Technology Review:

Enhancing Heat Transfer on Surfaces

Qpedia continues its review of technologies developed for electronics cooling applications. We are presenting selected patents that were awarded to developers around the world to address cooling challenges. After reading the series, you will be more aware of both the historic developments and the latest breakthroughs in both product design and applications. We are specifically focusing on patented technologies to show the breadth of development in thermal management product sectors. Please note that there are many patents within these areas. Limited by article space, we are presenting a small number to offer a representation of the entire field. You are encouraged to do your own patent investigation. Further, if you have been awarded a patent and would like to have it included in these reviews, please send us your patent number or patent application.

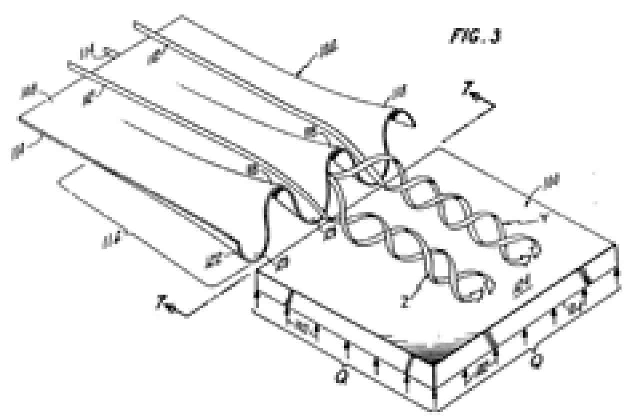
In this issue our spotlight is on enhancing heat transfer on surfaces. There is much discussion about its deployment in the electronics industry, and these patents show some of the salient features that are the focus of different inventors.

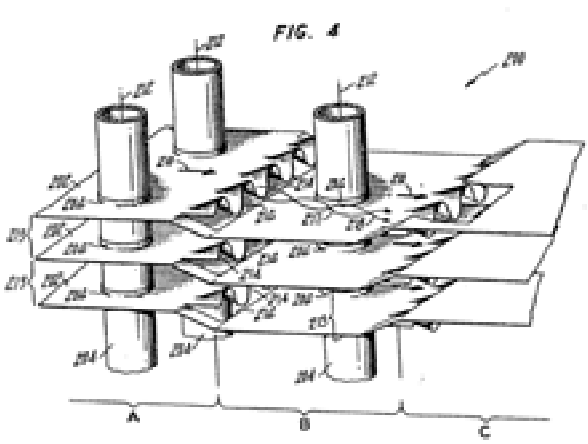
Heat Transfer Enhancing Device,
EP 0 275 813 B1, Werle, M., et al.

This invention relates to a heat transfer device comprising wall means defining a fluid flow channel and having a first surface portion over which a first fluid is adapted to flow in one direction for transferring heat energy between the first fluid and said wall means, and heat transfer enhancing means comprising a vortex generating wall adapted so that the fluid flows over both sides thereof in said one direction, said vortex generating wall having downstream edge and comprising a plurality of adjoining alternating lobes and troughs extending in said one direction from upstream ends thereof to said downstream edge, each lobe on one side of said wall having a corresponding trough opposite thereto on the other side of said wall such that said wall and said downstream edge are wave-shape. A heat transfer device of this type is disclosed in US-A-2,488,615.

It is desirable to improve the heat transfer rates in heat exchangers such as air conditioners, furnaces,

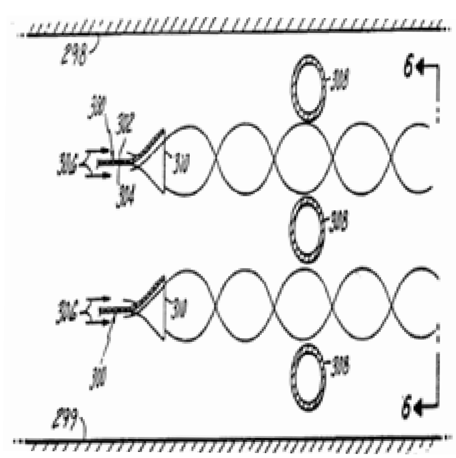
PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
EP 0 275 813 B1	HEAT TRANSFER ENHANCING DEVICE	Werle, M., et al.	Feb 27, 1991
EP 1 592 060 A1	APPARATUS FOR ENHANCING HEAT TRANSFER EFFICIENCY OF ENDOTHERMIC/ EXOTHERMIC ARTICLE	Sim Won, C., et al.	Feb 11, 2005
US 8356658 B2	HEAT TRANSFER ENHANCING SYSTEM AND METHOD FOR FABRICATING HEAT TRANSFER DEVICE	Bunker, R., et al.	Jan 22, 2013





and in other apparatus which requires the efficient exchange of heat between a fluid and the wall over which the fluid flows. The effectiveness of the geometry of the convective heat transfer surfaces of such apparatus in producing efficient heat exchange with a minimal amount of friction losses can influence the required size and thus the initial cost of such apparatus, as well as operating costs and pumping power requirements. In applications where the heat exchanging geometry is for the purpose of reducing the temperature of the structure to permit it to operate in a hot environment, such as internal cooling geometries for gas turbine engine turbine airfoils, more efficient heat transfer means can reduce the needed mass flow rate of coolant, allow the apparatus to operate in a hotter environment, or permit the use of less exotic, less costly materials. It is known that a fundamental contributor to the limiting of local convective heat transfer is the rapid growth and persistence of thermal boundary layers within internal flow passages of heat exchangers. The boundary layer acts as a thermal insulator between the wall and the flowing fluid. For this reason numerous geometrical schemes have been devised to disrupt this boundary layer and its insulating effect. Among these schemes have been the introduction of tabs, slits, and other flow disturbing elements and geometries (see for example FR-A-472122) to generate random and ordered velocity fluctuations which increase heat transfer coefficients locally; however, excess pressure drops are created across these devices. When large numbers of these flow disturbing elements are used, which is often the case, a significant increase in the total pressure drop through the apparatus is incurred which requires increased fluid pumping power needs that offset some of the benefits of improved heat transfer. Additionally, such flow disturbing elements may be difficult and costly to fabricate.

Reference is also made to US-A-2,344,588 in which corrugated baffle plates are disposed in the fluid flow passages of a heat exchanger. The corrugations are at right angles to the direction of fluid flow. In US-A-2,488,615 already referred to oil cooler tube is disclosed having a corrugated fin disposed therein. The corrugations defining lobes and troughs of constant amplitude along the length thereof. Suitable embossments are formed in the fin for the purpose of inducing turbulence.



Lobed mixers having troughs increasing in depth in a downstream direction are known in the art for mixing two streams flowing on either side of the lobed wall, such as for mixing the cooler fan exhaust stream with the core engine stream in a gas turbine engine, generally for the purpose of sound reduction. One patent describing such a device is US-A-4,066,214.

The object of the present invention is to provide a heat transfer device having an improved rate of heat transfer between a fluid and the wall over which it flows without creating high pressure drops within the fluid.

To achieve this the heat transfer device according to the invention is characterized in that said troughs increase in depth in said one direction from the upstream ends thereof, said first surface portion being disposed downstream of said downstream edge of said vortex generating wall to generate a plurality of adjacent vortices downstream of said downstream edge adjacent said first surface portion, adjacent vortices rotating in opposite directions about respective axes extending in the direction of the bulk fluid flow adjacent said lobes and troughs such that fluid flowing over both said sides mixes together downstream of said downstream edge adjacent said first surface portion, the contour and dimensions of each said lobes and troughs being selected to ensure that each trough flows full throughout its length.

The troughs and lobes are sized and contoured to flow full throughout their length to minimize losses and to generate vortices which wash over the downstream heat transfer surface scrubbing away the insulating thermal boundary layer and stirring in the core flow to maintain as large a temperature difference as possible between the surface and the fluid in contact with the surface. The axial vortices produced in the wake of the vortex generating wall are large scale in that their "diameter" is comparable to the amplitude of the lobes which create them. The vortices scrub the boundary layer fluid from the wall, transport it up into the vortex core, and subsequently convey it downstream. Simultaneously the fluid vortex motion creates a mixing which averages out temperature non-uniformities within the fluid flow passage adjacent the heat transfer surface.

An important advantage of the present invention is in its ability to improve heat transfer efficiencies with the introduction of relatively low total pressure losses. The buildup of an insulating boundary layer is minimized on a heat exchanger surface and mixing of a fluid within the flow channel of a heat exchanger is improved, without inducing an excessive pressure drop within the fluid. Prior art devices often introduced relatively high pressure losses, which seriously detracted from and/or limited their usefulness.

By varying the lobe to lobe spacing (i.e., wave length) and the amplitude of the undulations, the size and lateral spacing of the vortices can be controlled. Furthermore, trough and lobe size and shape can be used to control the vortex intensity. It is therefore possible to establish a secondary flow field downstream of the vortex generator which is not simply a turbulent, random mixing process.

Apparatus For Enhancing Heat Transfer Efficiency of Endothermic/Exothermic Article,
EP 1 592 060 A1, Sim Won, C., et al.

The present invention relates to an apparatus for enhancing thermal transmission efficiency of an endothermic/exothermic article, and more particularly, to an apparatus that can enhance heat transfer efficiency of an endothermic/exothermic article, which can absorb or generate heat during its operation, such as a semiconductor integrated circuit and a heat exchanger.

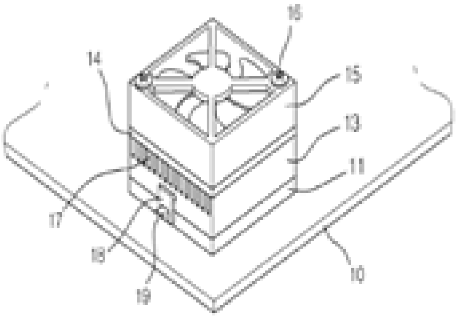
Generally, an electronic integrated circuit is formed by mounting a plurality of circuit devices such as a resistor, a transistor, a diode, and a condenser in a small chip to realize the miniaturization and the reliable operation. However, due to the integration of the circuit devices in the small chip, the electronic integrated circuit emits superheat that may be cause the deterioration of the performance of the circuit.

Meanwhile, a heat exchanger is installed in an indoor or outdoor unit of an air conditioning system to absorb or transmit heat from or to a refrigerant. When the heat exchanger is operated, a thermal transmission is realized between an outer circumference of the heat exchanger and outer air. A performance of the heat exchanger is determined according to how quickly the transmission is realized.

According to the prior art, to enhance the heat transfer efficiency of the endothermic/exothermic article, a heat sink is mounted on the source to heat -exchange with the source so that the heat can be transmitted from the heat sink to outer air. However, even when the heat sink is mounted on the endothermic/exothermic article, there is a limitation in properly controlling the temperature of the source. Therefore, a size of the heat sink and/ or the endothermic/exothermic article should be increased or the wind velocity or amount should be increased.

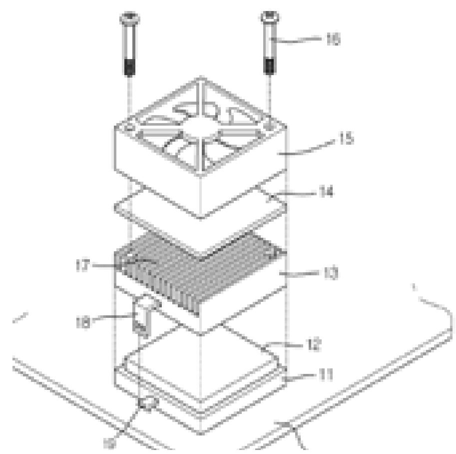
However, the size increase of the heat sink and/ or the endothermic/exothermic article is increased causes the size increase of a product where the source is applied, deteriorating the customer's preference. In addition, in order to increase the wind velocity or wind amount is increased, a size of a fan should be increased, causing the increase of the product size and power consumption.

FIG. 1



That is, the enhancement of the heat transfer efficiency of the endothermic/exothermic article with the heat sink is affected by many limitations such as a space limitation, a structural limitation and the like.

Accordingly, the present invention is directed to an apparatus for enhancing thermal transmission efficiency of an endothermic/exothermic article, which substantially obviates one or more problems due to limitations and disadvantages of the related art.



An object of the present invention is to provide an apparatus for enhancing thermal transmission efficiency of an endothermic/exothermic article, which can sufficiently transmit heat in a limited space.

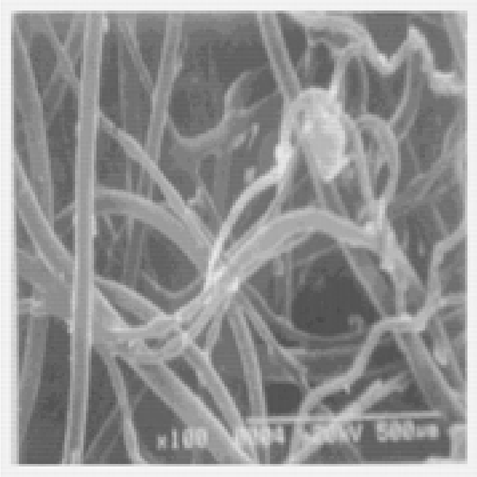
Another object of the present invention is to provide an apparatus for enhancing thermal transmission efficiency of an endothermic/exothermic article, which can effectively transmit heat by adding a single pad without mounting a large -sized additional element.

Still another object of the present invention is to provide an apparatus for enhancing heat transfer efficiency of an endothermic/exothermic article, which is particularly suitable for a semiconductor integrated circuit and a heat exchanger of an air conditioning system.

Additional advantages, objects, and features of the invention will be set forth in part in the description which follows and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention.

To achieve these objects and other advantages and in accordance with the purpose of the invention, as embodied and broadly described herein, there is provided an apparatus for enhancing heat transfer efficiency of an endothermic/exothermic article, the apparatus including: a heat sink disposed on the endothermic/exothermic article to enhance heat transmission; a plurality of fins formed on the heat sink to enhance heat exchange; and a porous medium disposed on the fins to increase cooling efficiency of the endothermic/exothermic article by air flowing between gaps between the fins and the porous medium.

In another aspect of the present invention, there is provided an apparatus for enhancing heat transfer efficiency of an endothermic/exothermic article, the apparatus including: an endothermic/exothermic article; a porous medium contacting the endothermic/exothermic article to transmit heat to each other, air being directed to the endothermic/exothermic article through porosities formed in the porous medium to enhance cooling efficiency of the endothermic/exothermic article.

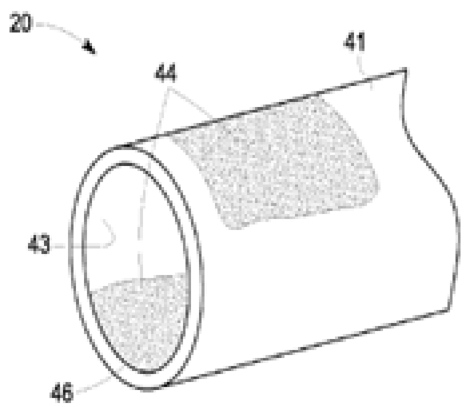


In still another aspect of the present invention, there is provided an apparatus for enhancing heat transfer efficiency of an endothermic/exothermic article, the apparatus including: a porous medium disposed on the endothermic/exothermic article to perform quick heat exchange; and a fan disposed on the porous medium for forcedly generating air current.

According to the present invention, the heat transfer efficiency can be effectively improved for the endothermic/exothermic article in a limited space.

The porous medium 14 is designed to quickly absorb the heat from the heat sink 13, thereby enhancing a heat -emission performance. In addition, since outer air freely comes in and out through the porosities, the cooling efficiency of the porous medium 14 can be improved by the air introduced or exhausted by the cooling fan 15. The porous medium 14 has an area identical or slight less than that of the top surface of the heat sink 13 and a 1 -10 mm thickness, being disposed between a surface defined by tops of the cooling fins 17 and the cooling f and 15. Accordingly, air forcedly formed by the cooling fan 15 is exhausted to an exterior side through porosities of the porous medium 14 and gaps defined between the cooling fins 17, thereby improving the cooling efficiency of the exothermic article (the integrated circuit 12). In addition, the heat of the cooling fins 17 can be quickly transmitted to the porous medium 14 to improve the cooling performance of the heat sink 13, thereby further enhancing the cooling efficiency of the exothermic article.

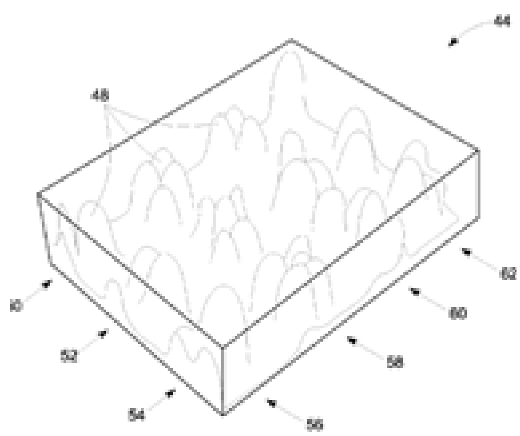
Heat Transfer Enhancing System And Method For Fabricating Heat Transfer Device,
US 8356658 B2, Bunker, R., et al.
In accordance with one exemplary embodiment of the present invention, a heat transfer device includes at least one heat transfer wall configured to separate a first fluid and a second fluid. A heat transfer enhancing system is provided to

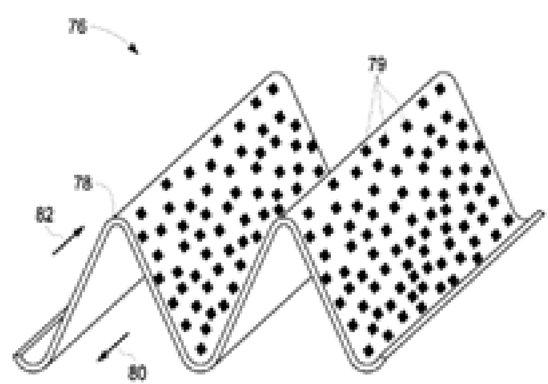


at least one heat transfer wall. The heat transfer enhancing system includes a plurality of micro turbulating particles that are bonded to at least one heat transfer wall, or portions thereof, using a binding medium. The heat transfer enhancing system includes a selected variation in particle size, or particle distribution density, or particle region spacing, or a combination thereof.

In accordance with another exemplary embodiment of the present invention, a natural gas heat exchanger includes at least one heat transfer wall configured to separate a first fluid and a second fluid, wherein the first fluid comprises a natural gas process fluid. A plurality of micro turbulating particles is bonded to the at least one heat transfer wall, or portions thereof, using a binding medium. The heat transfer enhancing system is provided to the at least one heat transfer wall. A plurality of micro turbulating particles are bonded to the at least one heat transfer wall, or portions thereof, using a binding medium.

The heat transfer tube 20 is in accordance with the aspects of FIG. 1 is illustrated. In the illustrated embodiment, the heat transfer enhancing system 44 is provided to an exterior surface 41 and an interior surface 43 of the heat transfer wall 46 of the tube 20. As described previously, the system 44 includes a plurality of micro turbulating particles bonded to the surfaces 41, 43 of the tube 20 using a binding medium. In certain exemplary embodiments, the plurality of micro turbulating particles may include nickel, cobalt, aluminum, silicon, or iron, or alloys thereof, or a combination including any of the foregoing. The binding medium may include epoxy, or metal foil, or solder, or braze material, or weld material, or a combination thereof. It should be noted that the above-mentioned list of materials of the micro turbulating particles and binding medium are not exhaustive and other metallic material or metallic alloys suitable for enhancing heat transfer characteristics are also envisaged. The amount and type of binder generally ensures sufficient adhesive strength of the micro turbulating particles to the heat transfer wall in system 44.





The system 44 includes a plurality of protuberances 48 provided in a predetermined pattern to a heat transfer wall 46 of the heat transfer tube. The plurality of protuberances together defines "turbulation", which appears as a roughened surface that is effective to increase heat transfer through the heat transfer wall 46. Even though the protuberances are shown approximately spherical shaped, other shapes may also be envisaged to meet the desired roughness and surface area characteristics and thus obtain a desired heat transfer enhancement. The protuberances 48 are provided along three rows 50, 52, 54 and four columns 56, 58, 60, and 62 to the heat transfer wall 46. In certain exemplary examples, the height "h" of each protuberance 48 is 9 mils (0.009 inches). It should be noted that value of height "h" should not be construed as a limiting value and may vary depending on the heat transfer requirement. Each protuberance 48 includes one or more of micro turbulating particles packed closely together. The protuberances 48 are bonded to the heat transfer surface 46 using the binding medium. It should again be noted that the illustrated example is merely an exemplary embodiment and that particle size, distribution density, spacing and pattern may be varied to achieve desired thermal enhancement. Size of the particles is determined based on the desired degree of surface roughness and surface area that will be provided by the protuberances. The micro turbulating particles facilitate enhanced heat transfer between the first fluid and the second fluid via the heat transfer wall 46. Additional pressure loss in the heat transfer device is minimal relative to that without the system 44.

A heat transfer device 76 (heat exchanger) is in accordance with other aspects of the present invention. The heat transfer device 76 includes a corrugated panel 78 in which the process fluid and heating/cooling fluid flows in alternate channels 80, 82 respectively. The exemplary heat transfer enhancing system 44 in accordance with aspects of the present invention is provided and includes a plurality of micro turbulating particles 79 bonded to one side or both sides of the corrugated panel 78 using the binding medium. The micro turbulating particles 79 and the binding medium are applied to the corrugated panel 78 using techniques such as spraying, or slurry, or dipping, or sprinkling, or flame spray, or roll coating, or a combination thereof and then heat treated to perform curing. The micro turbulating particles 79 increase the micro turbulated surface area and heat transfer coefficient of the corrugated panel 78 that results in enhanced heat transfer rates and reduced relative pressure losses. Here again, it should be noted that the illustrated example is merely an exemplary embodiment and that particle size, spacing and pattern may be varied to achieve desired thermal enhancement.