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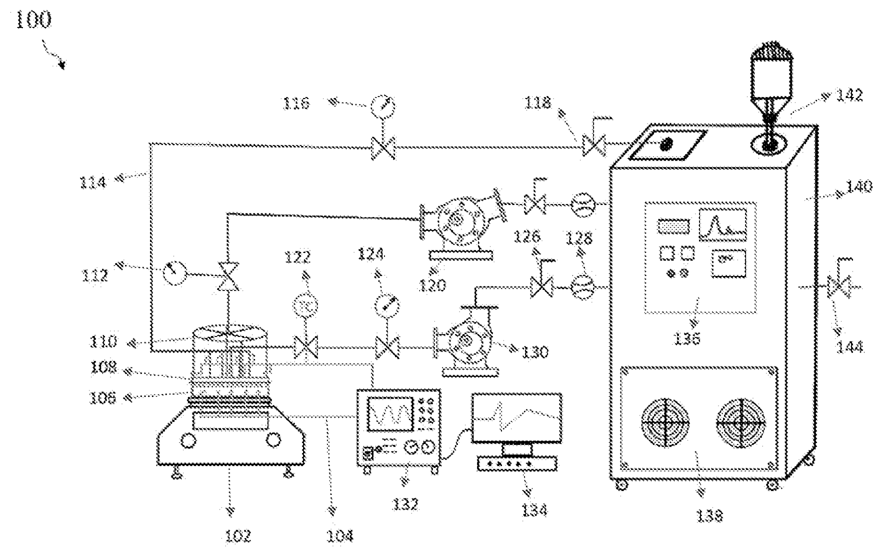
(54) **Title:** BIRADIAL MULTIPLE ENTRY MESOCHANNEL HEAT SINK WITH DIELECTRIC ORGANIC COOLANT AND METHOD THEREOF

[Fig. 1]



(57) **Abstract:** The present invention discloses biradial multiple entry mesochannel heat sink with dielectric organic coolant. The biradial multiple entry mesochannel heat sink (100) comprises a central base with multiple radial channels. A circular plate is positioned at a central base of the heat sink. Biradial multiple entry mesochannels for enhancing heat dissipation through multiple radial pathways. A top plate (108) for housing multiple fluid inlets and outlets. The multiple fluid inlets and outlets attached to the top plate and positioned at a periphery of the circular plate to facilitate fluid entry and exit. A single inlet and multi-outlet manifold (110 and 114) attached to the periphery of the circular plate, to regulate the fluid flow through the heat sink. A dielectric organic coolant circulating through the biradial multiple entry mesochannels. A bottom plate (106) interfaced with at least one electronic component to enable continuous effective heat dissipation.

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Description

Title of Invention: BIRADIAL MULTIPLE ENTRY MESOCHANNEL HEAT SINK WITH DIELECTRIC ORGANIC COOLANT AND METHOD THEREOF

Technical Field

[0001] The field of invention generally relates to a biradial multiple entry mesochannel heat sink with dielectric organic coolant. More specifically, it relates to a biradial multiple entry mesochannel heat sink with dielectric organic coolant and method thereof.

Background Art

[0002] The The demanding technical advancement in computation creates a necessary environment for chip manufacturers to develop nano-sized processors with high-speed data transfer ability and computations. High-speed data transfer in micro and nano chips dissipates significant heat, which leads to deterioration of electronic devices. To manage such high heat dissipation while maintaining dielectric properties, researchers are searching for efficient coolants that operate across a wide temperature range. Keeping environmental considerations in mind, the search for less toxic chemicals with an optimum working range and restricted contact area has led to the development of unconventional cooling solutions.

[0003] However, existing designs suffer from significant drawbacks such as high pressure drops, and improper heat transfer due to the single-entry and single-exit configuration of the fluid flow.

[0004] Currently, existing systems do not succeed in effectively dissipating heat in high-power electronic components while ensuring uniform temperature distribution, minimal thermal resistance, and reduced pressure drops. Conventional microchannel heat sinks suffer from limitations in coolant flow management, leading to inefficiencies in heat transfer.

[0005] Other existing systems have tried to address this problem. However, their scope was limited to traditional microchannel heat sinks, which experienced excessive pressure drops and inefficient heat transfer due to their single-entry and exit fluid flow design. Constructable geometry limitations further restrict their performance, necessitating alternative approaches to enhance cooling efficiency.

[0006] Thus, in light of the above discussion, it is implied that there is need for a biradial multiple entry mesochannel heat sink with dielectric organic coolant and method thereof, which is reliable, with improved heat dissipation, efficient airflow management, and reduced thermal resistance while maintaining a compact and lightweight structure and does not suffer from the problems discussed above.

Object of Invention

[0007] The principal object of this invention is to provide a biradial multiple entry mesochannel heat sink using dielectric organic coolant for electronic materials processing.

[0008] A further object of the invention is to provide a unique heat sink with Dual Radial geometry and multiple inlet fluid entry and multiple fluid exit for electronic device cooling using organic coolants with dielectric properties with a wide range of freezing and boiling points.

[0009] Another object of the invention is to rectify the application difficulties in microchannel and to provide optimized flow rate and increased surface area to enhance the heat transfer by addressing the hot spots in the radial geometry with a single entry.

[0010] Another object of the invention is to reduce thermal hot spots in the single-entry geometry by introducing multiple inlets and outlets in various locations.

[0011] Another object of the invention is to introduce fresh coolant entry in the periphery of heat sink that leads to optimum temperature difference and enhances the heat transfer rate.

[0012] Another object of the invention is to provide a device and method for efficiently transferring heat and providing instant cooling to electronic devices.

Brief Description of Drawings

[0013] This invention is illustrated in the accompanying drawings, throughout which, like reference letters indicate corresponding parts in the various figures.

[0014] The embodiments herein will be better understood from the following description with reference to the drawings, in which:

Fig. 1

[0015] [Fig.1] depicts/illustrates a system for biradial multiple entry mesochannel heat sink using dielectric organic coolant for electronic materials processing, in accordance with an embodiment of the present disclosure;

Fig. 2a

[0016] [Fig.2a] depicts/illustrates a 2-dimensional (2D) drawing of the mesochannel heat sink with inlet outlet pipes given for manufacturing, in accordance with an embodiment of the present disclosure;

Fig. 2b

[0017] [Fig.2b] depicts/illustrates a Four-way manifold 2D drawing, in accordance with an embodiment of the present disclosure;

Fig. 3a

[0018] [Fig.3a] depicts/illustrates a skeleton framework of the proposed mesochannel sealing mechanism for the top and bottom plate 106 of the heat sink, in accordance with an embodiment of the present disclosure;

Fig. 3b

[0019] [Fig.3b] depicts/illustrates top plate 108 stainless steel with inlet and outlet pipes welded and assembled with a bottom plate 106 made of aluminum with radial channels manufactured by using advanced manufacturing methods, in accordance with an embodiment of the present disclosure;

Fig. 3c

[0020] [Fig.3c] depicts/illustrates test section with thermocouples and fittings assembled and connected with the inlet and outlet Stainless steel hoses, in accordance with an embodiment of the present disclosure;

Fig. 4

[0021] [Fig.4] depicts/illustrates comparison of fluid flow model design, in accordance with an embodiment of the present disclosure;

Fig. 5a, 5b and 5c

[0022] [Figure 5a, 5b and 5c] depict/illustrate cooling curves plots from temperatures (°C) data taken from the bottom plate 106 thermocouples, in accordance with an embodiment of the present disclosure;

Fig. 6

[0023] [Fig.6] depicts/illustrates effect of fluid flow rates and its effect compared with simulation results and found to be in alignment with experimental data for both the total flow rates of 2.5 LPM and 3 LPM, in accordance with an embodiment of the present disclosure;

Fig. 7

[0024] [Fig.7] depicts/illustrates effect of inlet fluid temperature on heat transfer compared with simulation for a fluid flow rate 1, 1.5 LPM for the heater plate maintained at 60 °C, in accordance with an embodiment of the present disclosure;

Fig. 8

[0025] [Fig.8] depicts/illustrates effect of inlet fluid temperature on heat transfer compared with simulation for a fluid flow rate of 1, 2 LPM for the heater plate maintained at 60 °C, in accordance with an embodiment of the present disclosure; and

Fig. 9

[0026] [Fig.9] illustrates a method for biradial multiple entry mesochannel heat sink using dielectric organic coolant for electronic materials processing, in accordance with an embodiment of the present disclosure.

Statement of Invention

[0027] The present invention discloses a biradial multiple entry mesochannel heat sink with dielectric organic coolant and method thereof.

[0028] The biradial multiple entry mesochannel heat sink comprises a central base for thermal distribution and structural support. The multiple radial channels attached to the central base extending outwardly, wherein the multiple radial channels facilitate multiple fluid entry and multiple fluid exit to enhance heat dissipation.

[0029] Furthermore, the biradial multiple entry mesochannel heat sink comprises a circular plate positioned at a central base of the heat sink, for facilitating uniform heat distribution.

[0030] Additionally, the biradial multiple entry mesochannel heat sink comprises biradial multiple entry mesochannels positioned on the central base for enhancing heat dissipation through multiple radial pathways.

[0031] Subsequently, the biradial multiple entry mesochannel heat sink comprises a top plate 108 positioned at upper section of the heat sink, configured for housing multiple fluid inlets and outlets.

[0032] Furthermore, the biradial multiple entry mesochannel heat sink comprises the multiple fluid inlets and outlets attached to the top plate 108 and positioned at a periphery of the circular plate to facilitate fluid entry and exit.

[0033] Additionally, the biradial multiple entry mesochannel heat sink comprises a single inlet and multi-outlet manifold attached to the periphery of the circular plate, to regulate the fluid flow through the heat sink.

[0034] Furthermore, the biradial multiple entry mesochannel heat sink comprises a dielectric organic coolant circulating through the biradial multiple entry mesochannels to regulate thermal performance.

[0035] Subsequently, the biradial multiple entry mesochannel heat sink comprises a bottom plate 106 attached to the central base and interfaced with at least one electronic component to enable continuous effective heat dissipation, wherein the biradial multiple entry mesochannel heat sink ensures continuous heat dissipation and maintains bottom base plate of the biradial multiple entry mesochannel heat sink at ambient temperature.

Detailed Description

[0036] The The embodiments herein and the various features and advantageous details thereof are explained more fully with reference to the non-limiting embodiments that are illustrated in the accompanying drawings and/or detailed in the following description. Descriptions of well-known components and processing techniques are omitted so as to not unnecessarily obscure the embodiments herein. The examples used herein are intended merely to facilitate an understanding of ways in which the embodiments herein may be practiced and to further enable those of skill in the art to practice the embodiments herein. Accordingly, the examples should not be construed as limiting the scope of the embodiments herein.

[0037] The present invention discloses a biradial multiple entry mesochannel heat sink with dielectric organic coolant and method thereof. The present invention discloses a unique heat sink with Dual Radial geometry and multiple inlet fluid entry and multiple fluid exit for electronic device cooling using organic coolant with dielectric properties with a wide range of freezing and boiling points. The Dual Radial multiple entry heat sink (DRMEHS) features two distinct radial pathways for heat dissipation. Radial channels extend outward channels from a central base, providing a more efficient means of heat transfer through fluid flow compared to conventional single-path designs. A unique four-way manifold is designed for multiple entry purposes and the inlet is optimized in the periphery of the circular plate to enhance the heat transfer rate by pumping fresh coolant. This dual radial configuration facilitates a larger surface area for heat transport and accelerates the heat dissipation process. Organic solvents with high dielectric properties are introduced into the system as a cooling medium. These solvents, known for their superior heat transfer characteristics, further augment the heat dissipation process. The integration of organic solvents consistently facilitates a uniform temperature profile across the bottom base plate of the electronic device by cooling the baseplate and maintaining it at an ambient temperature.

[0038] [Fig.1] depicts/illustrates a biradial multiple entry mesochannel heat sink 100 with dielectric organic coolant, in accordance with an embodiment of the present disclosure;

[0039] The biradial multiple entry mesochannel heat sink 100 is hereinafter referred to as the heat sink 100.

[0040] The biradial multiple entry mesochannel heat sink 100 is fabricated from a material comprising at least one of aluminum, brass, titanium, composites, and alloys thereof.

[0041] The biradial multiple entry mesochannel heat sink 100 comprises a central base (not shown) for thermal distribution and structural support. The biradial multiple entry mesochannel heat sink 100 comprises multiple radial channels attached to the central base extending outwardly. The multiple radial channels facilitate multiple fluid entry and multiple fluid exit to enhance heat dissipation. The radial channels comprise a biradial configuration with increased surface area for heat dissipation,

[0042] The circular plate positioned at the center base of the heat sink 100. The circular plate is used for facilitating uniform heat distribution. The biradial multiple entry mesochannels positioned on the central base for enhancing heat dissipation through multiple radial pathways.

[0043] The biradial multiple entry mesochannel heat sink 100 comprises at least one of a heater (3 kw) 102, K-type thermocouple 104, bottom plate 106, top plate with multi entry and exit 108, single inlet four-way outlet manifold 110, at least one pressure sensor (112, 116, 124), hot fluid outlet with a manifold 114, outlet control valve 118, gear pump 2 120, Thermocouple to the centre 122, control valve 126, mass flow controller 128, gear pump 1 130, agilent data logger 132, monitor connected to the computer 134, flow control panel with on and off and safety switch 136, secondary cooling fan for the compressor 138, cryogenic chiller 140, circulation pump/ stirrer 142, and vent 144.

[0044] The heater 102 is placed at the bottom in direct contact with the aluminum bottom plate 106 to provide uniform heating. The heater 102 provides heat to the aluminum bottom plate 106 to create a controlled heat transfer scenario.

[0045] The K-type thermocouple 104 is attached to the stainless steel top plate 108. The K-type thermocouple 104 measures temperature variations for real-time monitoring.

[0046] The aluminum bottom plate 106 is located directly above the heater 102. The aluminum bottom plate 106 acts as a thermal conductor, ensuring uniform heat distribution.

[0047] The bottom plate 106 is attached to the central base and interfaced with at least one electronic component to enable continuous effective heat dissipation. The biradial multiple entry mesochannel heat sink 100 ensures continuous heat dissipation and maintains bottom base plate of the biradial multiple entry mesochannel heat sink 100 at ambient temperature. The bottom plate 106 of the biradial multiple entry mesochannel heat sink 100 comprises pressure transmitters and flow meters to monitor fluid dynamics and optimize cooling performance.

[0048] The stainless steel top plate with multi entry and exit 108 is placed above the aluminum bottom plate 106, in contact with the test fluid. The stainless steel top plate with multi entry and exit 108 facilitates heat exchange between the heated plate and circulating coolant. The top plate 108 is positioned at upper section of the heat sink 100. The top plate 108 is configured for housing multiple fluid inlets and outlets.

[0049] The single inlet four-way outlet manifold 110 is connected to the top plate 108. The single inlet four-way outlet manifold 110 distributes coolant evenly over the heated surface for efficient cooling.

[0050] The at least one pressure sensors 112, 116, 124 are strategically positioned 112 near the fluid inlet, 116 at the outlet, and 124 before the gear pump 2 120 to ensure precise pressure regulation. The at least one pressure sensor (112, 116, 124) monitors inlet pressure to ensure proper coolant flow. The at least one pressure sensors 112, 116, 124 are hereinafter referred to as the pressure transmitters.

[0051] The hot fluid outlet with a manifold 114 is positioned at the exit of the top plate 108. The hot fluid outlet with a manifold 114 collects heated coolant and directs it toward the cooling system.

[0052] The single inlet and multi-outlet manifold (110 and 114) are strategically placed at the periphery of the circular plate of the heat sink 100 to introduce fresh coolant into the periphery of the circular plate. The single inlet and multi-outlet manifolds 108 comprise stainless steel, PTFE (Polytetrafluoroethylene) gasket sealing to prevent thermal leaks and silicone gasket sealing to prevent fluid leakage within the biradial multiple entry mesochannel heat sink 100. The single inlet and multi-outlet manifold 110 and 114 attached to the periphery of the circular plate, to regulate the fluid flow through the heat sink 100. The multiple fluid inlets and outlets attached to the top plate 108 and positioned at a periphery of the circular plate to facilitate fluid entry and exit.

[0053] The outlet control valve 118 is installed on the hot fluid outlet with a manifold 114. The outlet control valve 118 regulates the coolant flow rate leaving the test section,

[0054] The gear pump 2 120 is placed along a fluid return line. The gear pump 2 120 ensures continuous fluid circulation through the cooling loop.

[0055] The thermocouple to the centre 122 is located at the central point of the test section. The thermocouple to the centre 122 provides precise temperature measurement at the most critical point.

[0056] The control valve 126 is positioned before the gear pump 1. The control valve 126 adjusts the flow rate of coolant before entering the heat sink 100.

[0057] The mass flow controller 128 measures and controls the mass flow rate of the cooling fluid. The mass flow controller 128 provides precise flow regulation for experimental accuracy.

[0058] The gear pump 1 130 ensures continuous circulation of the cooling fluid. The gear pump 1 130 maintains stable flow and pressure within the system.

[0059] The agilent data logger 132 records temperature, pressure, and flow rate data. The agilent data logger 132 interfaces with thermocouples and sensors for real-time data acquisition.

[0060] The monitor connected to the computer 134 displays real-time system data for analysis. The monitor connected to the computer 134 receives input from the Agilent data logger 132 for monitoring.

[0061] The flow control panel with on and off and safety switch 136 controls and monitors the entire system operation. The flow control panel with on and off and safety switch 136 is integrated with safety mechanisms for reliable performance.

[0062] The secondary cooling fan for the compressor 138 provides additional cooling to the compressor unit. The secondary cooling fan for the compressor 138 enhances heat dissipation to prevent overheating.

[0063] The cryogenic chiller 140 maintains a low-temperature coolant supply. The cryogenic chiller 140 uses cryogenic technology for precise temperature control.

[0064] The circulation pump/ stirrer 142 ensures uniform mixing of the cooling medium. The circulation pump/ stirrer 142 enhances heat exchange efficiency.

[0065] The vent 144 allows excess pressure release from the heat sunk 100. The vent 144 prevents overpressure conditions ensuring system safety.

[0066] The dielectric organic coolant circulating through the biradial multiple entry mesochannels to regulate thermal performance. The dielectric organic coolant comprises a deep eutectic solvent (DES) with a wide range of freezing and boiling points and with optimized thermophysical properties for the heat dissipation. The wide range of the freezing and boiling point ranging from -10 to 188℃. The dielectric organic coolant is circulated at an optimized flow rate between 1.5 and 2.5 liters per minute.

[0067] The biradial multiple entry mesochannel heat sink 100 comprises a PID (Proportional-Integral-Derivative) controller to control the dielectric organic coolant flow rate to maintain the uniform temperature profile across the bottom base plate of the at least one electronic device.

[0068] The biradial multiple entry mesochannel heat sink 100 comprises a computational validation system to compare experimental and simulated thermal performance data, and wherein a numerical computational approach is used to optimize the biradial multiple entry mesochannel heat sink design.

[0069] The biradial multiple entry mesochannel heat sink 100 comprises the biradial multiple entry mesochannel heat sink 100 operates in the temperature range of -10°C to 100°C.

[0070] [Fig.2a] depicts/illustrates a 2-dimensional (2D) drawing of the mesochannel heat sink with inlet outlet pipes given for manufacturing, in accordance with an embodiment of the present disclosure;

[0071] The mesochannel heat sink is designed with Dual Radial Geometry for efficient heat dissipation in electronic cooling applications. The heat sink features multiple inlet and outlet pipes, allowing for enhanced thermal management by optimizing fluid flow. The design comprises two distinct radial pathways, significantly improving heat transfer efficiency compared to conventional single-path configurations. The drawing highlights precisely spaced radial channels, enabling uniform coolant distribution.

[0072] [Fig.2b] depicts/illustrates a Four-way manifold 2D drawing, in accordance with an embodiment of the present disclosure;

[0073] The Four-Way Manifold designed using the COMSOL CAD kernel, which has been simulated to analyze fluid flow velocity before being sent for manufacturing. The manifold is fabricated from stainless steel, ensuring corrosion resistance and superior mechanical strength. This uniquely designed manifold features multiple inlet and outlet pathways, optimizing fluid entry from the periphery of the circular plate to enhance the heat transfer rate by continuously introducing fresh coolant. The dual radial configuration significantly increases the surface area for heat dissipation, thereby improving the overall cooling performance. The system employs organic solvents with high dielectric properties as a cooling medium, known for their superior thermal conductivity. These solvents enable efficient heat transport and help maintain a uniform temperature profile across the baseplate of the electronic device, ensuring it remains close to ambient temperature. The Four-way manifold 2D drawing illustrates top, side, and isometric views with precise dimensional annotations, providing a clear representation of the manifold's structure and design for effective manufacturing and implementation.

[0074] [Fig.3a] depicts/illustrates a skeleton framework of the proposed mesochannel sealing mechanism for the top and bottom plate of the heat sink, in accordance with an embodiment of the present disclosure;

[0075] The sealing mechanism utilizes PTFE gaskets to minimize thermal leaks, benefiting from their low thermal conductivity and superior thermal resistance to enhance heat retention. Meanwhile, silicone gaskets are employed to prevent fluid leakage, leveraging their flexibility, durability, and chemical resistance to maintain a secure seal within the flow channels. This dual-gasket approach optimally manages both thermal insulation and fluid containment, improving overall system efficiency and minimizing leakage risks. Ensuring proper material compatibility, precise installation, and regular maintenance is crucial for achieving optimal sealing performance. A representative assembly illustration is provided.

[0076] [Fig.3b] depicts/illustrates top plate 108 stainless steel with inlet and outlet pipes welded and assembled with a bottom plate 106 made of aluminum with radial channels manufactured by using advanced manufacturing methods, in accordance with an embodiment of the present disclosure;

[0077] A real-time view of the bottom 106 and top plates 108 assembled before fastening the setup. Multiple connection drills are incorporated to ensure secure coupling between the top and bottom plates, preventing misalignment.

[0078] [Fig.3c] depicts/illustrates test section with thermocouples and fittings assembled and connected with the inlet and outlet Stainless steel hoses, in accordance with an embodiment of the present disclosure;

[0079] The final meso-channel setup after fastening, featuring the single-entry and four-way outlet manifold. All inlet and outlet temperatures are monitored using RTD thermal sensors, as illustrated in the [Fig.3c].

[0080] [Fig.4] depicts/illustrates comparison of fluid flow model design, in accordance with an embodiment of the present disclosure;

[0081] A comparative analysis of different flow channel configurations and temperature profiles is conducted to assess the performance of multiple entry-exit mesochannels. The dual-radial multi-entry mesochannel heat sink demonstrates a temperature drop comparable to that of a radial channel with a single entry, outperforming the conventional spiral channel.

[0082] The proposed geometry is designed and optimized with fluid flow and heat transfer in radial geometry using the numerical method of analysis on Multiphysics software. The major constraints in the design are solved and estimated as shown in [Fig.4]. The pressure drops limitations in the radial spiral geometry i.e., Case 01 are addressed as the pressure is reduced to three orders of magnitude in comparison with Case 02 by modifying the spiral channel into radial channels. The attempt to reduce the pressure further for practical usage is achieved by changing the radial channel with a circular channel by increasing the resident time of the fluid. The increase in surface area with increasing the number of channels and also the residence time increases the heat transfer and ΔT is observed to increase from case 02 to case 03 as shown in the figure below. The thermal boundary layer of the geometry can be enhanced for an increase in heat transfer and a decrease in pressure drop is achieved by adding a greater number of inlet entries in the periphery and allowing the fluid in the midline of the circular channel to intermix. The summary in Table 01 shows the results clearly and thus the pressure drop is reduced with an increase in the heat transfer as well as the ΔT. Similarly, the plate average temperature from the experimental data is considered as the initial condition for the modelling the data from the simulation results for all the four cases is summarized in Table 02.

[0083] Table 01: Simulation summary with initial condition Heat Flux at the bottom plate 106 kW/m2

ITEM NO	Meso channel Geometry	Heat Flux (kW/m^2)	Fluid Flow Rate (lpm) In (1)	Fluid Flow Rate (lpm) In (2)	Fluid Inlet Temp T1_in (°C)	Fluid Inlet Temp T2_in (°C)	Fluid Outlet Temp T_O (°C)	Pressure @Inner inlet(Pa)	Pressure @Outer Inlet(Pa)	Heat Transfer by the fluid (kW)
Case:01	Spiral	1.76	2.5	NA	32.8	NA	58.5	7.75E+06	NA	1.904
Case:02	Radial with single entry		2.5	NA	32.8	NA	58.3	18316	NA	1.895
Case:03	Dual Radial single entry		2.5	NA	32.8	NA	57.9	16529	NA	1.859
Case:04	Dual Radial Multiple entry		1	1.5	32.8	32.189	58.6	3251.7	3957.2	1.944

[0084] Table 02: Summary of simulation data with the initial condition Average bottom plate 106 temperatures 39.71°C

ITEM NO	Meso channel Geometry	Bottom Plate Temp (°C)	Fluid Flow Rate (lpm) In (1)	Fluid Flow Rate (lpm) In (2)	Fluid Inlet Temp T1_in(°C)	Fluid Inlet Temp T2_in(°C)	T_{in_Avg} (°C)	Fluid Outlet Temp T_O (°C)	Pressure @Inner inlet(Pa)	Pressure @Outer Inlet(Pa)	Heat Transfer by the fluid (kW)
Case:01	Spiral	39.71	2.5	NA	32.8	NA	32.8	39.6	7.67E+06	NA	0.503
Case:02	Radial with single entry	39.71	2.5	NA	32.8	NA	32.8	35.7	19082	NA	0.212
Case:03	Dual Radial Single entry	39.710	2.5	NA	32.800	NA	32.8	36.7	16969	NA	0.288
Case:04	Dual Radial Multiple entry	39.71	1	1.5	32.8	32.2	32.4	36.2	3511.3	4298.8	0.282

Table 01 and 02 shows that we are able to achieve the same heat transfer at much lower pressure drop and also the double entry geometry gives better uniformity across the cooled plate.

[0085] Figures 5a, 5b and 5c depict/illustrate cooling curves plots from temperatures in °C data taken from the bottom plate 106 thermocouples, in accordance with an embodiment of the present disclosure;

[0086] [Fig.5a] depicts the cooling behavior of the bottom plate 106 at various radial locations and is examined. Temperature measurements are recorded from ambient conditions of 30°C down to the set temperature of 25°C. Heat gain from the surrounding environment is limited to 28°C, and the data reveals a steady-state condition with consistent thermographic fluctuations, exhibiting a sinusoidal-like pattern.

[0087] [Fig.5b] depicts the cooling performance of the bottom plate 106 at different radial locations is analyzed. Temperature readings are taken from ambient conditions of 30°C to the set coolant temperature of 5°C. The environmental heat gain is restricted to 9°C, which corresponds to the coolant's entry temperature. The data confirms a steady-state condition with consistent thermographic variations, as depicted in the graphs.

[0088] [Fig.5c] depicts the cooling performance of the bottom plate 106 at different radial locations is analyzed. Temperature readings are recorded from ambient conditions of 30°C to the set coolant temperature of -5°C. The environmental heat gain is limited to 1 to 2°C, which corresponds to the coolant's entry temperature. The data indicates a steady-state condition with consistent thermographic variations. These fluctuations, as shown in the graphs, are attributed to the below ambient conditions, as the coolant temperature approaches 0°C.

[0089] The Deep eutectic coolant with optimum thermo physical properties is the coolant of interest for the meso-channel work run validation. The combination of Diphenyl ether and Dibenzyl ether is mixed in a flat bottom round flask for 12-24 h and the molar ratio is mixed as per the details mentioned in the Patent application no: IN202241038156. The geometry is fabricated as per the design and the leak test is performed using DI water. The complete experimental flow setup schematic is used as shown in Figure 5. Higher sensitive thermal sensors and Agilent and Tempsen Make data logging are used for experimental data acquisition. The chiller is customized for the coolant requirement and all the censors are calibrated. The material of choice for the pump is stainless steel and all the sealants are silicone rubber and PTFE materials. Since the DES solvent is acidic with a pH of 5.5 and also dissolves the material other than silicone rubber and PTFE.

[0090] Both the silicone and PTFE are immersed in the DES solvent and verified for solubility, and it is found to be insoluble in DES. Furthermore, a PID controller with a precision of 1%. Every experimental data is taken when the fluid flow in the system reaches a steady state and heat load is given to the geometry through a heater which is maintained with constant temperature assisted by the PID controller.

[0091] The bottom plate 106 can be made from the materials selected from the group comprising Aluminum, brass, titanium, composites, and alloys of these materials, most preferably aluminum. The top plate 108 is made of material that does not form an oxide layer when exposed to the environment, most preferably Stainless steel.

[0092] The bottom plate 106 of the geometry will be in contact with the heat-generating appliance. The invention is to aim for an optimum cooling plate for any given heat source with the working range tested between -10 to 100°C. Since DES is a dielectric coolant in nature the channel is prevented from electrical conductivity through the fluid transport. The thermal profiles shown in Figures 5a, 5b and 5c are the bottom plate 106 cooling curves for the inlet fluid temperatures 30, 5, and -5°C respectively. The oscillation in the cooling curves is observed due to the changes in the fluid viscosity with respect to the inlet fluid temperature changes. A total of 5 K-type thermocouples are placed in the bottom plate 106 at an equidistance of 72° radians and 4 mm from the bottom surface. The gap in the drill area is sealed with thermal conductive paste grade in case of thermal conductivity probe. The bottom plate 106 is assembled and sealed with thermal paste to avoid air resistance between heat sink and heater source.

[0093] [Fig.6] depicts/illustrates effect of fluid flow rates and its effect compared with simulation results and found to be in alignment with experimental data for both the total flow rates of 2.5 LPM and 3 LPM, in accordance with an embodiment of the present disclosure;

[0094] [Fig.6] depicts the experimental validation performed by comparing computational predictions with experimental results. The data is plotted for different inlet and outlet fluid temperatures, with the center inlet maintained at a flow rate of 1 LPM, while the peripheral flow rate varies at 1.5 LPM and 2 LPM. The experimental findings show a strong correlation with the computational data.

[0095] [Fig.7] depicts/illustrates effect of inlet fluid temperature on heat transfer compared with simulation for a fluid flow rate 1, 1.5 LPM for the heater plate maintained at 60 °C, in accordance with an embodiment of the present disclosure;

[0096] A graphical comparison of experimental (Exp) and simulated (Sim) heat transfer data at different average inlet temperatures (Tin_Avg) is presented. The y-axis represents heat transfer in watts ranging from 0 to 300 W, while the x-axis denotes the average inlet temperature of 7°C, 13°C, and 30°C for a fluid flow rate of 1 and 1.5 LPM, with the bottom plate 106 heated to 60°C. At lower temperatures, experimental results exceed simulations due to ambient heat gain, whereas at ambient conditions, heat loss to the surroundings is observed.

[0097] [Fig.8] depicts/illustrates effect of inlet fluid temperature on heat transfer compared with simulation for a fluid flow rate of 1, 2 LPM for the heater plate maintained at 60°C, in accordance with an embodiment of the present disclosure;

[0098] A similar trend is depicted in [Fig.8], which compares experimental and simulated heat transfer data at various inlet temperatures. The y-axis again represents heat transfer of 0 to 300 W, while the x-axis shows average inlet temperatures of 6°C, 13°C, and 29°C for a flow rate of 1 and 2 LPM.

[0099] Variables such as channel width, height, length, initial velocity, pressure and plate heat flux are explored and a more effective heat sink in consideration with all the variables is chosen for manufacturing as shown in [Fig.4], summary of the data is given in the Table 01and outlet fluid temperature and the heat transfer for the given average plate temperature is measure and shown in [Fig.6], 7 and 8 respectively. Apart from the heat sink design, the most important factor in cooling devices is coolant. Since the application of the invention is intended for electronic device manufacturing, the real-time cooling curve in the bottom plate 106 (4 mm away from the heating surface) for the given fluid flow temperature ranges from 30,5 and -5 in Figures 5a, 5b and 5c respectively. The simulation evidence with experimental validation gives a complete heat sink model that the electronic device manufacturers can use to optimize the temperature instability during device processing. The coolant used in this microchannel heat sink is free from chlorofluorocarbon and is eco-friendly. The working model is optimized for single-phase binary coolant and observed to work well between

-10 to 80 °C. The coolant viscosity varies with temperature, and it is evident in the cooling curves as shown in Figures 5a, 5b and 5c. The variation in temperature is in the acceptable limit and the increase in flow rate from 1.5 to 2 LPM shows an increase in heat transfer shown in Figures 7 and 8.

[0100] [Fig.9] illustrates a method 900 for biradial multiple entry mesochannel heat sink 100 with dielectric organic coolant. The method begins with providing a central base for thermal distribution and structural support in the biradial multiple entry mesochannel heat sink 100, as depicted at step 902. Subsequently, the method 900 discloses attaching multiple radial channels to the central base extending outwardly, wherein the multiple radial channels facilitate multiple fluid entry and multiple fluid exit to enhance heat dissipation, as depicted at step 904. Furthermore, the method 900 discloses facilitating uniform heat distribution by a circular plate positioned at the central base of the biradial multiple entry mesochannel heat sink 100, through the dual radial multiple entry mesochannels, as depicted at step 906. Additionally, the method 900 discloses housing multiple fluid inlets and outlets by a top plate 108 positioned at upper section of the biradial multiple entry mesochannel heat sink 100, as depicted at step 908. Furthermore, the method 900 discloses attaching the multiple fluid inlets and outlets to the top plate 108 and positioned at a periphery of the circular plate to facilitate fluid entry and exit, as depicted at step 910. Thereafter, the method 900 discloses attaching a single inlet and multi-outlet manifold 110 and 114 to the periphery of the circular plate, to regulate the fluid flow through the biradial multiple entry mesochannel heat sink 100, as depicted at step 906. Subsequently, the method 900 discloses circulating a dielectric organic coolant through the biradial multiple entry mesochannels to regulate thermal performance, as depicted at step 912. Thereafter, the method 900 discloses interfacing a bottom plate 106 attached to the central base with at least one electronic component to enable effective heat dissipation, wherein the biradial multiple entry mesochannel heat sink 100 ensures continuous heat dissipation and maintains bottom base plate of the biradial multiple entry mesochannel heat sink 100 at ambient temperature, as depicted at step 916.

[0101] This proposed invention rectifies the application difficulties in microchannel, optimized flow rate and increased surface area to enhance the heat transfer by addressing the hot spots in the radial geometry with a single entry. Thermal hot spots in the single-entry geometry are reduced by introducing multiple inlets and outlets in various locations. The fresh coolant entry in the periphery leads to optimum temperature difference and enhances the heat transfer rate. A unique circular manifold with a single inlet and quadruple outlet with uniform fluid flow is achieved using computational techniques. With the computational solution, the device is fabricated and validated by real-time experiments. This technology is modified to the geometry size and application and can be readily taken as a prototype for real-time industrial thermal management purposes. Pressure drop restriction and heat dissipation limits are rectified in the current idea by introducing fresh coolant in the periphery using a four-way manifold.

[0102] The integration of organic solvent cooling with the Dual Radial Multiple Entry Heat Sink presents a promising solution for advanced electronic device cooling. The dual radial heat paths, coupled with the superior heat transfer properties of the organic solvent, result in enhanced heat dissipation and improved temperature control. Computational analysis and experimental validation support the effectiveness and safety of this innovative cooling approach. Further research can explore optimization opportunities and broader applications in various electronic devices.

[0103] The advantages of the current invention include improved heat dissipation efficiency by utilizing a Dual Radial multiple entry heat sink (DRMEHS), which enhances thermal management for electronic devices.

[0104] An additional advantage is that the unique radial channel design increases the surface area for heat transfer, leading to superior cooling performance compared to conventional single-path designs.

[0105] An additional advantage is that the multiple inlet and outlet fluid entry configuration ensures uniform coolant distribution, thereby minimizing temperature hotspots on the cooling plate.

[0106] An additional advantage is that the integration of organic dielectric coolants with a wide range of freezing and boiling points allows stable operation in varied temperature conditions, making it suitable for extreme environments.

[0107] An additional advantage is that the computational optimization of fluid flow dynamics ensures enhanced thermal boundary layer interaction, further improving heat dissipation.

[0108] An additional advantage is that the bottom plate temperature is maintained within the optimal working range, preventing thermal degradation of sensitive electronic components.

[0109] An additional advantage is that the proposed heat sink design is compatible with various materials such as aluminum, brass, titanium, and composites, providing flexibility in manufacturing.

[0110] An additional advantage is that the novel four-way inlet manifold design allows effective mixing of coolants, leading to an even temperature profile across the heat sink.

[0111] Applications of the current invention include high-performance computing systems, power electronics cooling, avionics thermal management, electric vehicle battery cooling, industrial automation electronics, telecommunications infrastructure, and advanced semiconductor manufacturing.

[0112] The foregoing description of the specific embodiments will so fully reveal the general nature of the embodiments herein that others can, by applying current knowledge, readily modify and/or adapt for various applications such specific embodiments without departing from the generic concept, and, therefore, such adaptations and modifications should and are intended to be comprehended within the meaning and range of equivalents of the disclosed embodiments. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation. Therefore, while the embodiments herein have been described in terms of preferred embodiments, those skilled in the art will recognize that the embodiments herein can be practiced with modification within the scope of the embodiments as described here.

Claims

[Claim 1] A biradial multiple entry mesochannel heat sink (100) with dielectric organic coolant, comprising:
a central base for thermal distribution and structural support;
multiple radial channel attached to the central base extending outwardly, wherein the multiple radial channels facilitate multiple fluid entry and multiple fluid exit to enhance heat dissipation;
a circular plate positioned at a central base of the heat sink (100), for facilitating uniform heat distribution;
biradial multiple entry mesochannels positioned on the central base for enhancing heat dissipation through multiple radial pathways;
a top plate (108) positioned at upper section of the heat sink (100), configured for housing multiple fluid inlets and outlets;
the multiple fluid inlets and outlets attached to the top plate (108) and positioned at a periphery of the circular plate to facilitate fluid entry;
a single inlet and multi-outlet manifold (110 and 114) attached to the periphery of the circular plate, to regulate the fluid flow through the biradial multiple entry mesochannel heat sink (100) in the peripheral side of the base plate;
a dielectric organic coolant circulating through the biradial multiple entry mesochannels to regulate thermal performance; and
a bottom plate (106) attached to the central base and interfaced with at least one electronic component to enable continuous effective heat dissipation, wherein the biradial multiple entry mesochannel heat sink (100) ensures continuous heat dissipation and maintains bottom base plate of the biradial multiple entry mesochannel heat sink (100) at ambient temperature.

[Claim 2] The biradial multiple entry mesochannel heat sink (100) as claimed in claim 1, wherein the radial channels comprise a biradial configuration with increased surface area for heat dissipation, and wherein the single inlet and multi-outlet manifold (110 and 114) are strategically placed at the periphery of the circular plate of the heat sink (100) to introduce fresh coolant into the periphery of the circular plate.

[Claim 3] The biradial multiple entry mesochannel heat sink (100) as claimed in claim 1, wherein the dielectric organic coolant comprises a deep eutectic solvent (DES) with a wide range of freezing and boiling points of approximately -10 to 188 °C, and with optimized thermophysical properties for the heat dissipation, and wherein the dielectric organic coolant is circulated at an optimized flow rate between 1.5 and 2.5 liters per minute.

[Claim 4] The biradial multiple entry mesochannel heat sink (100) as claimed in claim 1, wherein the biradial multiple entry mesochannel heat sink (100) is fabricated from a material comprising at least one of aluminum, brass, titanium, composites, and alloys thereof.

[Claim 5] The biradial multiple entry mesochannel heat sink (100) as claimed in claim 1, wherein the single inlet and multi-outlet manifolds (108) comprise:
stainless steel;
PTFE (Polytetrafluoroethylene) gasket sealing to prevent thermal leaks; and
silicone gasket sealing to prevent fluid leakage within the biradial multiple entry mesochannel heat sink (100).

[Claim 6] The biradial multiple entry mesochannel heat sink (100) as claimed in claim 1, wherein the bottom plate (106) of the biradial multiple entry mesochannel heat sink (100) comprises pressure transmitters and flow meters to monitor fluid dynamics and optimize cooling performance.

[Claim 7] The biradial multiple entry mesochannel heat sink (100) as claimed in claim 1, comprising a PID (Proportional-Integral-Derivative) controller to control the dielectric organic coolant flow rate to maintain the uniform temperature profile across the bottom base plate of the at least one electronic device.

[Claim 8] The biradial multiple entry mesochannel heat sink (100) as claimed in claim 1, comprising a computational validation system to compare experimental and simulated thermal performance data, and wherein a numerical computational approach is used to optimize the biradial multiple entry mesochannel heat sink design.

[Claim 9] The biradial multiple entry mesochannel heat sink (100) as claimed in claim 1, wherein the biradial multiple entry mesochannel heat sink (100) operates in the temperature range of -10°C to 100°C.

[Claim 10] A method for biradial multiple entry mesochannel heat sink (100) with dielectric organic coolant, the method comprising:
providing a central base for thermal distribution and structural support in the biradial multiple entry mesochannel heat sink (100);

attaching multiple radial channels to the central base extending outwardly, wherein the multiple radial channels facilitate multiple fluid entry and multiple fluid exit to enhance heat dissipation;
facilitating uniform heat distribution by a circular plate positioned at the central base of the biradial multiple entry mesochannel heat sink (100), through the dual radial multiple entry mesochannels;
housing multiple fluid inlets and outlets by a top plate (108) positioned at upper section of the biradial multiple entry mesochannel heat sink (100);
attaching the multiple fluid inlets and outlets to the top plate (108) and positioned at a periphery of the circular plate to facilitate fluid entry;
attaching a single inlet and multi-outlet manifold (110 and 114) to the periphery of the circular plate, to regulate the fluid flow through the biradial multiple entry mesochannel heat sink (100) in the peripheral side of the base plate;
circulating a dielectric organic coolant through the biradial multiple entry mesochannels to regulate thermal performance;
interfacing a bottom plate (106) attached to the central base with at least one electronic component to enable effective heat dissipation, wherein the biradial multiple entry mesochannel heat sink (100) ensures continuous heat dissipation and maintains bottom base plate of the biradial multiple entry mesochannel heat sink (100) at ambient temperature.

[Claim 11] The method as claimed in claim 10, wherein the radial channels comprise a biradial configuration with increased surface area for heat dissipation, and wherein the single inlet and multi-outlet manifold (110 and 114) are strategically placed at the periphery of the circular plate of the biradial multiple entry mesochannel heat sink (100) to introduce fresh coolant into the periphery of the circular plate.

[Claim 12] The method as claimed in claim 10, wherein the dielectric organic coolant comprises a deep eutectic solvent (DES) with a wide range of freezing and boiling points of approximately -10 to 188 °C and with optimized thermophysical properties for the heat dissipation, and wherein the dielectric organic coolant is circulated at an optimized flow rate between 1.5 and 2.5 liters per minute.

[Claim 13] The method as claimed in claim 10, comprising fabricating the biradial multiple entry mesochannel heat sink (100) from a material comprising at least one of aluminum, brass, titanium, composites, and alloys thereof.

[Claim 14] The method as claimed in claim 10, comprising the single inlet and multi-outlet manifolds (108) comprise:
stainless steel;
PTFE (Polytetrafluoroethylene) gasket sealing to prevent thermal leaks; and
silicone gasket sealing to prevent fluid leakage within the biradial multiple entry mesochannel heat sink (100).

[Claim 15] The method as claimed in claim 10, comprising providing the bottom plate (106) of the biradial multiple entry mesochannel heat sink (100) comprises pressure transmitters and flow meters to monitor fluid dynamics and optimize cooling performance.

[Claim 16] The method as claimed in claim 10, comprising controlling the dielectric organic coolant flow rate by a PID (Proportional-Integral-Derivative) controller to maintain the uniform temperature profile across the bottom base plate of the at least one electronic device.

[Claim 17] The method as claimed in claim 10, comprising comparing experimental and simulated thermal performance data by a computational validation system, and wherein a numerical computational approach is used to optimize the biradial multiple entry mesochannel heat sink design.

[Claim 18] The method as claimed in claim 10, comprising operating the biradial multiple entry mesochannel heat sink (100) within a temperature range of -10°C to 100°C to ensure efficient cooling across different operational conditions.

[Fig. 1]

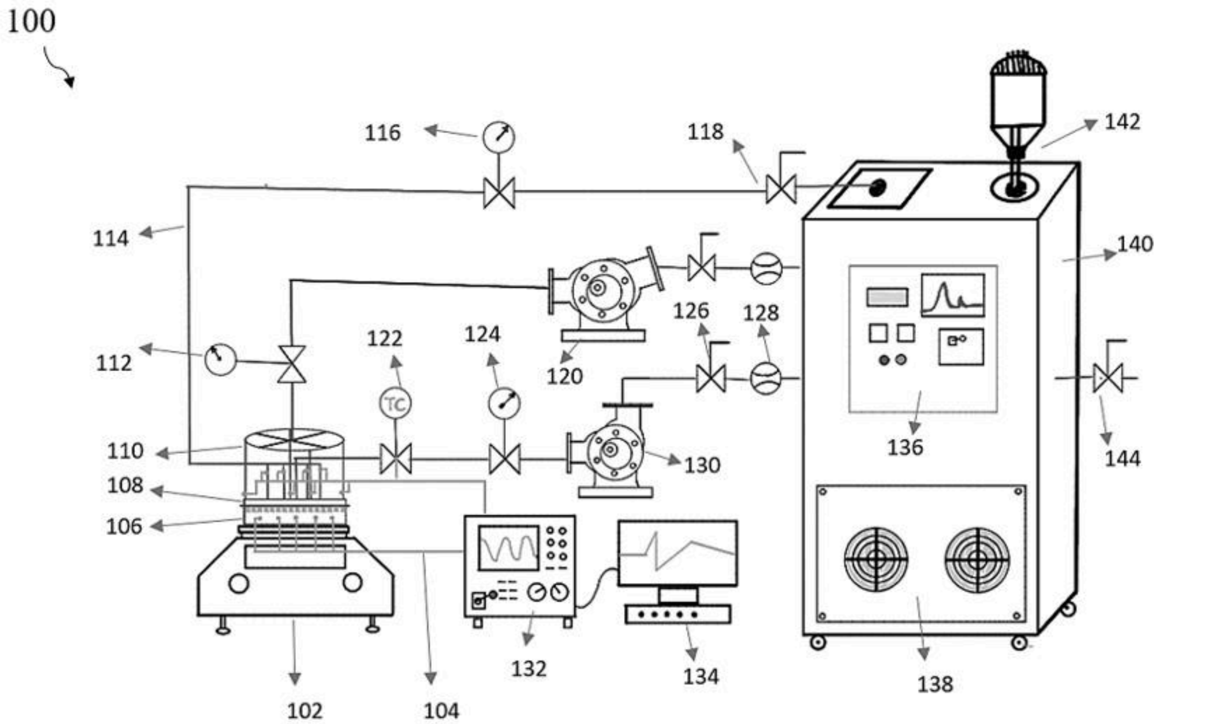


Fig. 1

[Fig. 2a]

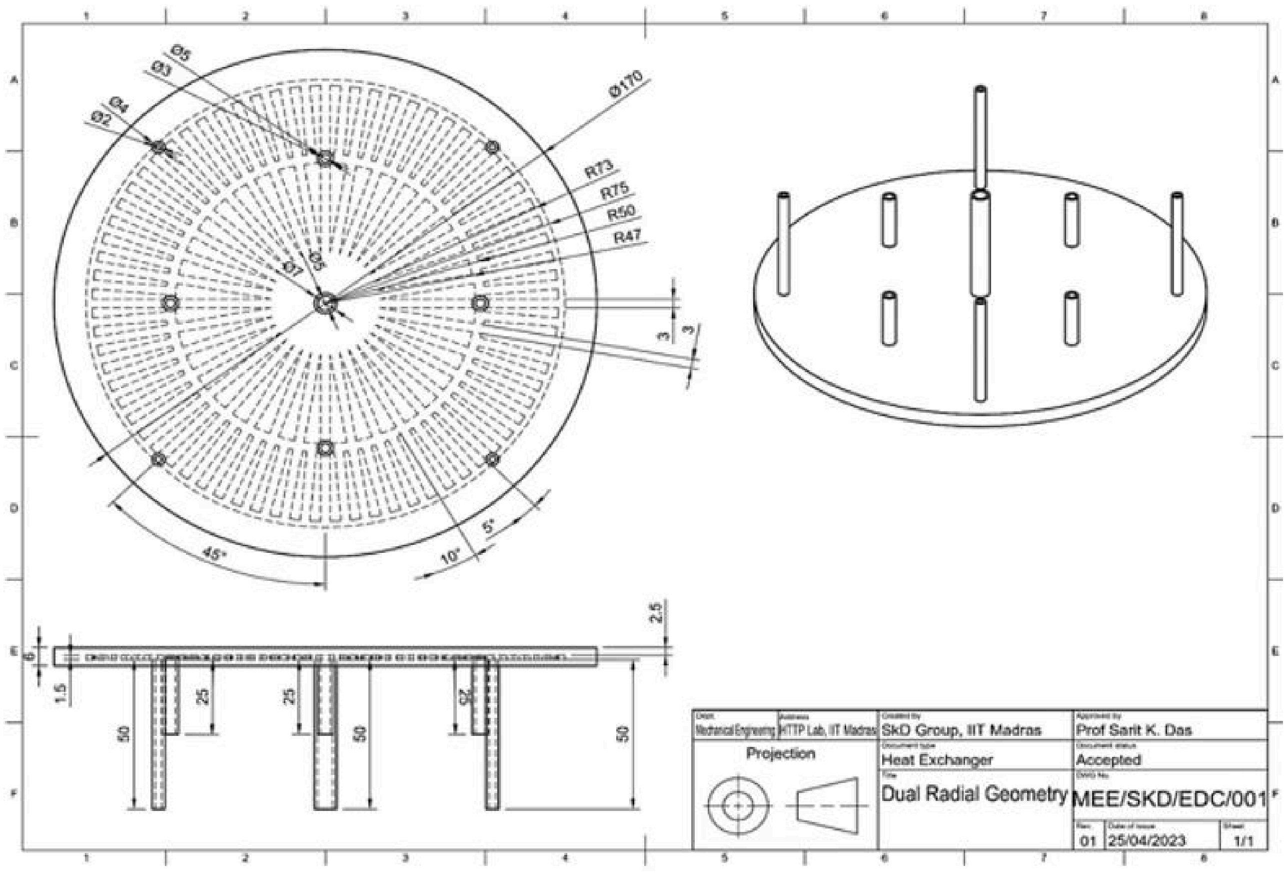


Fig. 2a

[Fig. 2b]

200

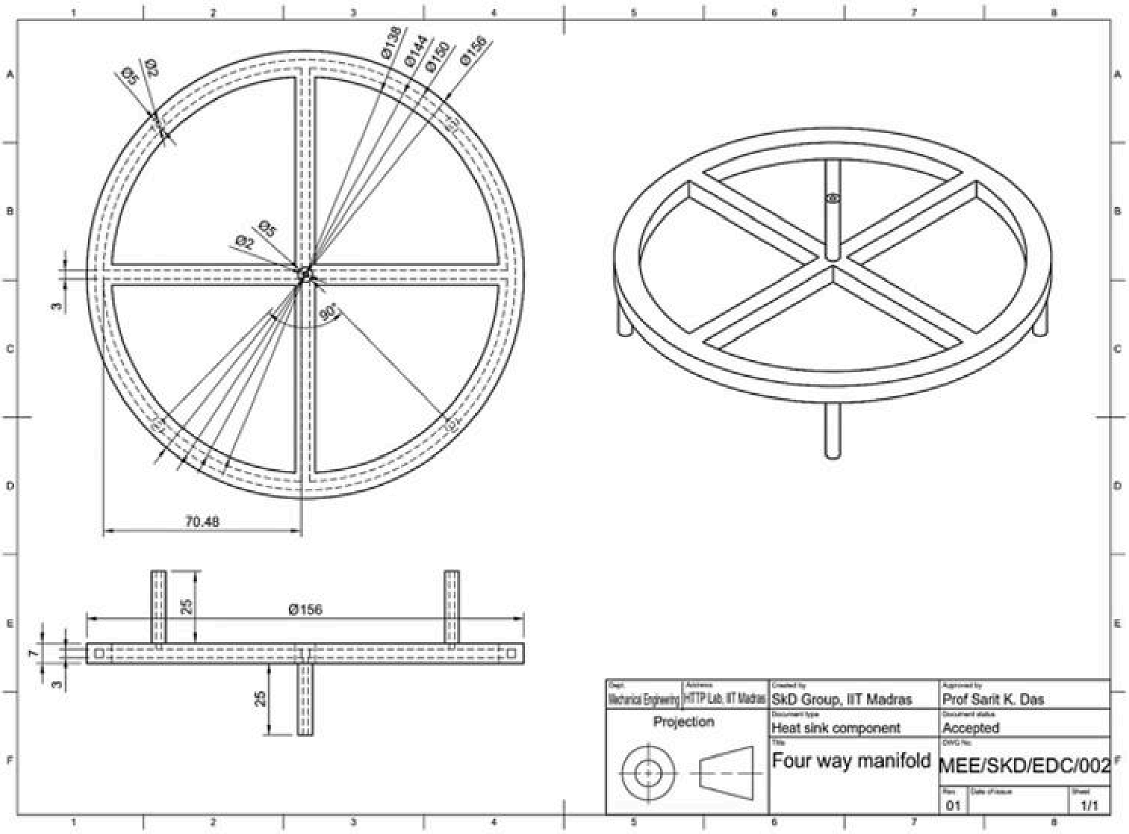


Fig. 2b

[Fig. 3a]

300

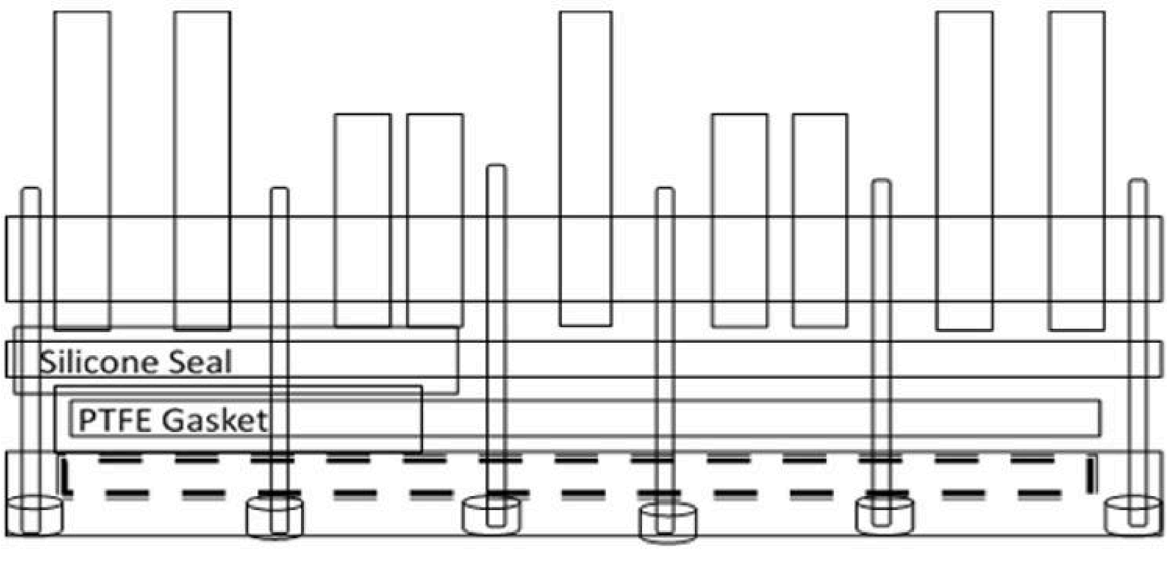


Fig. 3a

[Fig. 3b]

300

Fig. 3b

[Fig. 3c]

300

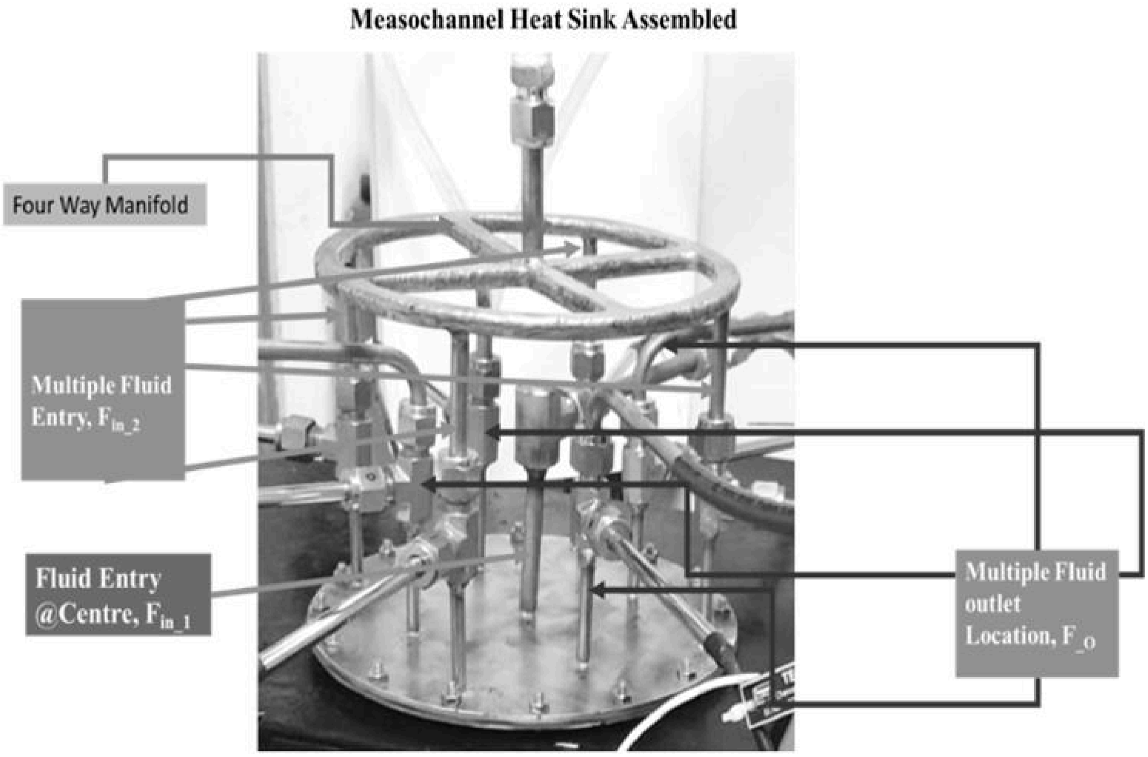


Fig. 3c

[Fig. 4]

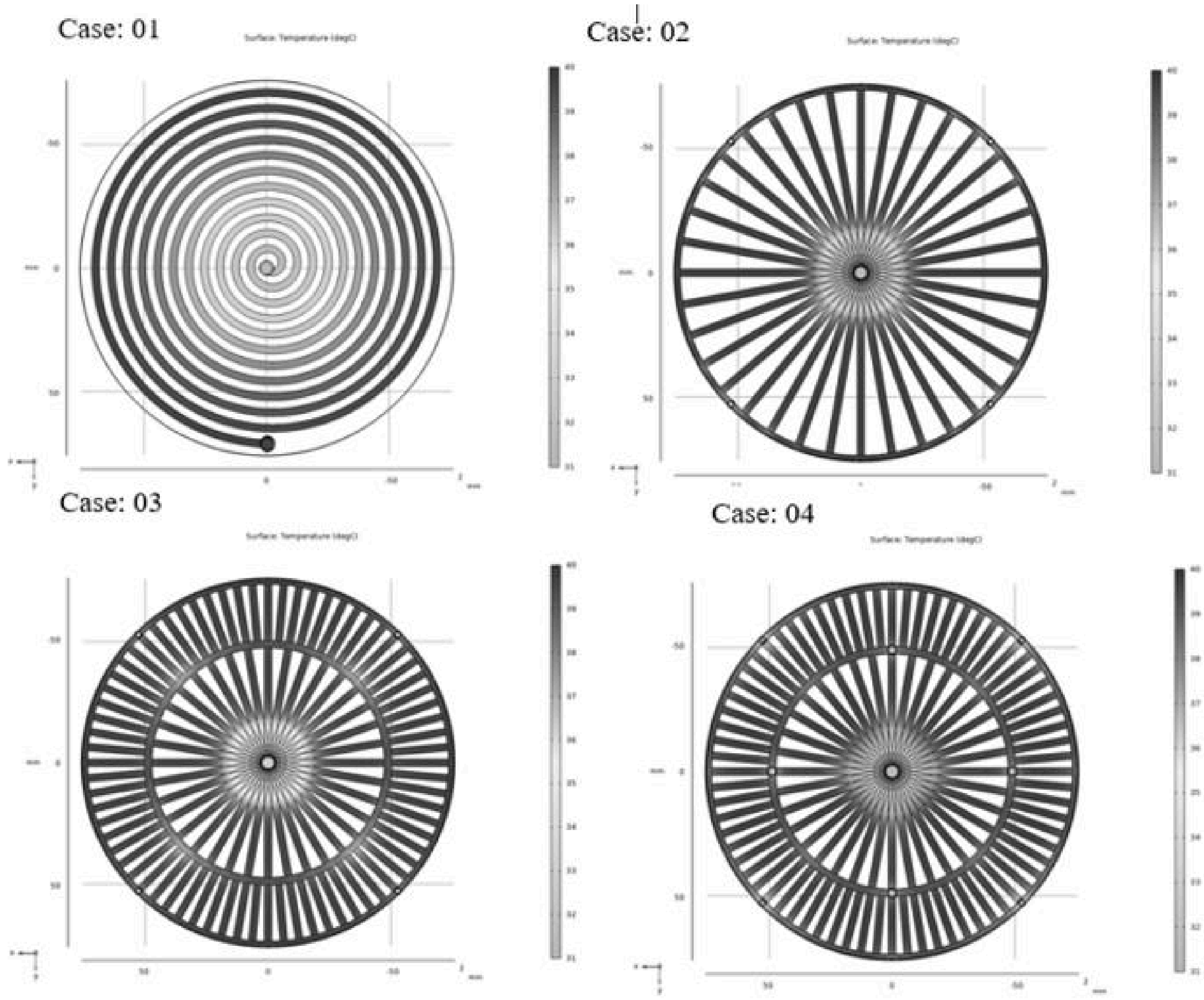
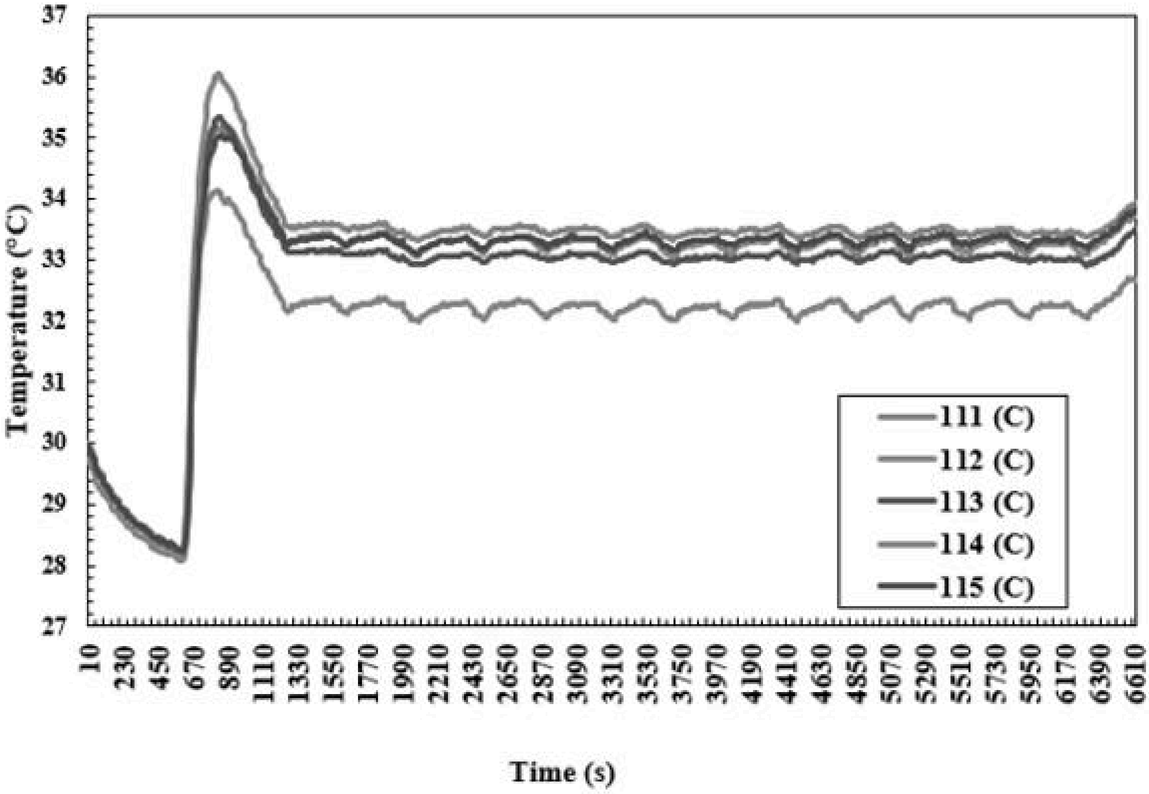


Fig. 4

[Fig. 5a]


Temperature (°C)
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36
35
34
33
32
31
30
29
28
27
10
230
450
670
890
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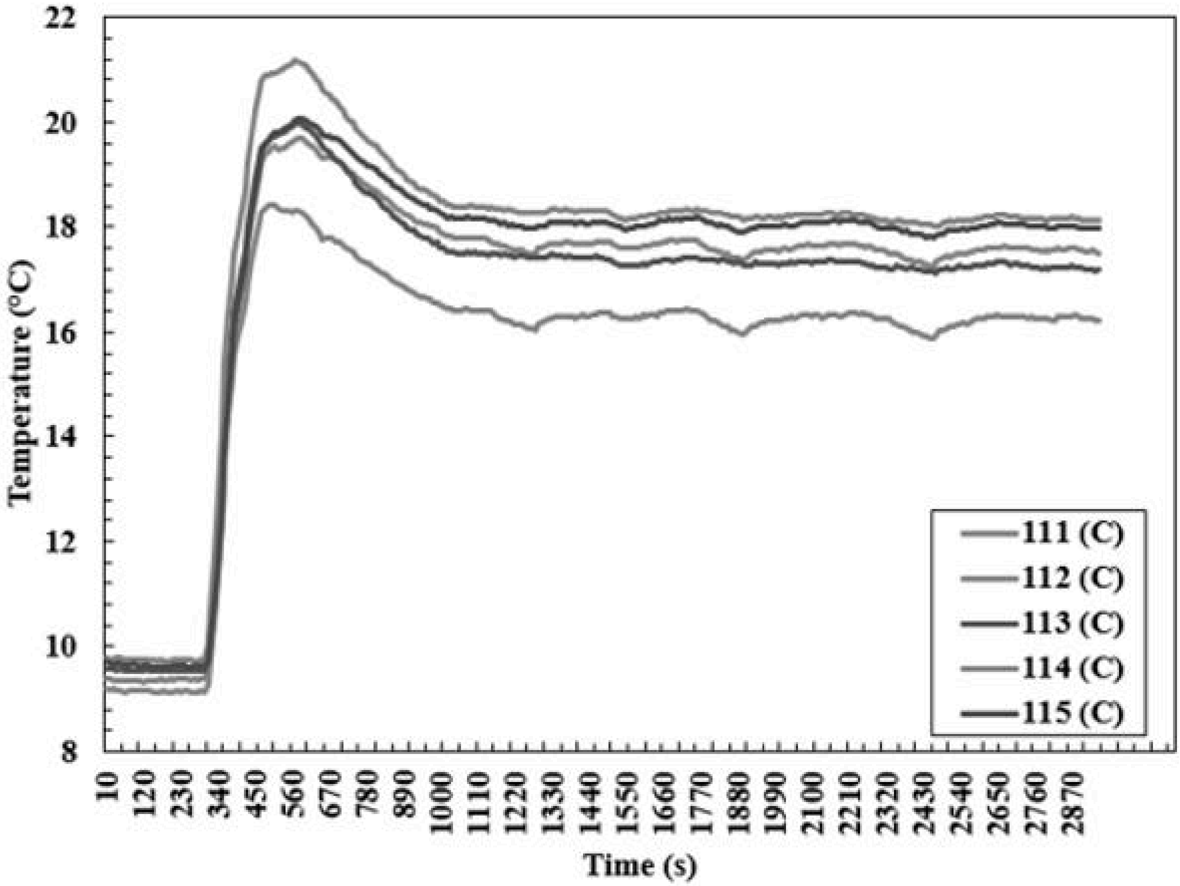
1550
1770
1990
2210
2430
2650
2870
3090
3310
3530
3750
3970
4190
4410
4630
4850
5070
5290
5510
5730
5950
6170
6390
6610
Time (s)
111 (C)
112 (C)
113 (C)
114 (C)
115 (C)

Fig. 5a

[Fig. 5b]


22
20
18
16
14
12
10
8
Temperature (°C)
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120
230
340
450
560
670
780
890
1000
1110
1220
1330
1440
1550
1660
1770
1880
1990
2100
2210
2320
2430
2540
2650
2760
2870
Time (s)
111 (C)
112 (C)
113 (C)
114 (C)
115 (C)

Fig. 5b

[Fig. 5c]

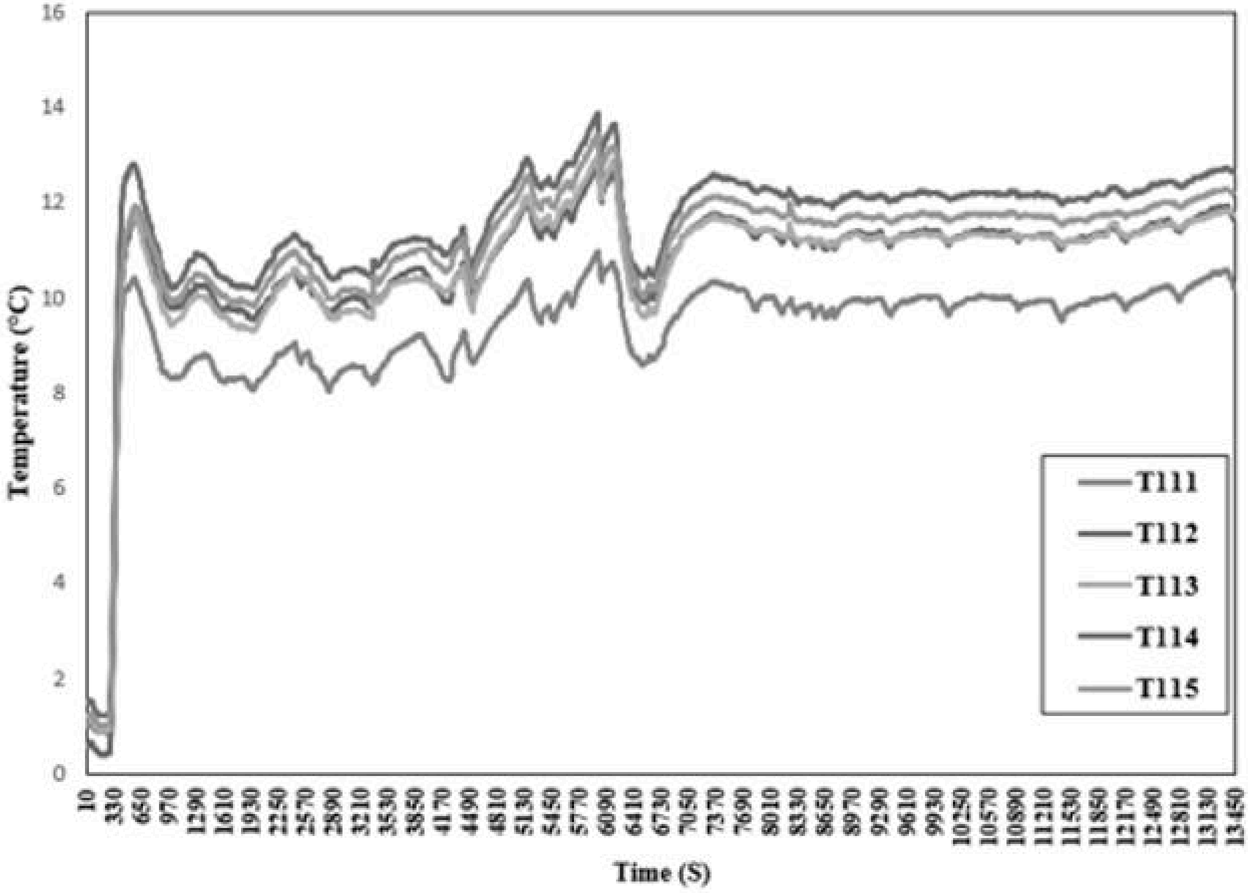


Fig. 5c

[Fig. 6]

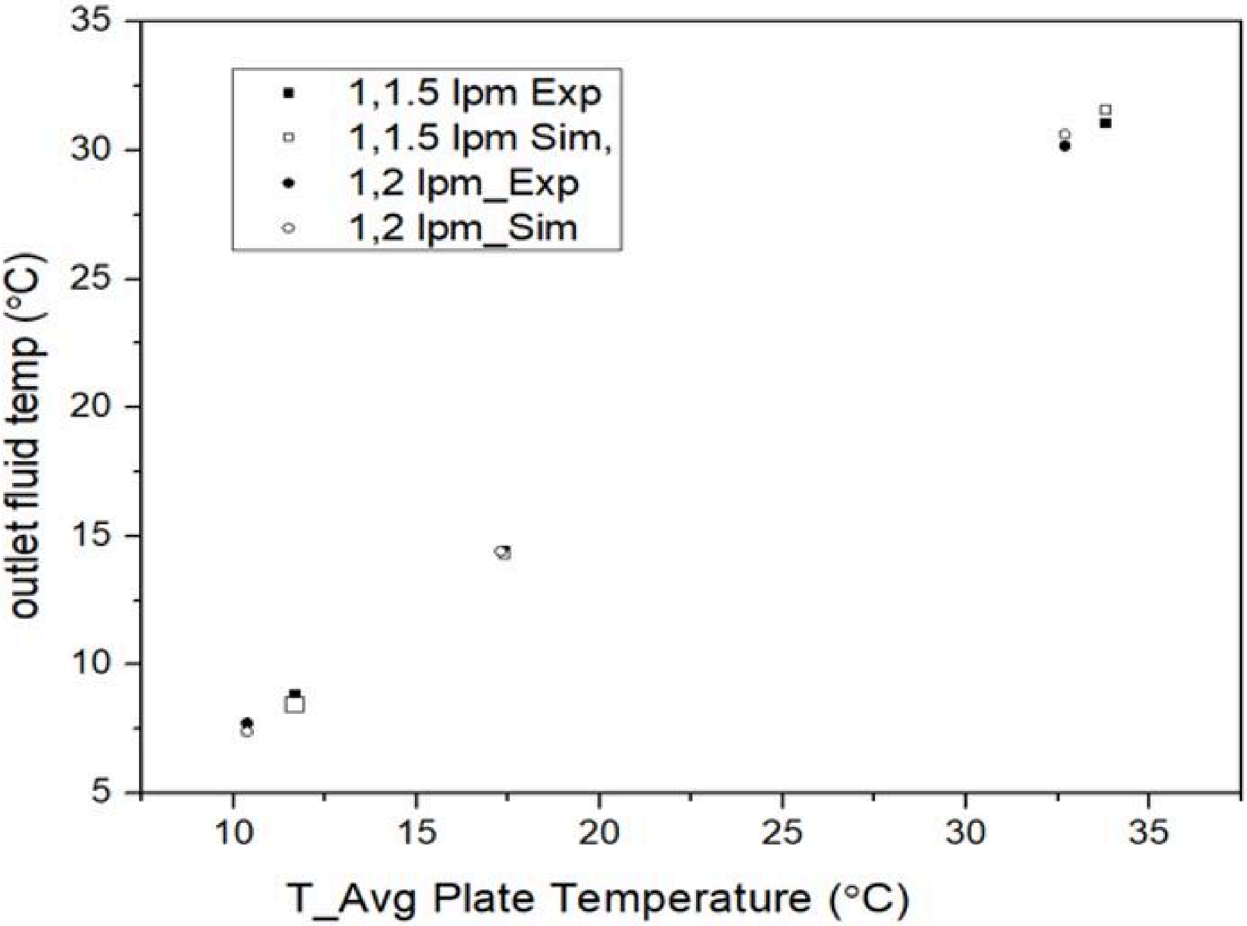
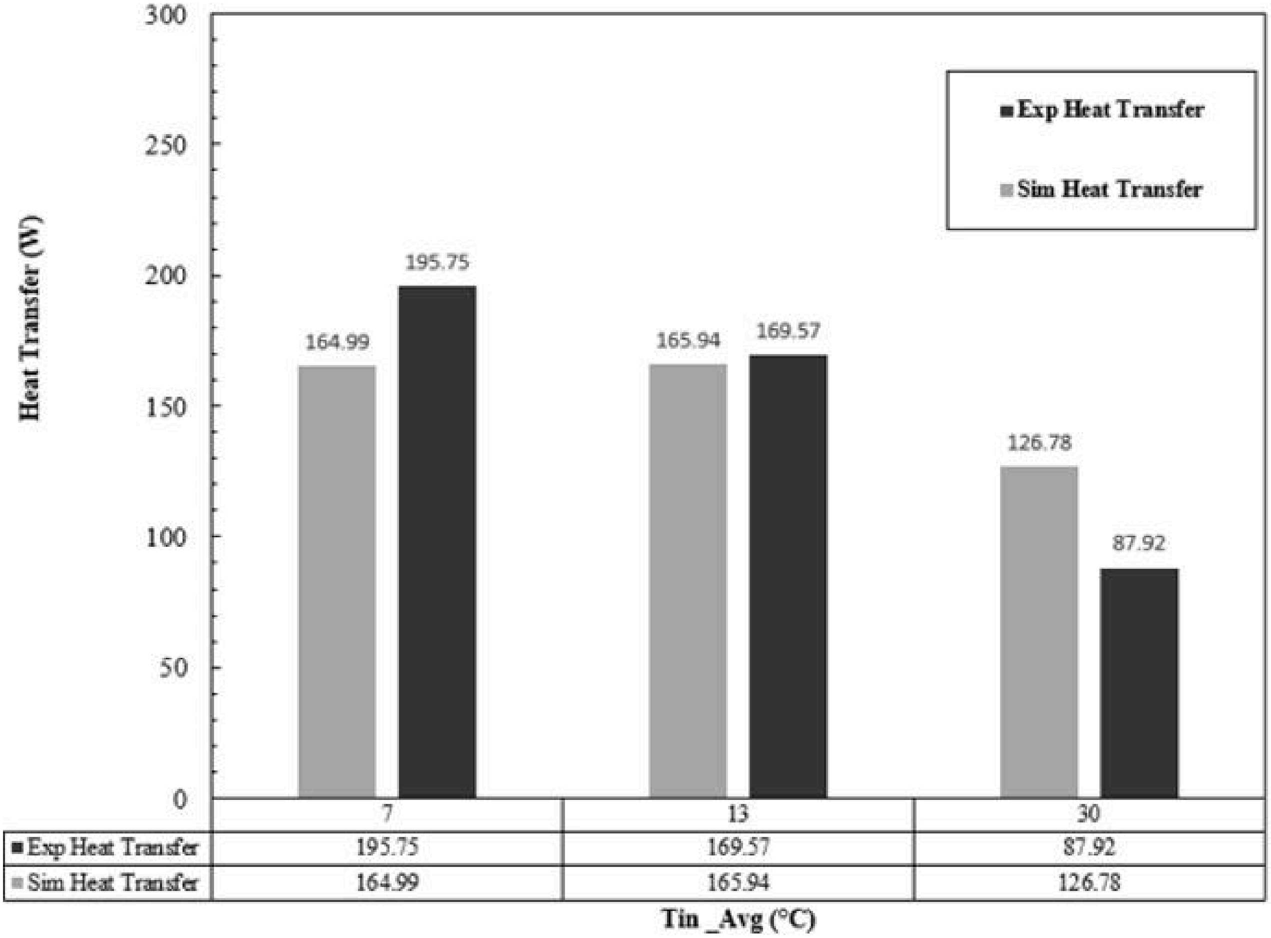

1,1.5 lpm Exp
1,1.5 lpm Sim,
1,2 lpm_Exp
1,2 lpm_Sim
outlet fluid temp (°C)
T_Avg Plate Temperature (°C)
5
10
15
20
25
30
35
10
15
20
25
30
35

Fig. 6

[Fig. 7]


Heat Transfer (W)
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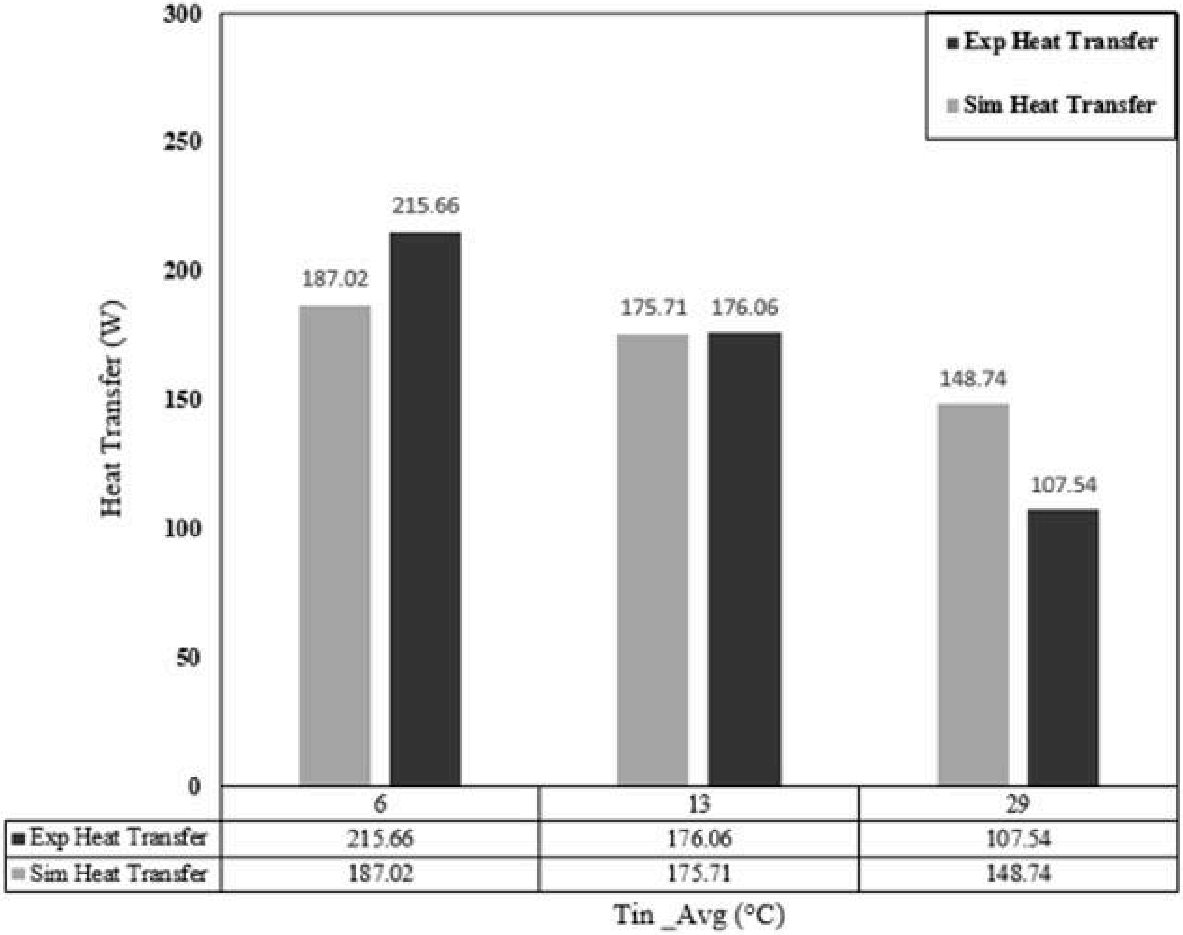
250
200
150
100
50
0
Exp Heat Transfer
Sim Heat Transfer
164.99
195.75
165.94
169.57
126.78
87.92
7
13
30
Exp Heat Transfer 195.75 169.57 87.92
Sim Heat Transfer 164.99 165.94 126.78
Tin _Avg (°C)

Fig. 7

[Fig. 8]



Exp Heat Transfer
Sim Heat Transfer
Heat Transfer (W)
300
250
200
150
100
50
0
187.02
215.66
175.71
176.06
148.74
107.54
6
13
29
Exp Heat Transfer 215.66 176.06 107.54
Sim Heat Transfer 187.02 175.71 148.74
Tin _Avg (°C)

Fig. 8

[Fig. 9]

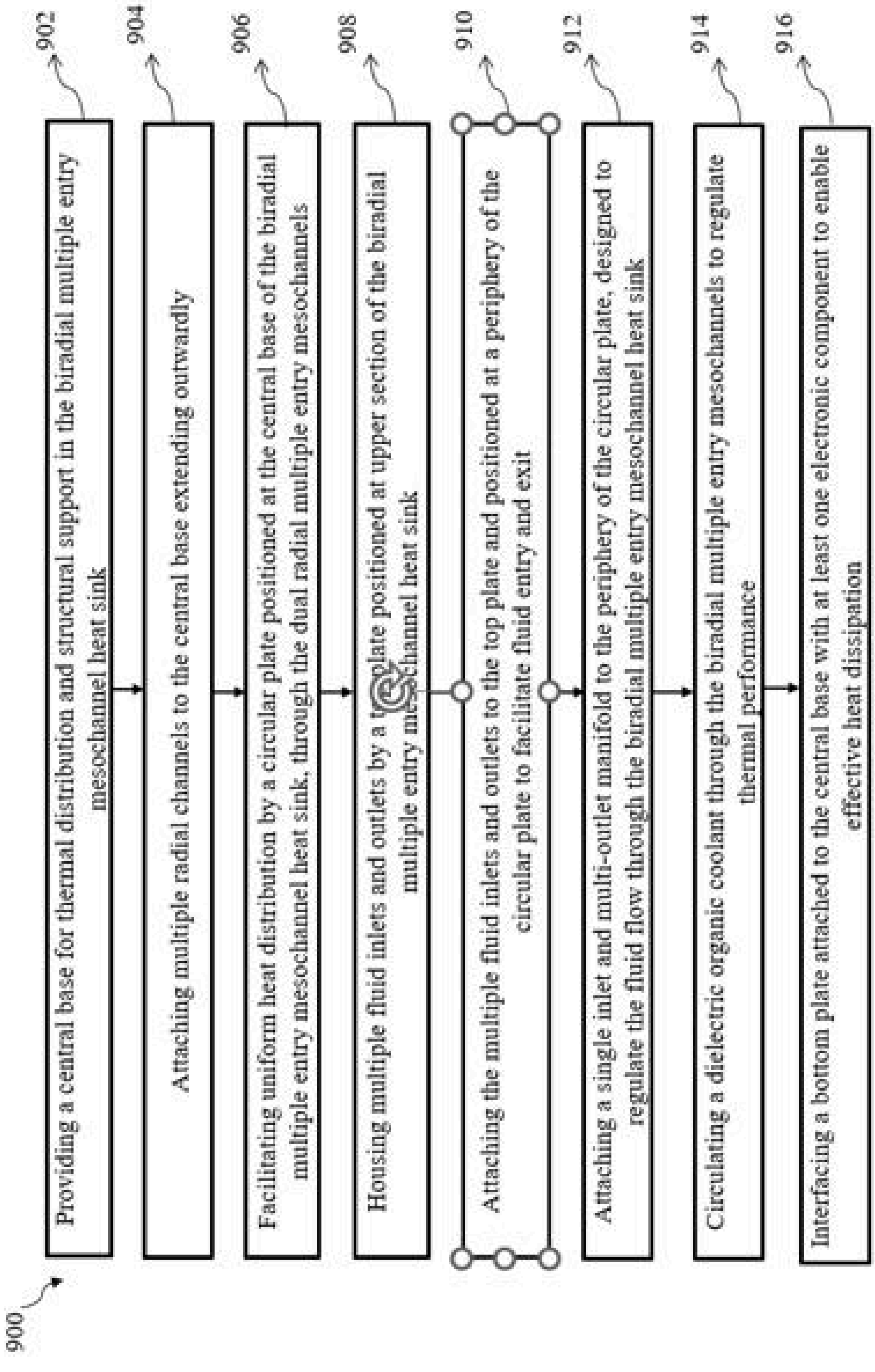

900
902
Providing a central base for thermal distribution and structural support in the biradial multiple entry mesochannel heat sink
904
Attaching multiple radial channels to the central base extending outwardly
906
Facilitating uniform heat distribution by a circular plate positioned at the central base of the biradial multiple entry mesochannel heat sink, through the dual radial multiple entry mesochannels
908
Housing multiple fluid inlets and outlets by a top plate positioned at upper section of the biradial multiple entry mesochannel heat sink
910
Attaching the multiple fluid inlets and outlets to the top plate and positioned at a periphery of the circular plate to facilitate fluid entry and exit
912
Attaching a single inlet and multi-outlet manifold to the periphery of the circular plate, designed to regulate the fluid flow through the biradial multiple entry mesochannel heat sink
914
Circulating a dielectric organic coolant through the biradial multiple entry mesochannels to regulate thermal performance
916
Interfacing a bottom plate attached to the central base with at least one electronic component to enable effective heat dissipation

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2025/050484

A. CLASSIFICATION OF SUBJECT MATTER
F28F13/00,H01L23/46 Version=2025.01

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F28F,H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

PatSeer, IPO Internal Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US2022412672A1(CHEN NAN Et al.) 29 DECEMBER 2022 (29.12.2022) Abstract; Claims 1-8, 15-17; Figures 1-4B	1-18
A	US2007074849A1(DELPHI TECH INC [US]) 05 APRIL 2007 (05.04.2007) Claims 1-13; Para 015-027	1-18
A	US8934250B2(IBM [US]) 13 JANUARY 2015 (13.01.2015) Claims 7, 16-19	1-18

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11-08-2025	11-08-2025

Name and mailing address of the ISA/	Authorized officer
Indian Patent Office Plot No.32, Sector 14,Dwarka,New Delhi-110075 Facsimile No.	Mahendra Dongre Telephone No. +91-1125300200

International application No.
PCT/IN2025/050484

Citation	Pub.Date	Family	Pub.Date
US 2022412672 A1	29-12-2022	US 12209821 B2	28-01-2025
		US 2025172353 A1	29-05-2025
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		EP 1772903 A3	05-11-2008
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		DE 102013218386 B4	08-09-2022
		US 2014085817 A1	27-03-2014
		US 2014085823 A1	27-03-2014
		US 8929080 B2	06-01-2015