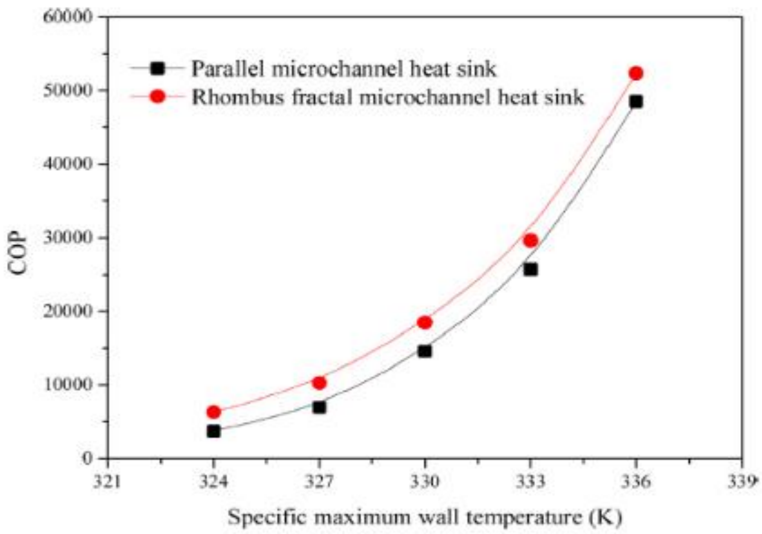

Figure 3: Comparison of COP values between parallel MCHS and Rhombus MCHS

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III. COOLING APPLICATION OF CHANNELS IN ELECTRONICS

Mini-channel heat exchangers were experimentally analyzed to boost flow distribution and thermal expansion with non-uniform bewilders at the inner pipe. Obtained results compared with mini channel heat sink without baffles by using finite volume method. The findings demonstrate that perhaps the mini-channel heat sink has a stronger temperature difference with non-uniform bewilders, which would be useful for their use in thermoelectric coolers. The downside to this configuration is the high-stress fall[13].

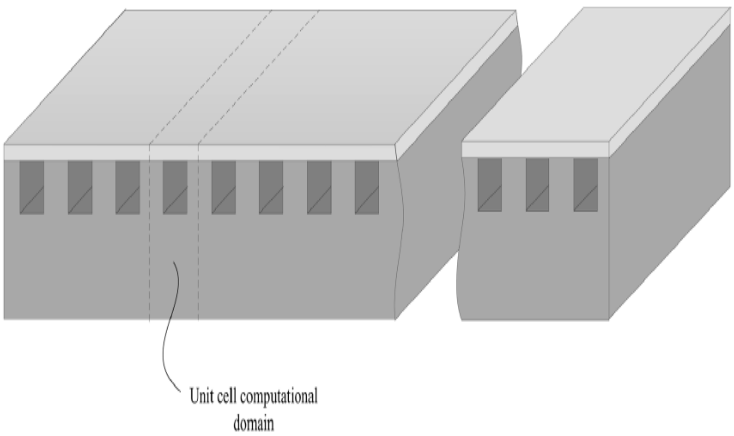

Figure 4: Schematic diagram of the mini-channel heat sink

Higher the pressure of microcapsules switching frequency substance particles by 10 percent will potentially prevent that spread of temperature profile by up to 20 percent, thus decreasing the variance here between bulk fluid and the temperature of both the ground, resulting in increased heat transfer. The divergence of the cross-section of sources results in an improvement in the COP value[14].It's also stronger than traditional SMCHS for thermal conductivity and pressure variation for serpentine mini-channel heat exchanger[15].So many thermal energy improvement strategies were analytically explored, given the redevelopment of the rectangle mini-channel layer. The changes are made by applying bumps of varying sizes within the tube, incorporating a bridge of streams by bringing consistency or disparate valves beside each other. Implementing a bump increases thermal resistance. Hydraulic capacity rises are considered higher than the traditional rectangular mini-channel for merging and differing nozzle schemes[16].

Heat exchangers of three distinct stream configurations were manufactured and tested with hybrid nanofluids with different volume fractions and filtered water beside one's heat transfer performance. Results demonstrate that the magnitude of convective heat transfer greatly improves when using nanofluids that filtered water[17]. Designed a hybrid straight wavy channel on a cylindrical mini-channel heat sink (CMCHS) to get a very less possible drop in pressure. Showed that average CMCHS output with such a clear wavy channel is greater than that together under the operational conditions with such a straight channel. In minimizing the greater temperature change all along the channel width of the CMCHS, the plain wavy channel is much higher efficient than the traditional linear channel[18]. While that amount of Reynolds increases, the PEC of the reverse flow mini-channel quality indicates a growing trend[19].

Thermal tolerance has reduced relative to that example of nano-encapsulated PCM molecules through the use of al-$Al_2\,O_3$ nanoparticles[20]. In contrast to the case of nano-encapsulated PCM particles, it also gives significantly higher thermal conductivity ratios. In contrast to that of micro PCM particles, the impact of al-Al_2O_3 nanoparticles are larger. Experiments have been carried out to measure the thermal-hydraulic efficiency of mini-channel heat sinks, slot jet range heat floors, and hybrid systems[21]. In contrast to some other two heat pipes, the hybrid scheme has improved cooling efficiency. Oscillations in the hybrid heat pipe channel facilitate the flow of heat.Pressure dropcould decrese by geometry improvement.

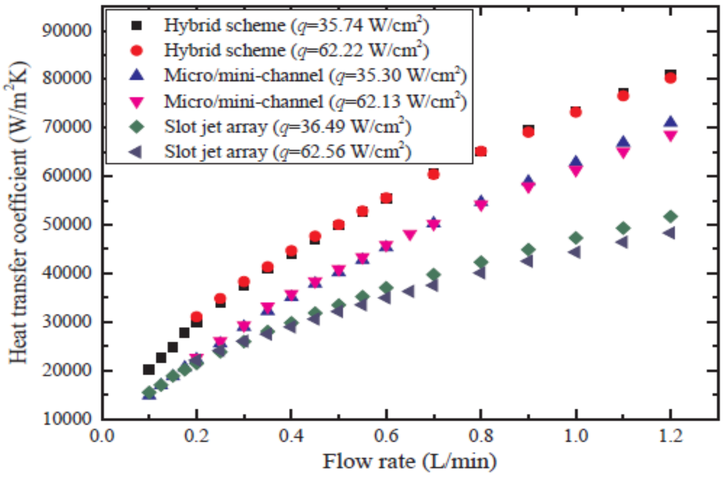

Figure 5: Heat transfer coefficient of 3 heat sinks versus flow rate.

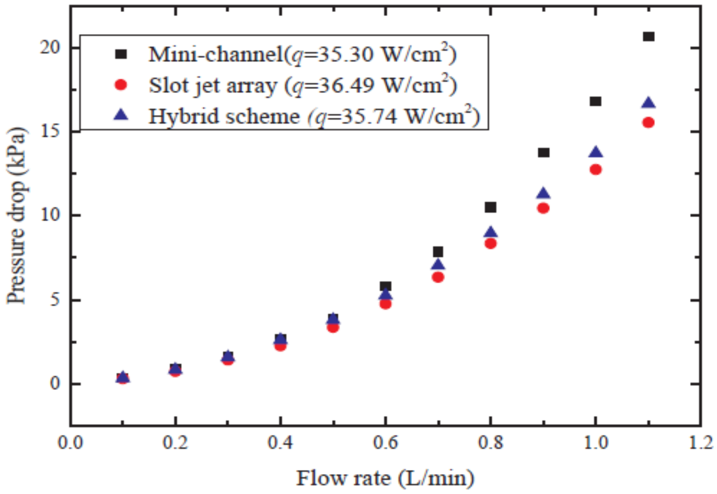

Figure 6: Pressure drop of 3 heat sinks versus flow rate.

To use the cooling system as a Nano-encapsulated Phase Transition Product (NEPCM) material distributed in water, experimental results observed thermal energy output of a microchannel heat sink. The findings demonstrate that the inclusion of NEPCM molecules increases the rate of heat transfer for the reduced number of Reynolds. Owing to the existence of NEPCM particles, the value for thermal conductivity for large Reynolds numbers is declining. An increase in viscosity leads to high pumping power[22]. Heat transfer rate is higher for liquid metal but pumping power is high[23]. To boosting the initial flow design, introduced v-ribs for roughening that traditional mini-channel heat exchanger. The findings indicate that the total mini-channel efficiency has been improved. A multi-longitudinal stream of swirls was developed and the initial flow structure has been improved[24].

IV. COOLING APPLICATION OF CHANNELS IN REFRIGRATION

A comparison is introduced to classify the heat transfer characteristics of heating flows for poor volume fractions on square and rectangular pipes quantitatively tested by a connection. R-113 is often used as a solvent for testing. The heat transfer parameters rise with flow velocity and regional performance, however, the influence of heat flux tends to also be minimal[25].For various numbers of tubes and tube lengths, the model was used to achieve the optimum design parameters. The findings indicate that the necessary pipe length for the decreased section reduces with both the number of pipes and pipe diameter. The new condenser, therefore, is much stronger than the condensers commonly used in real domestic refrigerators[26]. The overall heat flow on the coolant side is more vulnerable to shifts in coolant flow velocity than it is to shifts in saturated temperature and rate of heat transfer[27].The coefficient of heat trasfer for higher heat flux is almost independent of mass velocity. The friction coefficient pressure loss would improve with both the growth in water vapour content and mass acceleration. There is indeed a significantly higher decrease in pressure from a smaller wavelength altitude[28]. Thermal conductivity, intensity proportion, and viscosity ratio perform a significant part in the difference in the heat exchange function.The values of heat transfer coefficients of R-1234yf is lessthan the R-134a. In case of refrigerant R-1234yf, two-phase flow pressure drops are also smaller[29].

Through a non-circular micro-channel for multiple sizes, feature proportions, and for different inlet vapor mass fluxes and touch angles, stream condensation was numerically analyzed[30]. By that the hydraulic diameter between 250 to 80 mm, the thickness of the compressor film decreases, and the total temperature distribution for the same mass flux rises by up to 39 percent. Growing in the contact area would increase the transfer of heat.experimentally investigated two-phase flow boiling in a mini-channel of R-134a refrigerant. The results show that Due to the dry out and boiling crisis at vapor grades above 0.5, the heat transfer rate increases sharply[31]. In the miniature vapour compression refrigeration system method,the two devices have a greater cooling capacity of around 160 W. In experiments, where the cooling load is above the capacity of cooling of avapor amplification process, the performance of cooling for the parallel system is greater than those of the series systems[32].

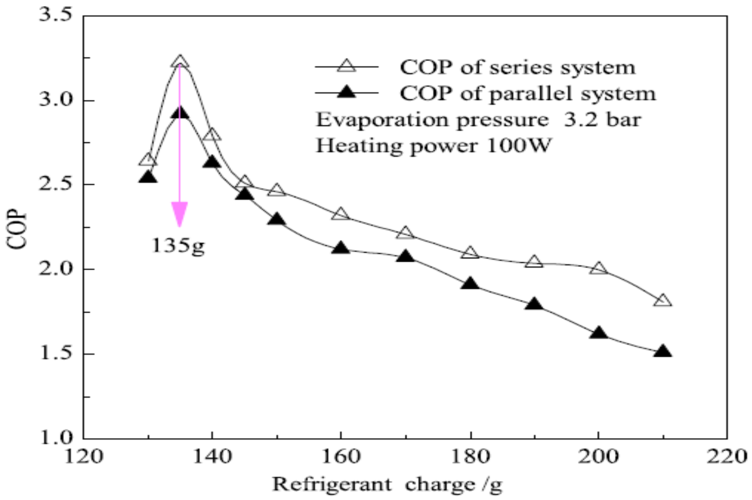

Figure 7: Refrigerant charge in series versus parallel systems.

Mathematical studies were conducted to explore the thermal-hydraulic properties of laminar flow through all of the sinusoidal wavy walled tunnels. The findings demonstrate that perhaps the heat exchange reliance mostly on the structure of both the wall is greatly influenced by the wavelength of its wall. Between both paths, the heat exchange rate is nearly the same about lower wavelength value systems, while the transfer of heat for the squirrel stream is often larger for greater wavelength values than for the sinuous path, and the variance appears to become more prominent for provides higher amplification and Reynolds number wavelength values. Overall findings suggest that a sinuous channel's output factor is often far more than a squirrel stream[33]. Studied the domestic freezer, where two forms of the mini-channel compressor are combined to increase the efficiency of the system. The findings indicate the parameters from either capillary duration or coolant amount, which seem to be 3.25 m and 50 g, to enhance more study[34]

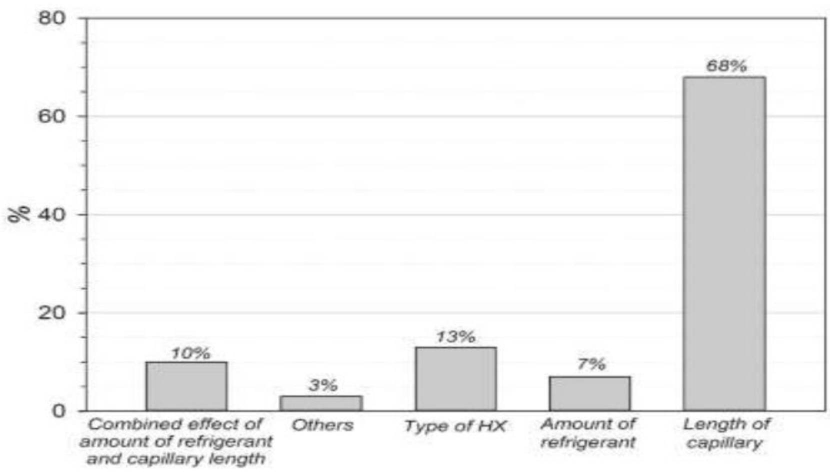

Figure 8: The effect of parameters on the energy consumption.

Researched metal on tube compressor and louver fin microchannel heat regenerator analytically and correlated the simulated based on experimental data from both heating systems. The findings show that with the same thermal efficiency, the micro-channel heating element consumes less energy and therefore less storage. A smaller cooling system cost than the tube compressor cable is required. Therefore, two louver fin micro-channel capacitors are suggested here to substitute wire on domestic fridge tube heat exchangers[35]. The condensation thermal efficiency of R447A (R32 / R1234ze / R125) in multi-port extruded (MPE) micro-tubes were researched empirically and analytically and compared the findings with R134a, R32, R1234ze, and their mixtures. Findings suggest that the thermal conductivity of R447A is slightly lesser than that of R32 and R134a is moderately lower, though greater than that of R1234ze[36].Respectively better heat transfer rates and larger pressure fall for both the smoother multi-port tubes were generated by tubing with a shorter hydraulic diameter. The tube with such a shorter hydraulic diameter produced a higher drop in pressure[37].

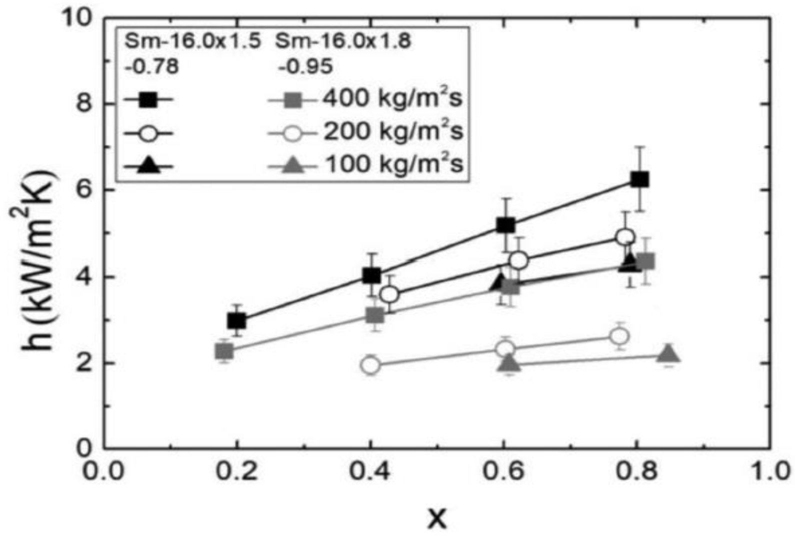

Figure 9: Heat transfer coefficients of smooth multiport tubes

Investigates the applicability of the micro-channel heat exchanger technology supplied by fans as condensers in household refrigeration appliances.The findings reveal that a micro-channel compressor with 200 fins per meter and 46 rectangular streams of 1.2 mm hydraulic diameter has been implemented when it was 200 mm high, 180 mm wide, and 72 mm deep, sensitivity analysis showed a 13 percent reduction in energy consumption[38]

V. CONCLUSION

In this article, we have reviewed the recent findings based on the cooling applications of channels in microelectronic devices, electronic devices, and refrigeration. The rectangular geometry is the better option for a mini/microchannel heat sink. Because the Nussult number and contact angle are high. Heat transfer and the mass transfer rate is also high for rectangular geometry. Liquid metal as a coolant gives the best heat transfer rate than water and nanofluid, but the pressure drop is high.The material dissolved in water by Nano crystallized phase shift increases the heat transfer rate at low Reynolds number and reduces thermal efficiency at higher Reynolds number.

Thermal sink hybrid device demonstrates stronger cooling efficiency than the heat pump and mini-channel heat pump of the channel jet series. Hybrid heat pipe pressure loss is larger than the channel jet array heat source and lower than the mini-channel heat source. Microchannel heat pipes with several fractal-like rhombus systems is a great pick to minimize the pressure loss and reduce the pumping capacity. Spaced flow transposition configuration in the center of micro-channel heat source is a great alternative to provide maximum total thermal performance. The impermissibility of energy transfer could be minimized by expanding the amount of phased flow differentiation systems.The hybrid temperature sink is also an intriguing idea because of the low thermal resistance to boost the freezing of the maximum transmit electrode arrays.

Opposed to individual layers of micro-channel heating elements, dual-layered micro-channel heat pipes have improved heat transfer and pressure drop functionality. Complicated perforated micro-channel heat pipes provide stronger heat transfer coefficient and pressure loss characteristic features comparison to standard cubic micro heating elements.The application of the micro-channel heat exchanger technology supplied by fans as condensers in household refrigeration appliances will reduce 13 percent energy consumption.The heat transfer focus on the wall structure is greatly influenced by wavelength of wall waviness. Friction factor will increase with respect to hydraulic diameter and with the inclusion of nano-particles. The ratio of precipitation heat exchange rises exponentially while using nano-fluids than filtered water.

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