ADVANCED TURBULATOR ARRANGEMENTS FOR MICROCIRCUITS

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0001] The present invention relates to advanced turbulator arrangements for cooling microcircuits used in turbine engine components.

(2) Prior Art

[0002] Turbulation devices have been used in cooling passageways as a way of increasing the heat being transferred. Typically, the previous trip-strip turbulation designs have centered around the designs shown in FIGS. 1 and 2. As shown in FIG. 1, a cooling passageway 10 having cooling fluid flowing in the direction 12 have had a pair of trip strips 14 and 16 forming a chevron design with the apex 18 of the chevron being along the flow direction 12 and the symmetrical axis 20 being parallel to the flow direction 12.

[0003] Referring now to FIG. 2, there is shown an alternative prior art turbulation system having a cooling passageway 10′ with a cooling fluid flowing in the direction 12′. As can be seen from this figure, a plurality of trip strips 14′ are arranged at an angle less than 90 degrees with respect to the flow direction 12′.

[0004] The contours 22 in the embodiments of FIGS. 1 and 2 illustrate areas of higher turbulence in the coolant flow field, and therefore more heat transfer pick-up. The heat transfer enhancement relative to channel flow with smooth walls is about two to three times the heat transfer obtained from the smooth channel flow depending on the Reynolds number for the coolant flow. The enhancement shown in FIGS. 1 and 2 is only local and washes away from its peak value either at the junction or apex

18 of the trip strips 14 and 16 in the chevron arrangement of FIG. 1 or close to the wall in an angled trip strip arrangement as shown in FIG. 2.

[0005] It is therefore desirable to extend the heat transfer regions that usually occur at the trip-strip junctions, either with other trip strips or connecting walls.

SUMMARY OF THE INVENTION

[0006] In accordance with the present invention, there is provided a turbulation arrangement for a cooling passageway which extends the heat transfer region to substantially the entire cooling surface area.

[0007] In accordance with the present invention, a passageway through which a fluid flows in a first direction is provided. The passageway broadly comprises a plurality of trip strips positioned within the passageway, and adjacent ones of the trip strips are oriented to converge towards each other at a first end to form an apex portion and to form a region in which turbulence is created. The apex portion is at an angle with respect to the first direction.

[0008] Further, in accordance with the present invention, a part, such as a turbine engine component is provided. The part broadly comprises a passageway through which a fluid flows in a first direction, which passageway having a plurality of trip strips positioned therein. Adjacent ones of the trip strips are oriented to converge towards each other at a first end to form an apex portion and to form a region in which turbulence is created. The apex portion is preferably at an angle with respect to the first direction.

[0009] Other details of the advanced turbulator arrangements for microcircuits of the present invention, as well as other objects and advantages attendant thereto, are set forth in the following

detailed description and the accompanying drawings, wherein like reference numerals depict like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a schematic representation of a prior art turbulation arrangement in a cooling passageway for increasing heat transfer;

[0011] FIG. 2 is a schematic representation of another prior art turbulation arrangement in a cooling passageway for increasing heat transfer;

[0012] FIG. 3 is a schematic representation of a turbulation arrangement for a cooling passageway in accordance with the present invention;

[0013] FIG. 4 is a schematic representation of the turbulation arrangement of FIG. 3 when fluid first forms two cells;

[0014] FIG. 5 is a schematic representation of the turbulation arrangement of FIG. 3 where the flows of the two cells merge;

[0015] FIG. 6 is a schematic representation of the turbulation arrangement of FIG. 3 showing the fluid cell spreading throughout the region between the adjacent trip strips in the turbulation arrangement;

[0016] FIG. 7 is a schematic representation of an alternative turbulation arrangement in accordance with the present invention; and

[0017] FIG. 8 is a schematic representation of yet another alternative turbulation arrangement in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0018] The present invention relates to a cooling passageway having an improved turbulation arrangement. As shown in FIG. 3, the cooling passageway may be a portion of a cooling

microcircuit (not shown) within a part 98, such as a turbine engine component.

[0019] Referring now to FIG. 3, there is shown a first turbulation arrangement 100 in accordance with the present invention. The turbulation arrangement 100 is provided within a passageway 102 in which a fluid, such as a cooling fluid, flows in a direction 104. The turbulation arrangement comprises a plurality of trip strips 106 arranged at an angle with respect to the flow direction 104. Adjacent ones of the trip strips 106 are arranged so that they converge towards each other and form an apex portion 108 with an opening 110 through which the cooling fluid enters a region 112 bounded by the adjacent ones of the trip strips 106. The apex portion 108 is preferably at an angle, preferably a right angle, with respect to the flow direction 104. A first region 112 in the passageway 102 may have an apex portion 108 adjacent a first wall 116, while a second region 112, adjacent to the first region 112, may have its apex portion 108 adjacent a second wall 120 opposed to the first wall 116.

[0020] Each trip strip 106 may be formed using any suitable technique known in the art. The trip strips 106 may be formed on the walls of the passageway 102 so as to wrap around the walls.

[0021] The regions 112 are preferably substantially triangularly shaped and are aligned along the flow direction 104. Each region 112 may have a plurality of vertices formed by the apex portion 108 and the trip strips 106 and the wall 116 or 120. Each region 112 preferably has an axis of symmetry 115 that is substantially perpendicular to the flow direction 104. If desired, as shown in FIG. 4, a series of cross over holes 122 may be provided at a base portion 124 of the region 112, which base portion 124 is at a second end of the region 112. The cross-over holes 122 offer a flow path by letting the flow through after or before

turbulation. The second end of the region 112 is opposed to the first end where the apex portion 108 is located. The base portion 124 is preferably located near a wall 116, 120.

[0022] Referring now to FIG. 4, there is shown a representation of a turbulation arrangement in accordance with FIG. 3 having a region 112. As can be seen from the figure, as flow enters the region 112 through the apex opening 110, two fluid cells 126 and 128 are formed. As shown in FIG. 5, as more fluid enters the region 112, the two fluid cells 126 and 128 unite into a single cell 130. Finally, as shown in FIG. 6, the cell 130 spreads throughout the region 112 with the cell 130 occupying most of the area of the region 112. As a result, there is full turbulence within the region 112. Again, the turbulence comes from vortices that start at the apex opening 110 formed by the adjacent trip strips 106 and the junction points 132 and 134 formed by the trip strips 106 and the wall 116 or 120. The vortices are amplified from two out of the three vertices of the triangular shaped region 112 in such a way as to create turbulent cells all over the enclosed two dimensional area of the region 112 formed by the wall 116 and the trip strips 106.

[0023] Extending this principle of creating turbulence, FIGS. 7 and 8 illustrate other turbulation arrangements with two or more active junctions to create areas of high heat transfer enhancement everywhere in a cooling passageway. The triangular junction points shown in the embodiments of FIGS. 7 and 8 may be in-phase or out-of-phase with each other. These high turbulence areas lead to an average heat transfer enhancement of two to three times not just locally, but also all over the entire two-dimensional enclosed area of the regions 112.

[0024] As shown in FIG. 7, a plurality of regions 112 may be formed by a plurality of rows 138 of trip strips 106 formed within the passageway 102. The rows 138 of trip strips 106 may

be positioned along the flow direction 104. Each row 138 of trip strips 106 may comprise three trip strips 106 angled with respect to each other so as to form a pair of intersecting joints 140 and 142. In each row 138, a first of the trip strips may be at a first angle with respect to the flow direction 104, a second of the trip strips may be at a second angle with respect to the flow direction 104, and a third of the trip strips may be at a third angle with respect to the flow direction 104. If desired, each row 138 may have more than three trip strips. Further, if desired, adjacent ones of the trip strips 106 in a row 138 may form the joints 140 and 142 may be spaced from each other to form a gap 144. In this turbulator arrangement, a plurality of regions 112 may be aligned along an axis transverse to the flow direction 104.

[0025] Referring now to FIG. 8, a plurality of regions 112 may be formed by a diamond shaped turbulation arrangement wherein a first trip strip 106′ extends from a point near the wall 116 to a point near the wall 120. The rest of each region 112 may be formed by two spaced apart trip strips 106″ and 106′′′ which are at an angle that intersects the trip strip 106′. In this turbulation arrangement, a plurality of regions 112 may be aligned along an axis at an angle with respect to the flow direction 104.

[0026] The contours 150 shown in FIGS. 4, 7, and 8 illustrate the high turbulence areas created in each of the regions 112.

[0027] One of the advantages of the turbulation arrangements of the present invention is the creation of a more uniform heat transfer coefficient throughout the cooling passageway. This is because the average heat transfer enhancement is distributed throughout the entire area enclosed by the trip strips as opposed to having a peak enhancement just locally. As a result, a part, such as a turbine engine component, having a cooling

passageway will experience less thermal mismatches. Part durability and life will improve with potentially less coolant flow, thus enhancing the performance of the part.

[0028] The turbulator arrangements of the present invention may be used in cooling passageways in a wide variety of turbine engine components including, but not limited to, blades, vanes, blade outer air seals, combustor panels, and any other part that contains a cooling passageway.

WHAT IS CLAIMED IS:

1. A passageway through which a fluid flows in a first direction, said passageway comprising:

a plurality of trip strips positioned within the passageway;

adjacent ones of said trip strips being oriented to converge towards each other at a first end to form an apex portion and to form a region in which turbulence is created; and

said apex portion is at an angle with respect to said first direction.

2. The passageway of claim 1, wherein said apex portion has an opening through which said fluid enters said region.

3. The passageway of claim 1, wherein said region has a base portion at a second end opposed to said first end and an axis of symmetry between said first end and said second end is transverse to said first direction and wherein said base portion is located near a wall of said passageway.

4. The passageway of claim 1, wherein said region is triangularly shaped.

5. The passageway of claim 1, further comprising:

said passageway having first and second opposed walls; and

said plurality of trip strips forming a plurality of said regions along the first direction, wherein a first of said

regions has its apex portion adjacent a first of said walls and a second of said regions has its apex portion adjacent a second of said walls.

6. The passageway of claim 1, further comprising:

said passageway having first and second opposed walls; and

said plurality of trip strips form a plurality of regions aligned along an axis transverse to said first direction.

7. The passageway of claim 6, wherein said plurality of regions are formed by at least two rows of trip strips, each said row of trip strips having a first trip strip angled at a first angle with respect to said first direction, a second trip strip angled at a second angle with respect to said first direction, and a third trip strip angled at a third angle with respect to said first direction.

8. The passageway of claim 7, wherein each row has two joints.

9. The passageway of claim 7, further comprising at least one gap between two of said trip strips in at least one of the rows.

10. The passageway of claim 1, further comprising:

said passageway having a first wall and a second wall opposed to said first wall;

a plurality of said regions between said walls; and

said plurality of regions being formed by a first trip strip extending from a first location near one of said walls to a second location near a second one of said walls and by a pair of spaced apart trip strips positioned at an angle which intersects the first trip strip.

11. The passageway of claim 1, wherein each said region has said apex portion and two vertices formed by a pair of said trip strips and a wall of said passageway.

12. A part comprising:

a passageway through which a fluid flows in a first direction;

said passageway having a plurality of trip strips positioned within the passageway;

adjacent ones of said trip strips being oriented to converge towards each other at a first end to form an apex portion and to form a region in which turbulence is created; and

said apex portion being at an angle with respect to said first direction.

13. The part according to claim 12, wherein said part comprises a turbine engine component.

14. The part according to claim 12, wherein said passageway comprises a cooling passageway in which a cooling fluid flows in said first direction.

15. The part of claim 12, wherein said apex portion has an opening through which said fluid enters said region.

16. The part of claim 12, wherein said region has a base portion at a second end opposed to said first end and an axis of symmetry between said first end and said second end is transverse to said first direction and wherein said base portion is located near a wall of said passageway.

17. The part of claim 12, wherein said region is triangularly shaped.

18. The part of claim 12, further comprising:

said passageway having first and second opposed walls; and

said plurality of trip strips forming a plurality of said regions along the first direction, wherein a first of said regions has its apex portion adjacent a first of said walls and a second of said regions has its apex portion adjacent a second of said walls.

19. The part of claim 12, further comprising:

said passageway having first and second opposed walls; and

said plurality of trip strips form a plurality of regions aligned along an axis transverse to said first direction.

20. The part of claim 19, wherein said plurality of regions are formed by at least two rows of trip strips, each said row of trip strips having a first trip strip angled at a first angle

with respect to said first direction, a second trip strip angled at a second angle with respect to said first direction, and a third trip strip angled at a third angle with respect to said first direction.

21. The part of claim 20, wherein each row has two joints.

22. The part of claim 20, further comprising at least one gap between two of said trip strips in at least one of the rows.

23. The part of claim 12, further comprising:

said passageway having a first wall and a second wall opposed to said first wall;

a plurality of said regions between said walls; and

said plurality of regions being formed by a first trip strip extending from a first location near one of said walls to a second location near a second one of said walls and by a pair of spaced apart trip strips positioned at an angle which intersects the first trip strip.

24. The part of claim 12, wherein each said region has said apex portion and two vertices formed by a pair of said trip strips and a wall of said passageway.