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(54) **CORRUGATED GRAPHITE SHEET HEAT
TRANSFER DEVICE**

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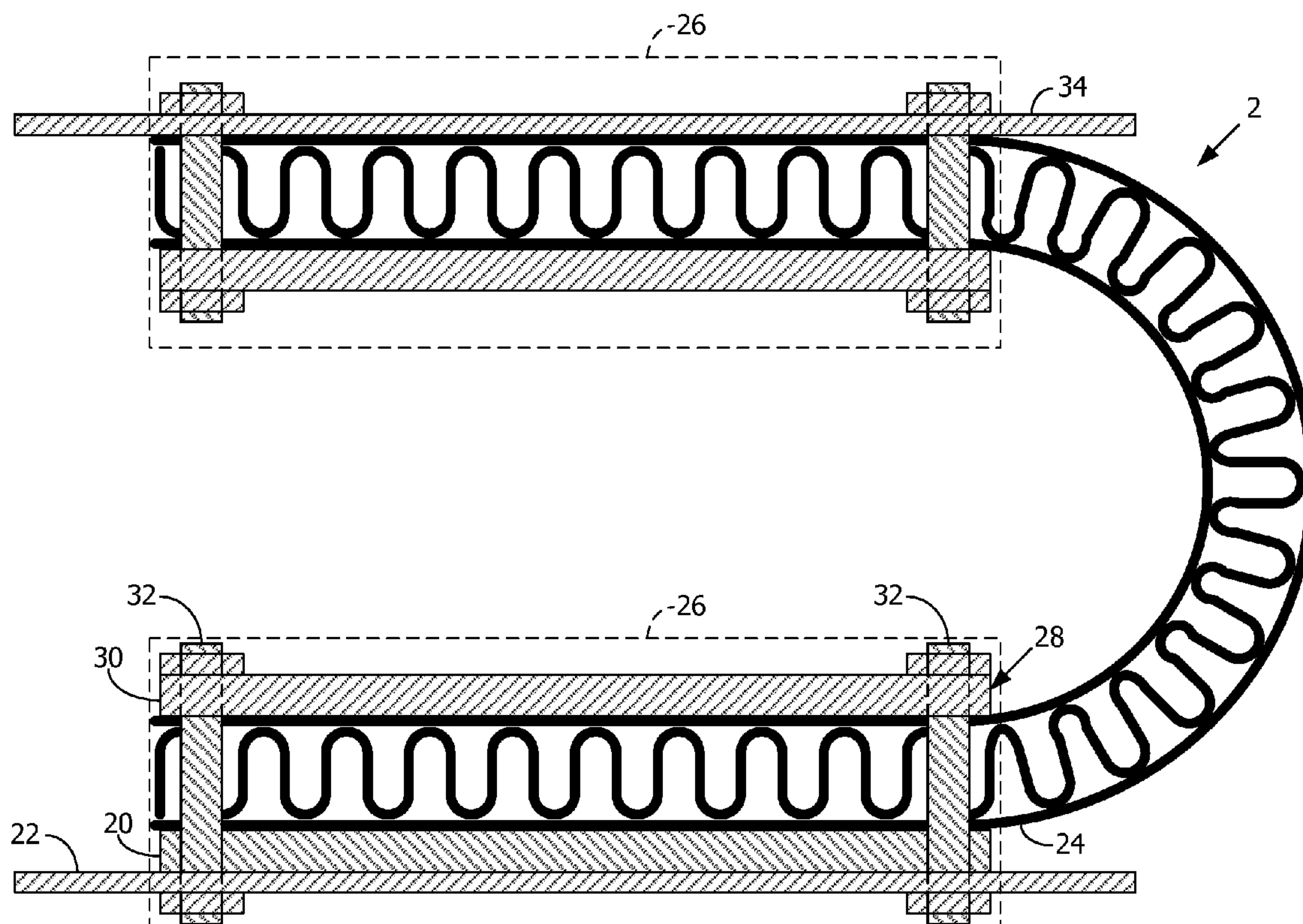
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(57) **ABSTRACT**

A heat transfer device includes at least one laminated structure. Each laminated structure includes: a graphite sheet core that has a pattern of corrugations over at least a portion thereof; a graphite sheet first outer layer with an inner surface that contacts a first surface of the core; and a graphite sheet second outer layer with an inner surface that contacts a second surface of the core.

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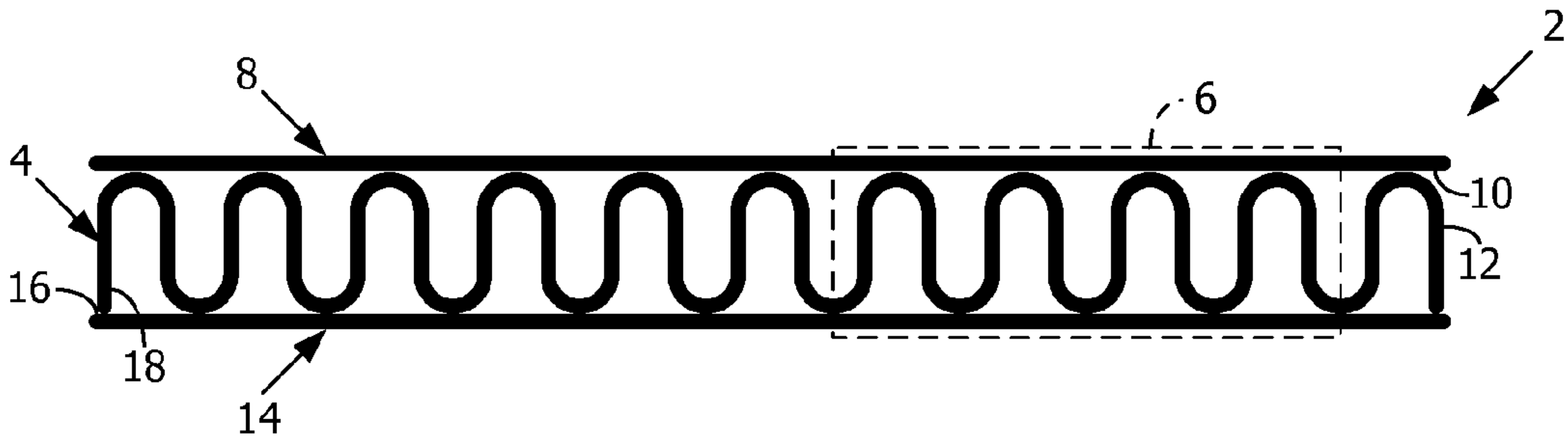


FIG. 1

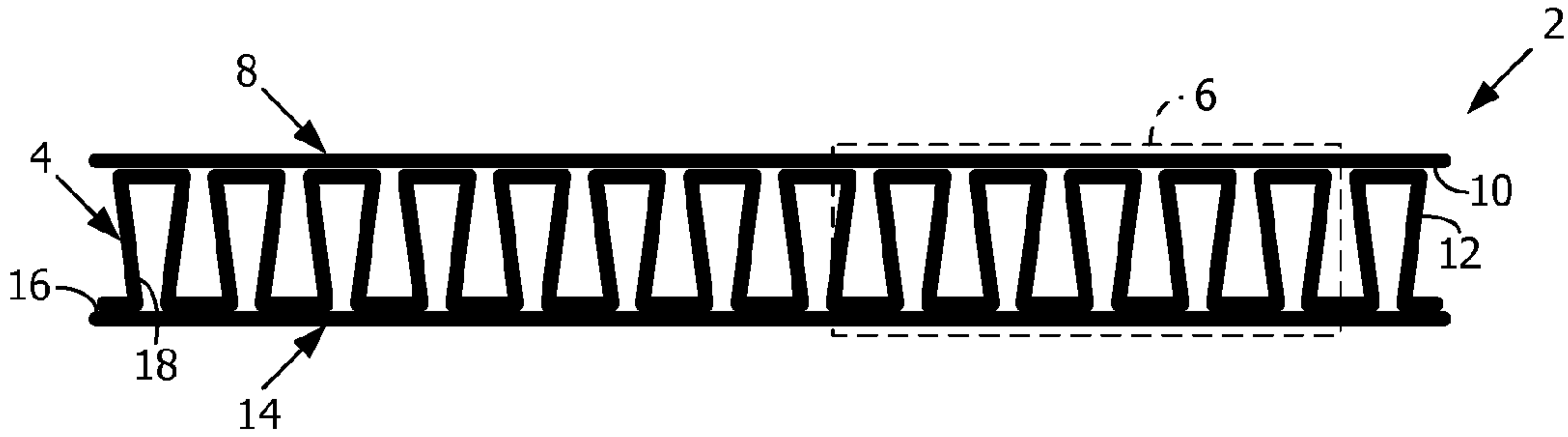


FIG. 2

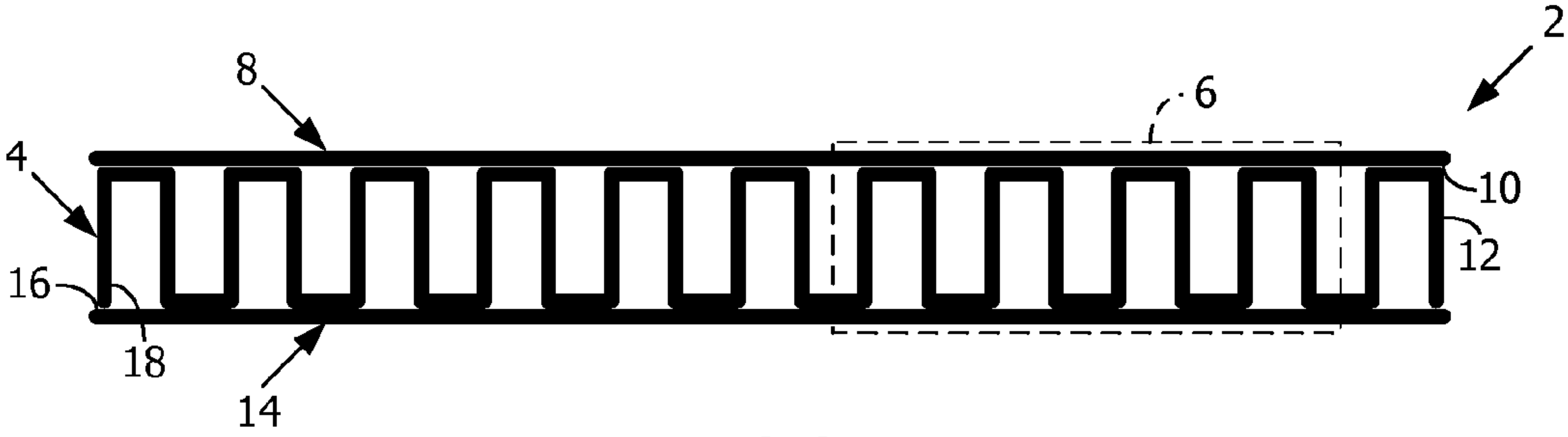


FIG. 3

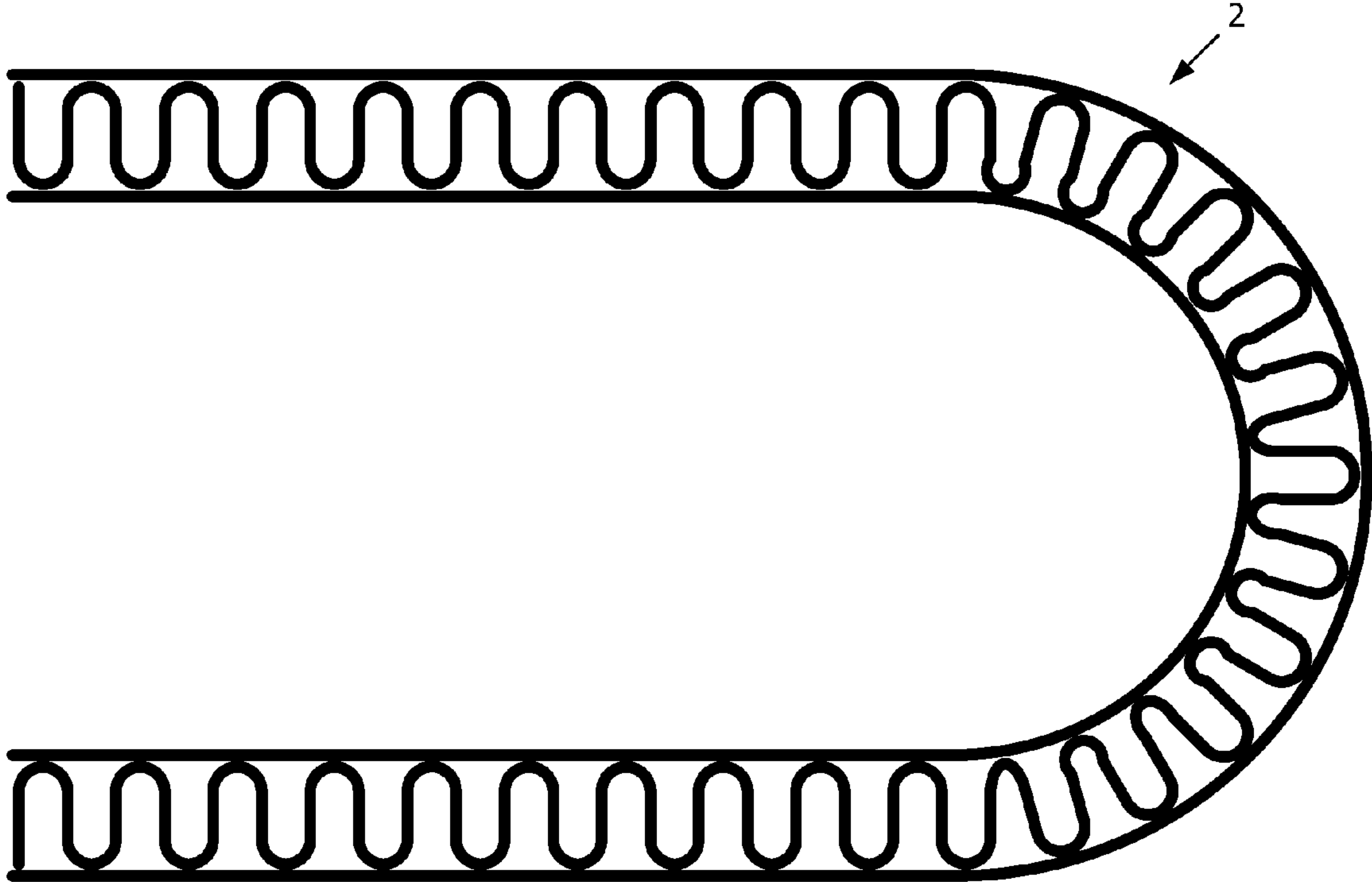


FIG. 4

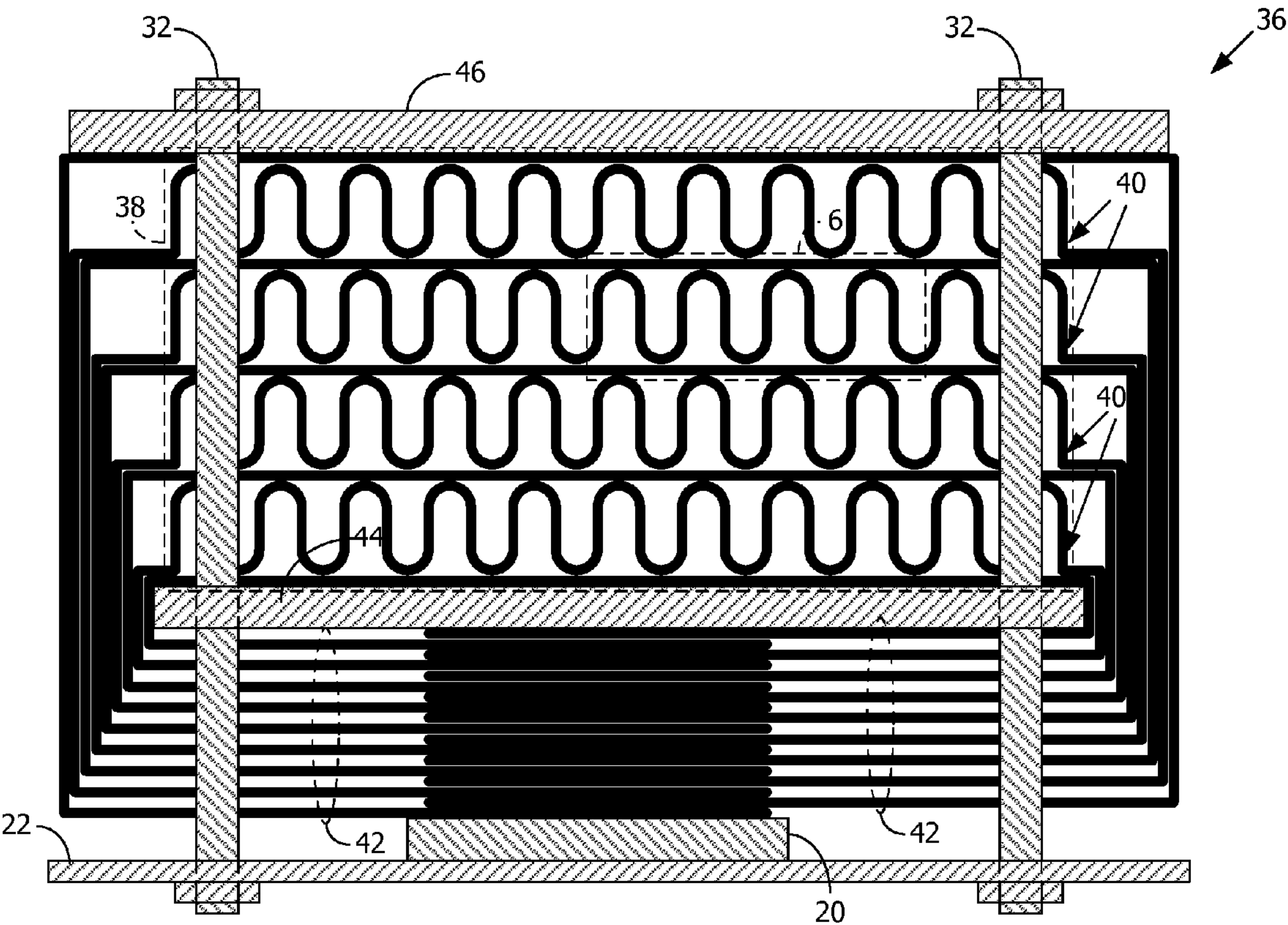


FIG. 6

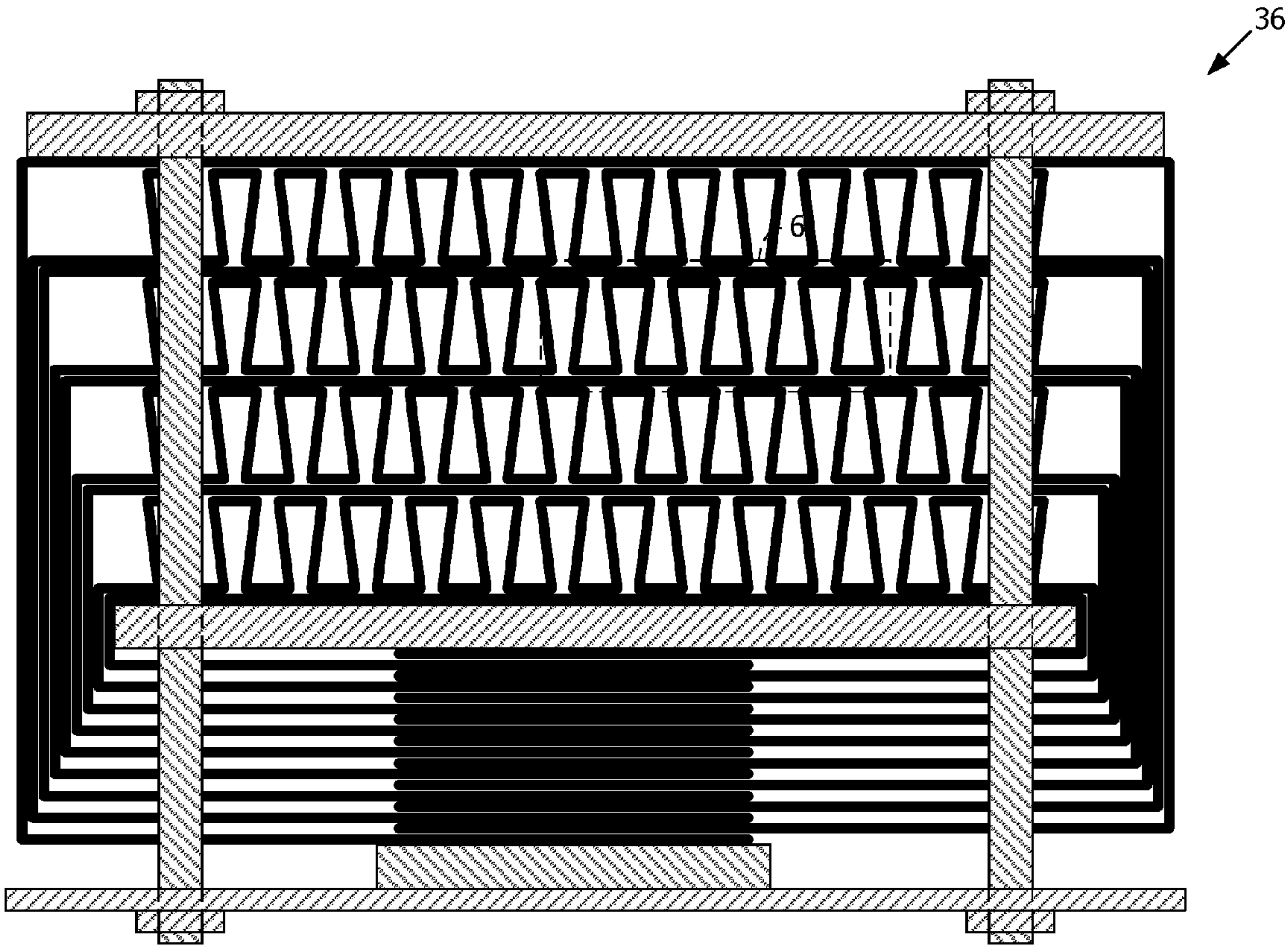


FIG. 8

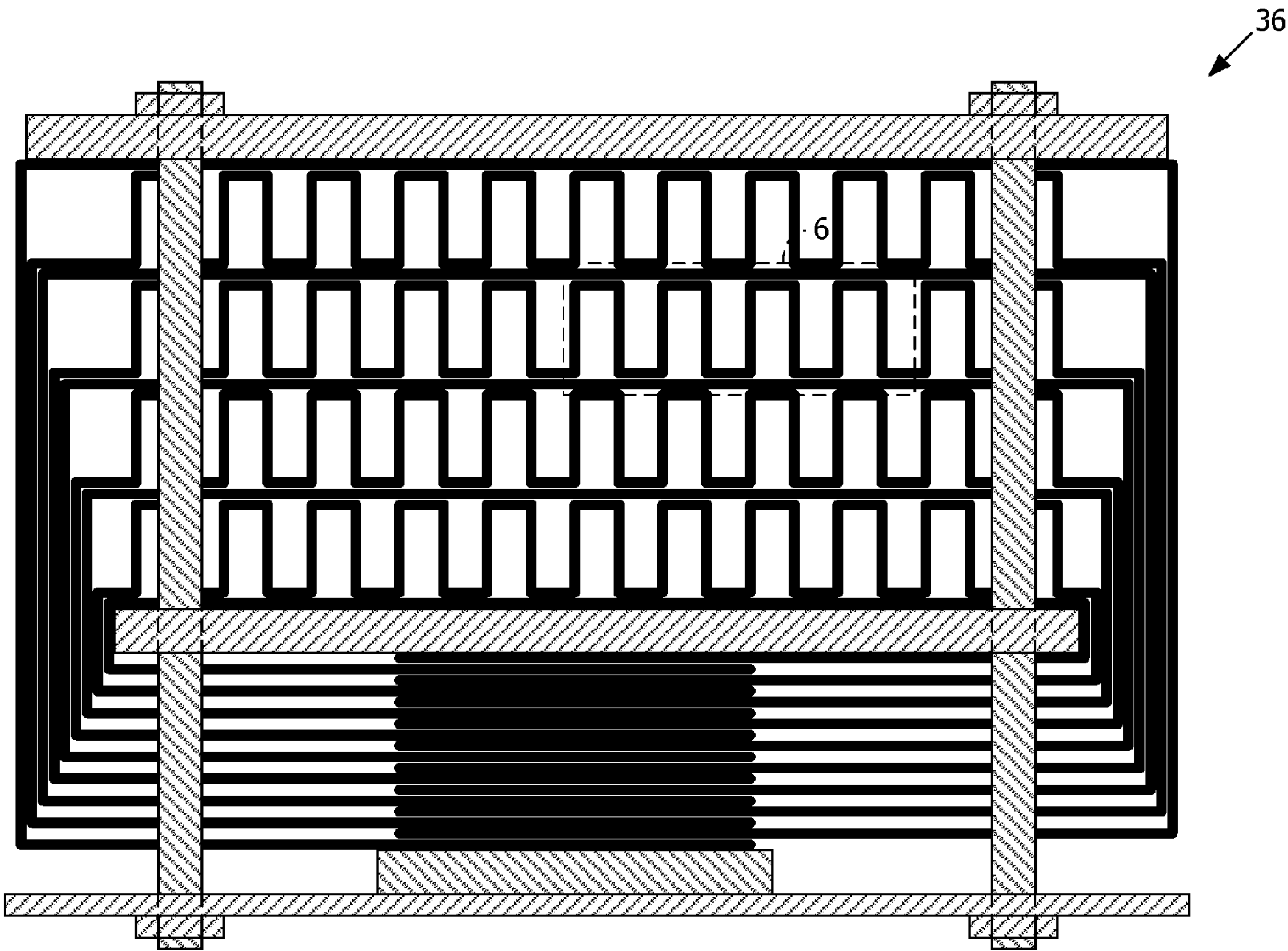


FIG. 9

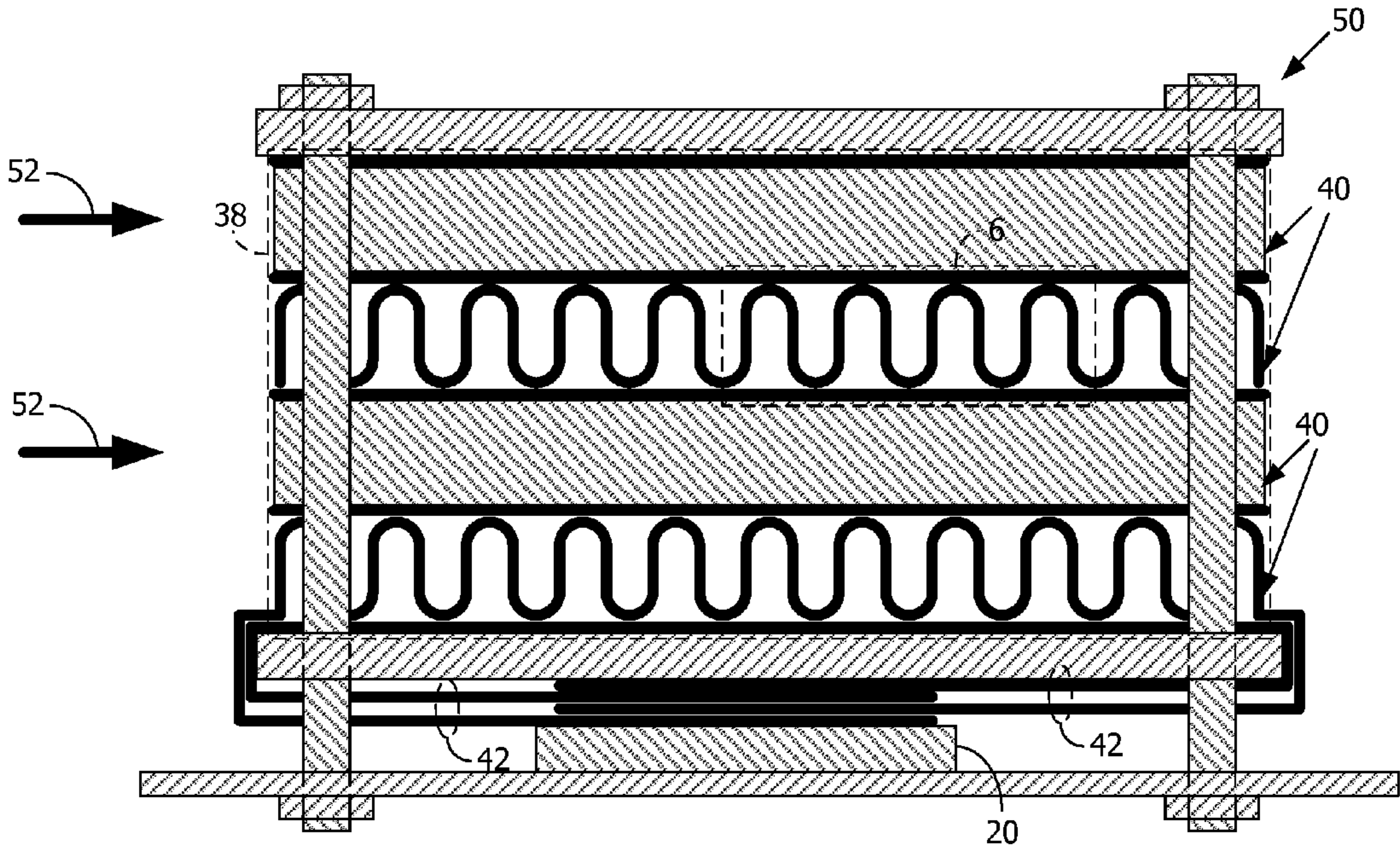


FIG. 10

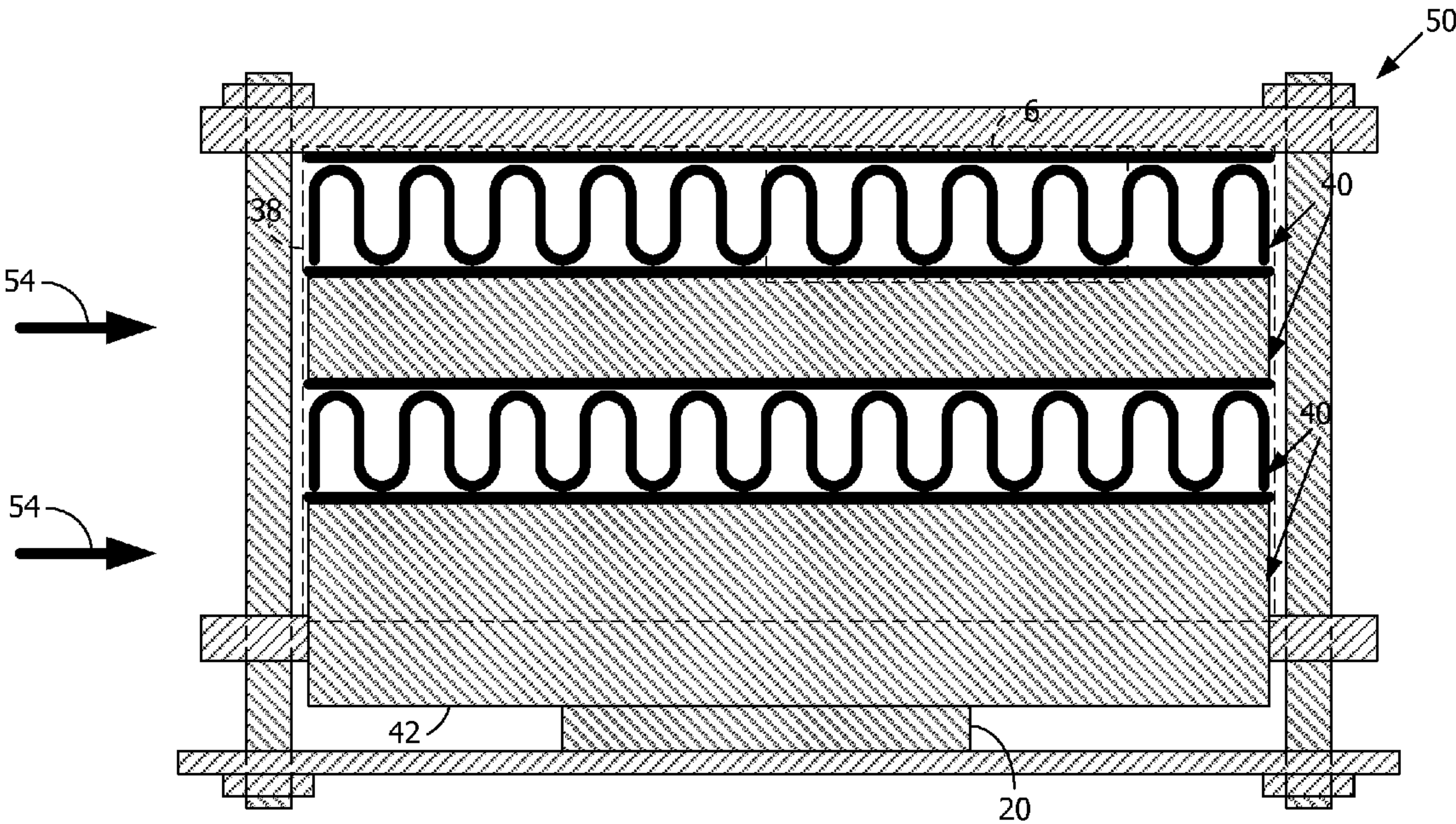


FIG. 11

CORRUGATED GRAPHITE SHEET HEAT TRANSFER DEVICE

[0001] FIGS. 1 through 5 show a heat transfer device according to a first possible embodiment. FIGS. 6 through 9 show a heat transfer device according to a second possible embodiment. FIGS. 10 and 11 show a heat transfer device according to a third possible embodiment.

[0002] Referring to FIG. 1 through 5 together, a heat transfer device 2 according to a first possible embodiment. The heat transfer device 2 comprises a laminated structure of thin graphite sheet, a graphite sheet core 4 that has a pattern of corrugations 6 over at least a portion thereof, a graphite sheet first outer layer 8 with an inner surface 10 that contacts a first surface 12 of the core 4, and a graphite sheet second outer layer 14 with an inner surface 16 that contacts a second surface 18 of the core 4. The first outer layer 8 and the second outer layer 14 may fasten to the core 4 with a fastening, such as an acrylic or silicon adhesive.

[0003] The core 4 may have any desired pattern of corrugations 6. FIGS. 1, 2 and 3 show several different possible patterns by way of illustration only. The pattern of corrugations 6 in FIG. 1 comprises an undulating pattern that is generally sinusoidal in shape. The patterns of corrugations 6 in FIGS. 2 and 3 are alternate rectilinear zigzag patterns, with FIG. 2 showing the pattern of corrugations 6 as generally tooth-shaped ridges and FIG. 3 showing the pattern of corrugations 6 as generally wedge-shaped ridges. Many other undulating or zigzag patterns may be suitable for the pattern of corrugations 6.

[0004] The heat transfer device 2 may serve as a heat sink, wherein it may thermally contact a heat source, or it may serve as a flexible and compressible heat transfer member that transfers heat from a heat source to a heat sink. Because graphite sheet is both foldable and flexible, FIG. 4 shows how the heat transfer device 2 may flex for use as a heat transfer member. FIG. 5 shows one way that the heat transfer device 2 may transfer heat from a heat source to a heat sink.

[0005] In FIG. 5, a heat source 20, represented by an electronic component, mounts on a heat source substrate 22, represented by a printed circuit board. An outer surface 24 of the first outer layer 8 or the second outer layer 14 of one end of the heat transfer device 2 fastens to the heat source by way of a fastening 26. The fastening 26 may comprise a fastening assembly 28 with a clamp 30 and fasteners 32 that connects to the substrate 22 as shown, or any other suitable fastening or fastening assembly, including an adhesive, such as an acrylic or silicon adhesive.

[0006] The outer surface 24 of the first outer layer 8 or the second outer layer 14 of the other end of the heat transfer device 2 fastens to a heat sink 34, represented by a housing wall in FIG. 5, by way of another fastening 26. As already described, this fastening 26 may be the fastening assembly 28, another suitable fastening assembly or even an adhesive.

[0007] FIGS. 6 through 9 show a heat transfer device 36 according to a second possible embodiment. The heat transfer device 36 comprises a stack 38 of laminated structures 40 that form the heat transfer device 2, or in other words, a stack of the heat transfer devices 2. Referring to FIGS. 6 and 7, the stack 40 is in thermal contact with the heat source 20 mounted on the heat source substrate 22. More specifically, distal ends 42 of each of the laminated structures 40 contact the heat source 20, a first support plate 44 that supports one side of the

stack 38 contacts the distal ends 42, the stack 38 contacts the first support plate 44, and a second support plate 46 supports the other side of the stack 38. The stack 38 fastens to the heat source 20 by way of another fastening 26, which may be another fastening assembly 28 comprising the second support plate 46 and fasteners 32 that connect to the substrate as shown, or alternately another fastening assembly or an adhesive.

[0008] The stack 38 of the heat transfer device 36 serves as a convective heat sink. Referring again to FIGS. 6 and 7, when the pattern of corrugations 6 in each laminated structure 40 are in general alignment, a stream of cooling fluid, represented by arrow 48 in FIG. 7, may easily pass through the stack 38. FIGS. 8 and 9 show the heat transfer device 36 with the alternate pattern of corrugations 6 shown in FIGS. 2 and 3.

[0009] FIGS. 10 and 11 show two views of a heat transfer device 50 according to a third embodiment. It is much the same as the described heat transfer device 36, except that the adjacent laminated structures 40 in the stack 38 have patterns of corrugation 6 that criss-cross each other to provide the stack 38 with greater structural stiffness. In this case, a first stream of cooling fluid, represented by arrows 52 in FIG. 10, will pass through half of the laminated structures 40 in the stack 38. Likewise, a second stream of cooling fluid, represented by arrows 54, that is orthogonal to the first stream of cooling fluid, will pass through the other half of the laminated structures of the stack 38. Another difference is that most of the thermal contact between the laminated structures 40 in the stack 38 and the heat source 20 is through the stack 38 itself. Only the distal ends 42 of the laminated structure 40 most proximate the heat source 20 make direct contact with the heat source 20.

[0010] The described embodiments are only some illustrative implementations of the invention as set forth in the attached claims. Changes and substitutions of various details and arrangement thereof are within the scope of the claimed invention.

1. A heat transfer device that comprises at least one laminated structure, each laminated structure comprising:
 - a graphite sheet core that has a pattern of corrugations over at least a portion thereof;
 - a graphite sheet first outer layer with an inner surface that contacts a first surface of the core; and
 - a graphite sheet second outer layer with an inner surface that contacts a second surface of the core.
2. The heat transfer device of claim 1, wherein the pattern of corrugations comprises an undulating pattern.
3. The heat transfer device of claim 2, wherein the undulating pattern is generally sinusoidal.
3. The heat transfer device of claim 1, wherein the pattern of corrugations comprises a rectilinear zigzag pattern.
4. The heat transfer device of claim 3, wherein the rectilinear zigzag pattern comprises a pattern of generally tooth-shaped ridges.
5. The heat transfer device of claim 3, wherein the rectilinear zigzag pattern comprises a pattern of generally wedge-shaped ridges.
6. The heat transfer device of claim 1, further comprising a fastening for fastening the first and second layers to the core.
7. The heat transfer device of claim 6, wherein the fastening comprises an adhesive.
8. The heat transfer device of claim 1, further comprising:
 - a first fastening to fasten an outer surface of at least one of the outer layers to a heat source; and

a second fastening to fasten an outer surface of at least one of the outer layers to a heat sink.

9. The heat transfer device of claim **8**, wherein the fastenings comprise an adhesive.

10. The heat transfer device of claim **8**, wherein the fastenings comprise fastening assemblies.

11. The heat transfer device of claim **1**, further comprising a stack of the laminated structures, with the laminated structures in the stack in thermal contact with a heat source.

12. The heat transfer device of claim **11**, wherein the stack of the laminated structures comprises a heat sink.

13. The heat transfer device of claim **11**, wherein the patterns of corrugations of adjacent laminated structures in the stack are in alignment with each other.

14. The heat transfer device of claim **11**, wherein the patterns of corrugations of adjacent laminated structures in the stack criss-cross each other.

15. The heat transfer device of claim **11**, wherein distal ends of the laminated structures are in direct thermal contact with the heat source.

16. The heat transfer device of claim **11**, further comprising a fastening that fastens the laminated structures together in the stack.

17. The heat transfer device of claim **16**, wherein the fastening comprises an adhesive.

18. The heat transfer device of claim **16**, wherein the fastening comprises a fastening assembly.

19. The heat transfer device of claim **16**, further comprising a fastening to fasten the stack to the heat source.

20. The heat transfer device of claim **19**, wherein the fastening comprises an adhesive.

21. The heat transfer device of claim **19**, wherein the fastening comprises a fastening assembly.

22. A heat transfer device that comprises:

a laminated structure comprising a graphite sheet core that has a pattern of corrugations over at least a portion

thereof, a graphite sheet first outer layer with an inner surface that contacts a first surface of the core and a graphite sheet second outer layer with an inner surface that contacts a second surface of the core;

a first fastening to fasten an outer surface of at least one of the outer layers to a heat source; and

a second fastening to fasten an outer surface of at least one of the outer layers to a heat sink.

23. The heat transfer device of claim **22**, wherein the fastenings comprise an adhesive.

24. The heat transfer device of claim **22**, wherein the fastenings comprise fastening assemblies.

25. A heat sink that comprises:

a stack of laminated structures, each laminated structure comprising a graphite sheet core that has a pattern of corrugations over at least a portion thereof, a graphite sheet first outer layer with an inner surface that contacts a first surface of the core and a graphite sheet second outer layer with an inner surface that contacts a second surface of the core; and

a fastening that fastens the laminated structures together in the stack and to a heat source;

wherein the stack of laminated structures comprises a heat sink.

26. The heat transfer device of claim **25**, wherein the patterns of corrugations of adjacent laminated structures in the stack are in alignment with each other.

27. The heat transfer device of claim **25**, wherein the patterns of corrugations of adjacent laminated structures in the stack criss-cross each other.

28. The heat transfer device of claim **25**, wherein distal ends of the laminated structures are in direct thermal contact with the heat source.

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