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SYSTEMS AND METHODS FOR ENHANCED RESISTANCE SPOT WELDING WITH TEXTURED SHEET METAL

FIELD OF THE INVENTION

This application relates to resistance spot welding, and, more particularly, to electrodes for resistance spot welding.

BACKGROUND

Metal manufacturing can involve welding metal sheets or metal alloy sheets together to form various parts or components of a final product. Various techniques or processes, including, for example, resistance spot welding, can be used to weld the metal sheets. Resistance spot welding can involve positioning metal sheets between electrodes and using the electrodes to apply a clamping force and an electric current to the metal sheets. Heat produced from a resistance of the metal sheets to the electric current, along with the clamping force of the electrodes, can be used to join the metal sheets at the interface, forming local cohesive zones known as weld nuggets. Current resistance spot welding processes use copper-based electrodes. However, the life of such electrodes is limited because the electrode tip becomes degraded at least partially due to the electric current flow path and tip temperature of the cap during resistance spot welding, which results in the weld quality over time becoming less consistent. As such, electrodes frequently must be dressed and replaced, which takes time away from the resistance spot welding process and increases the costs associated with resistance spot welding process.

SUMMARY

The terms “invention,” “the invention,” “this invention” and “the present invention” used in this patent are intended to refer broadly to all of the subject matter of this patent and the patent claims below. Statements containing these terms should be understood not to limit the subject matter described herein or to limit the meaning or scope of the patent claims below. Embodiments of the invention covered by this patent are defined by the claims below, not this

summary. This summary is a high-level overview of various embodiments of the invention and introduces some of the concepts that are further described in the Detailed Description section below. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used in isolation to determine the scope of the claimed subject matter. The subject matter should be understood by reference to appropriate portions of the entire specification of this patent, any or all drawings, and each claim.

According to some examples, a method of joining a first metal sheet with a second metal sheet includes applying a texture to a portion of a surface of the first metal sheet. The method includes positioning the first metal sheet relative to the second metal sheet such that the portion of the surface of the first metal sheet comprising the applied texture faces the second metal sheet. The method also includes joining the first metal sheet to the second metal sheet through a joining technique at an interface of the portion of the surface of the first metal sheet comprising the texture.

According to various examples, a method of resistance spot welding includes positioning a first metal sheet and a second metal sheet between two electrodes. In some cases, the first metal sheet includes a surface facing the second metal sheet, and a portion of the surface facing the second metal sheet includes a texture. The method includes applying a current to the first metal sheet and the second metal sheet through the two electrodes to form a weld nugget. In various examples, the current is applied to the portion of the first metal sheet including the texture, and forming the weld nugget joins the first metal sheet with the second metal sheet.

According to certain examples, a processing system for metal sheets includes a texturing system configured to apply a texture to a portion of a surface of a first metal sheet. The processing system includes a joining system downstream from the texturing system. In some aspects, the joining system is configured to join the first metal sheet with a second metal sheet by applying a joining technique at an interface of the portion of the surface of the first metal sheet with the texture and a corresponding portion of the second metal sheet to join the first metal sheet with the second metal sheet.

Various implementations described in the present disclosure can include additional systems, methods, features, and advantages, which cannot necessarily be expressly disclosed herein but will be apparent to one of ordinary skill in the art upon examination of the following

detailed description and accompanying drawings. It is intended that all such systems, methods, features, and advantages be included within the present disclosure and protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and components of the following figures are illustrated to emphasize the general principles of the present disclosure. Corresponding features and components throughout the figures can be designated by matching reference characters for the sake of consistency and clarity.

FIG. 1 is a schematic illustration of a processing system for metal sheets according to aspects of the current disclosure.

FIG. 2 is a schematic illustration of a stamping system of the processing system of FIG. 1.

FIG. 3 is a photograph of dies with various textures for forming a texture on a metal sheet according to aspects of the present disclosure.

FIG. 4 is a schematic illustration of a metal sheet having a textured surface formed by the processing system of FIG. 1.

FIG. 5 is schematic illustration of a resistance spot welding system of the processing system of FIG. 1 with the metal sheet having the textured surface.

FIG. 6 is another schematic illustration of the system of FIG. 5.

FIG. 7 is a schematic illustration of the resistance spot welding system of FIG. 5 with another metal sheet having a textured surface according to aspects of the current disclosure.

FIG. 8 is a schematic illustration of the resistance spot welding system of FIG. 5 with another metal sheet having a textured surface according to aspects of the current disclosure.

FIG. 9 is a flowchart illustrating a method of processing metal sheets according to aspects of the current disclosure.

DETAILED DESCRIPTION

The subject matter of embodiments of the present invention is described here with specificity to meet statutory requirements, but this description is not necessarily intended to limit the scope of the claims. The claimed subject matter may be embodied in other ways, may include different elements or steps, and may be used in conjunction with other existing or future technologies. This description should not be interpreted as implying any particular order or arrangement among or between various steps or elements except when the order of individual steps or arrangement of elements is explicitly described. Directional references such as “up,” “down,” “top,” “left,” “right,” “front,” and “back,” among others, are intended to refer to the orientation as illustrated and described in the figure (or figures) to which the components and directions are referencing.

Aspects and features of the present disclosure can be used with any suitable metal substrate, however may be especially useful for bonding aluminum and/or aluminum alloys. In this description, reference is made to alloys identified by aluminum industry designations, such as “series” or “7xxx.” For an understanding of the number designation system most commonly used in naming and identifying aluminum and its alloys, see “International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys” or “Registration Record of Aluminum Association Alloy Designations and Chemical Compositions Limits for Aluminum Alloys in the Form of Castings and Ingot,” both published by The Aluminum Association.

FIGs. 1-6 illustrate an example of a processing system 100 for metal sheets according to aspects of the present disclosure. In certain examples, and as described below, the processing system 100 is configured to provide a textured region 120 on a first metal sheet 106 and/or a second metal sheet 108 through a texturing system 102. The processing system is also configured to join the first metal sheet 106 with the second metal sheet 108 through a joining system 104 that applies a joining technique at a joining interface of the first metal sheet 106 and the second metal sheet 108. In other examples, the processing system 100 may join a metal sheet (e.g., the first metal sheet 106) to castings and/or extrusions. As one example, the processing system 100 may join a metal sheet to cast nodes and/or extrusions.

As best illustrated in FIG. 5, the first metal sheet 106 includes an upper surface 118 and a lower surface 122. The second metal sheet 108 likewise includes an upper surface 124 and a lower surface 126. When the metal sheets 106, 108 are joined together, the lower surface 122 of the first metal sheet 106 faces the upper surface 124 of the second metal sheet 108, and at least a portion of the lower surface 122 abuts a corresponding portion of the upper surface 124 to form a joining interface between the metal sheets 106, 108. As used herein, a sheet generally refers to a product having a thickness of less than about 4 mm. For example, a sheet may have a thickness of less than 4 mm, less than 3 mm, less than 2 mm, less than 1 mm, less than 0.5 mm, less than 0.3 mm, or less than 0.1 mm. A sheet plate generally has a thickness of from about 4 mm to about 15 mm. For example, a sheet plate may have a thickness of 4 mm, 5 mm, 6 mm, 7 mm, 8 mm, 9 mm, 10 mm, 11 mm, 12 mm, 13 mm, 14 mm, or 15 mm.

In various aspects, the first metal sheet 106 and the second metal sheet 108 may be various metals including, but not limited to, aluminum, aluminum alloys, steel, steel-based materials, nickel, nickel-based materials, copper, copper-based materials, cast iron, titanium, titanium-based materials, aluminum clad alloys, a monolithic alloy, a roll bonded alloy, and/or various other metals or combinations of metals. In examples where the first metal sheet 106 and/or the second metal sheet 108 includes an aluminum alloy, the aluminum alloy can be cast using various suitable casting methods including, but not limited to direct chill casting (including direct chill co-casting) or semi-continuous casting, continuous casting (including, for example, by use of a twin belt caster, a twin roll caster, a block caster, or any other continuous caster), electromagnetic casting, hot top casting, or any other casting method. In some examples, the first metal sheet 106 and/or the second metal sheet 108 may be selected from the group comprising a 1xxx series aluminum alloy, a 2xxx series aluminum alloy, a 3xxx series aluminum alloy, a 4xxx series aluminum alloy, a 5xxx series aluminum alloy, a 6xxx series aluminum alloy, a 7xxx series aluminum alloy, or an 8xxx series aluminum alloy.

In some examples, the first metal sheet 106 and the second metal sheet 108 may both be the same metal. For example, the first metal sheet 106 and the second metal sheet 108 may both be the same aluminum alloy. In other examples, the metal of the first metal sheet 106 may be different from the metal of the second metal sheet 108. For example, the first metal sheet 106 may be a first aluminum alloy and the second metal sheet 108 may be a second aluminum alloy that is different from the first aluminum alloy. As another example, the first metal sheet 106 may

be a steel-based material, and the second metal sheet 108 may be an aluminum alloy. As such, the type of materials used as the first metal sheet 106 and the second metal sheet 108 should not be considered limiting on the current disclosure.

Referring to FIGs. 1 and 2, in various examples, the texturing system 102 is a stamping system that includes at least one stamping station 110 having a stamping die 112. Although a stamping system is illustrated as the texturing system 102, various other suitable systems for providing a texture on at least one of the metal sheets 106, 108 may be utilized. In other examples where the metal sheet is to be joined to another component such as a casting or extrusion, the texture may only be provided on the metal sheet, although it need not in other examples.

As illustrated in FIGs. 1 and 2, at least one stamping surface 114 of the stamping die 112 includes a textured region 116. In some examples, the stamping surface 114 includes a plurality of textured regions 116, and as such, the number of textured regions should not be considered limiting on the current disclosure. Where a plurality of textured regions 116 are provided, a texture parameter (discussed below) of one of the textured regions 116 may optionally be different from a texture parameter of another textured region 116. Moreover, depending on which surface of the metal sheet the texture is to be applied to, one stamping surface or more than one stamping surface may include a textured region 116. In various examples where both the first metal sheet 106 and the second metal sheet 108 are to be textured, the texturing system 102 may optionally be controlled such that a texture parameter of the texture applied to the first metal sheet 106 is different from the texture parameter of the texture applied to the second metal sheet 108. In other examples where both metal sheets 106, 108 are to be textured, the same texture may be applied to both metal sheets 106, 108.

The stamping surface 114 may be textured through various suitable techniques for forming the textured region 116. For example, in some cases, the stamping surface may be textured through various texturing techniques including, but not limited to, electro-discharge texturing (EDT), electrodeposition texturing, electron beam texturing (EBT), laser beam texturing, electrofusion coatings and various other suitable techniques.

The texturing system 102 includes one or more controllable texture parameters that can be controlled to provide a desired texture on the metal sheet. The controllable texture parameter

may include, but is not limited to, a surface roughness of the textured region 116, a pressure used to impart the texture onto the metal sheet during stamping, a location of the textured region 116 on the stamping surface 114, and/or a size and shape of the textured region 116 on the stamping surface 114. In some cases, the surface roughness is controlled such that the texture imparted onto the metal sheet has a desired flatness profile and surface topography. Surface roughness can be quantified using optical interferometry techniques or other suitable methods. The pressure may be controlled to control how deep into the surface of the metal sheet the texture extends. The location of the textured region 116 on the stamping surface 114 may be controlled and adjusted such that the texture is applied at desired or predetermined locations on the metal sheet. For example, in some cases, the location of the textured region 116 is controlled such that the texture is provided only at desired joining interfaces between the metal sheets, although it need not be in other examples. The size and shape of the textured region 116 may be controlled and adjusted such that the texture is provided with a desired size or area on the metal sheet. For example, in some cases, the textured region 116 is generally circular and covers less than the entire stamping surface such that the texture on the metal sheet is generally circular and covers less than the entire surface of the metal sheet. In other examples, the textured region 116 may have various other shapes and/or sizes as desired. Various other parameters or combinations of parameters may be controlled to provide the desired texture, and the above list should not be considered limiting on the current disclosure.

In some examples, the joining system 104 includes one or more joining parameters that can be used to control the texture parameter to produce a desired textured region 120. In some cases, the joining parameter may include, but is not limited to, a material property of the first metal sheet 106, a material property of the second metal sheet 108, and/or a type of joining technique used by the joining system 104. As one example, in some cases, the joining system 104 may be a resistance spot welding (RSW) system and the joining technique is RSW, and the joining parameter may further include a contact resistance at the joining interface of the first metal sheet 106 and the second metal sheet 108, a desired weld current during RSW, and/or a desired weld nugget size produced by RSW. Various other suitable joining parameters may be utilized to control the texture parameter.

FIG. 3 illustrates an example of three stamping dies 312A-C having different textured regions 316A-C. In this example, the roughness of the textured region 316C is greater than the

roughness of the textured region 316B, and the roughness of the textured region 316B is greater than the roughness of the textured region 316A. In addition, in this example, the textured regions 316A and 316B are provided on substantially the entire stamping surfaces 314A and 314B, respectively, while the textured region 316C is provided in a band pattern on the stamping surface 314C with non-textured regions 315.

Referring back to FIG. 2, during the stamping process, the metal sheet to be stamped (e.g., the metal sheet 106) and the die 112 come together, and the texture is transferred onto a surface of the metal sheet 106 and forms a textured region 120 on a surface of the metal sheet (e.g., on the lower surface 122 of the first metal sheet 106). FIG. 4 illustrates an example of the first metal sheet 106 that has been stamped such that a plurality of textured regions 120 are present on the lower surface 122. It will be appreciated that in other examples, the upper surface 118 of the first metal sheet 106, the upper surface 124 of the second metal sheet 108, and/or the lower surface 126 of the second metal sheet 108 may also be textured through the texturing system 102. In various aspects, at least one of the lower surface 122 of the first metal sheet 106 and the upper surface 124 of the second metal sheet 108 include textured regions 120, although they need not be in other examples. In the example of FIGs. 1-6, and as best illustrated in FIG. 5, both the lower surface 122 of the first metal sheet 106 and the upper surface 124 of the second metal sheet 108 include textured regions 120.

Referring to FIGs. 1, 5, and 6, in some cases, the joining system 104 is a RSW system that is configured to join the first metal sheet 106 and the second metal sheet 108 through RSW. In other examples, the joining system 104 may be various other suitable types of joining systems for joining the first metal sheet 106 and the second metal sheet 108. For example, in some cases, the joining system 104 may be an adhesive bonding system that applies adhesive bonding to join the first metal sheet 106 and the second metal sheet 108. In other examples, the joining system 104 may be various suitable systems for joining a metal sheet (e.g., the first metal sheet 106) with another metal component such as a casting or extrusion. Various other suitable systems or combinations of joining systems may be utilized in other examples.

In the example where the joining system 104 is the RSW system, the joining system 104 includes a pair of electrodes 128A-B. Any number of electrodes 128 may be used as desired. To weld the first metal sheet 106 to the second metal sheet 108, at least a portion of the first metal

sheet 106 and at least a portion of the second metal sheet 108 are positioned between electrodes 128A-B such that the first metal sheet 106 and the second metal sheet 108 at least partially overlap. In various examples, the first metal sheet 106 and the second metal sheet 108 are positioned such that the textured region 120 of at least one of the metal sheets is positioned between the electrodes 128A-B. In various examples where both the first metal sheet 106 and the second metal sheet 108 include textured regions 120, the textured region 120 of the first metal sheet 106 may be aligned with the corresponding textured region 120 of the second metal sheet 108, and the aligned textured regions 120 are positioned between the electrodes 128A-B. The electrodes 128A-B are clamped together such that the electrodes contact opposing surfaces of the first metal sheet 106 and the second metal sheet 108 (e.g., the upper surface 118 of the first metal sheet 106 and the lower surface 126 of the second metal sheet 108).

While the electrodes 128A-B are clamped together, an electric current is applied via the electrodes 128A-B. Heat is generated at the interface of the metal sheets 106 and 108 (e.g., at the textured region(s) 120) and causes the metal sheets 106 and 108 to heat up and form a weld nugget 630 as illustrated in FIG. 6. As the current is applied, the weld nugget 630 grows and elongates within the metal sheets 106 and 108. When the current through the electrodes 128A-B is stopped, the molten metal forming the weld nugget 630 may cool to form a weld. In various examples, the electric current applied is at least a minimum current to form a weld having a minimum weld size (MWS) to join the first metal sheet 106 with the second metal sheet 108. MWS is defined as $4\sqrt{t}$, where t is the thickness of the governing metal thickness. In a stack of two aluminum alloy sheets, the governing metal thickness is generally the thinnest sheet. In a stack of three aluminum alloy sheets, the governing metal thickness is generally the thickness of the middle sheet. In various examples, the thickness may be any thickness that is suitable with RSW technology.

It is believed that by applying the joining technique to the textured regions 120, the joining system 104 can be improved while still suitably joining the first metal sheet 106 with the second metal sheet 108. For example, when the joining system 104 is the RSW system, the textured regions 120 may have a predetermined contact resistance at the joining interface that provides a certain amount of heat during the RSW process. In various aspects, the texture parameter (and thus the texture) may be controlled to increase, decrease, or maintain the contact

resistance and as such increase, decrease, or maintain the amount of heat generated during the RSW process. Controlling the texture and controlling the contact resistance may allow for the weld current during RSW to be controlled as desired. As one example, the texture may be controlled to provide an increased contact resistance (and thus increased heat during RSW) such that a lower weld current can be used to achieve the weld having the MWS. A lower weld current may improve the tip life of the electrodes 128A-B, which typically degrades and erodes faster at higher welding currents. Such reduced weld currents may also provide energy savings as well as provide less disruption of the metal of the metal sheets 106, 108 during RSW. As another example wherein the joining system 104 is the adhesive bonding system, the texture may be controlled to provide a suitable surface roughness and size that is suitable to provide an improved mechanical bond between the metal sheets. In other examples, the texture parameter may be controlled in various other ways to improve the joining system 104 and/or joining technique for joining the metal sheets 106, 108.

FIG. 7 illustrates another example where the joining system 104 is the RSW system. In the example of FIG. 7 and compared to the example of FIGs. 1-6, only the upper surface 124 of the second metal sheet 108 includes the textured region 120.

FIG. 8 illustrates another example where the joining system 104 is the RSW system. In the example of FIG. 8 and compared to the example of FIGs. 1-6, both the upper surface 118 and the lower surface 122 of the first metal sheet 106 include textured regions 120. In some examples, the textured region 120 on the upper surface 118 may be provided adjacent to the electrode 128A to further control the joining technique and/or weld formation during RSW. In some examples, the textured region 120 on the upper surface 118 facing the electrode 128A may have a texture parameter that is different from the textured region 120 on the lower surface 122. In various aspects, the textured regions 120 are provided (or omitted) on the upper surface 118 and lower surface 122 (and similarly on the upper surface 124 and the lower surface 126) such that there is asymmetric roughness of the surfaces to optimize the RSW process.

FIG. 9 is a flowchart illustrating a method of processing the metal sheets 106,108 with the processing system 100 according to various examples.

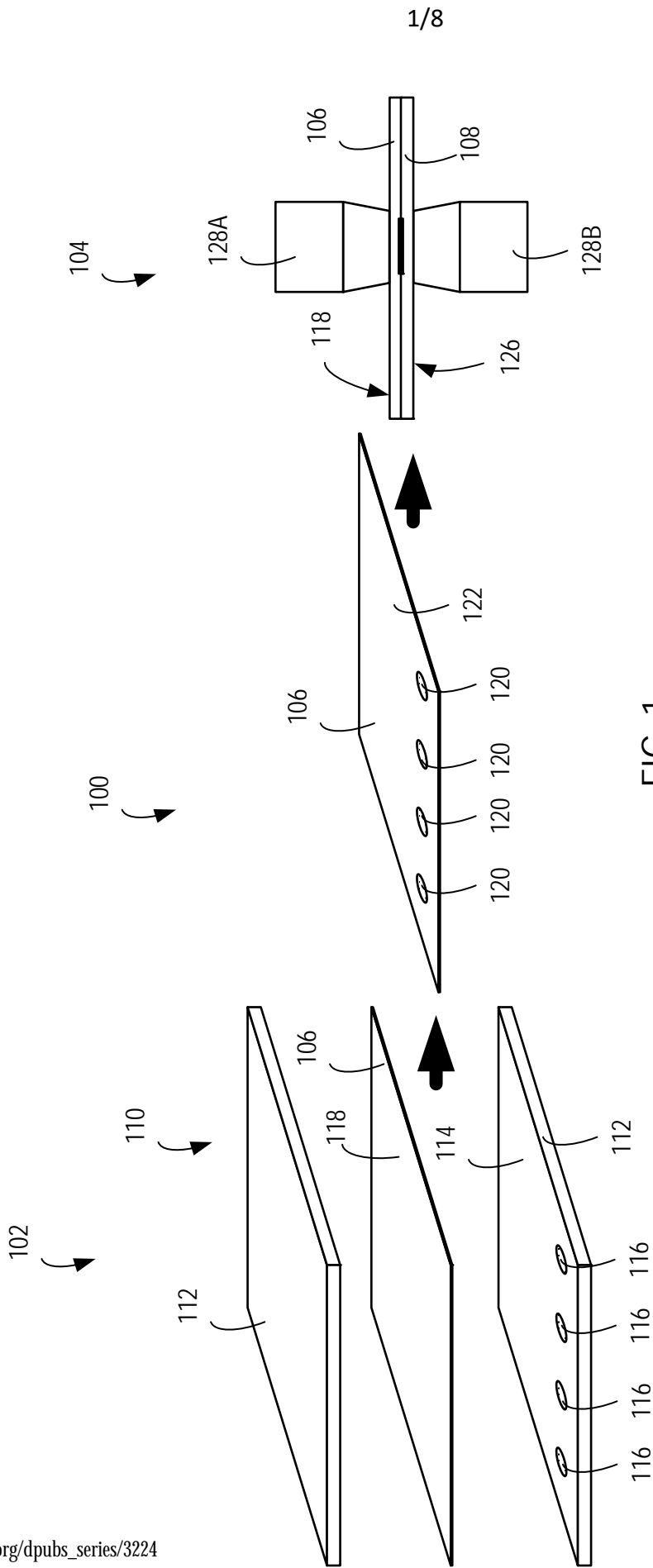
In a block 902, the desired texture parameter of the texture is determined or selected. The texture parameter may be determined/selected by a controller or an operator. As mentioned, the

texture parameter may include, but is not limited to, a surface roughness of the textured region 116, a pressure used to impart the texture onto the metal sheet during stamping, a location of the textured region 116 on the stamping surface 114, and/or a size and shape of the textured region 116 on the stamping surface 114 and/or another parameter influencing the textured region 120 imparted on the metal sheet. In some cases, one or more joining parameters are used to control the texture parameter.

In a block 904, the texture having the desired texture parameter is applied onto at least one of the first metal sheet 106 and the second metal sheet 108 by the texturing system 102. In some examples, applying the texture includes stamping one or both of the metal sheets. In some cases, the texture is applied onto at least one of the lower surface 122 of the first metal sheet 106 and the upper surface 124 of the second metal sheet 108, although it need not be in other examples. In other examples, the texture is applied onto any one or combination of the upper surface 118 of the first metal sheet 106, the lower surface 122 of the first metal sheet 106, the upper surface 124 of the second metal sheet 108, and/or the lower surface 126 of the second metal sheet 108.

In a block 906, the first metal sheet 106 is positioned relative to the second metal sheet 108 such that the at least one textured region 120 is at a joining interface of the first metal sheet 106 with the second metal sheet 108. In a block 908, the joining technique is applied by the joining system 104 at the joining interface. In certain cases, the joining system 104 is the RSW system, and the joining technique includes RSW.

The above-described aspects are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the present disclosure. Many variations and modifications can be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the present disclosure. All such modifications and variations are intended to be included herein within the scope of the present disclosure, and all possible claims to individual aspects or combinations of elements or steps are intended to be supported by the present disclosure. Moreover, although specific terms are employed herein, as well as in the claims that follow, they are used only in a generic and descriptive sense, and not for the purposes of limiting the described invention, nor the claims that follow.



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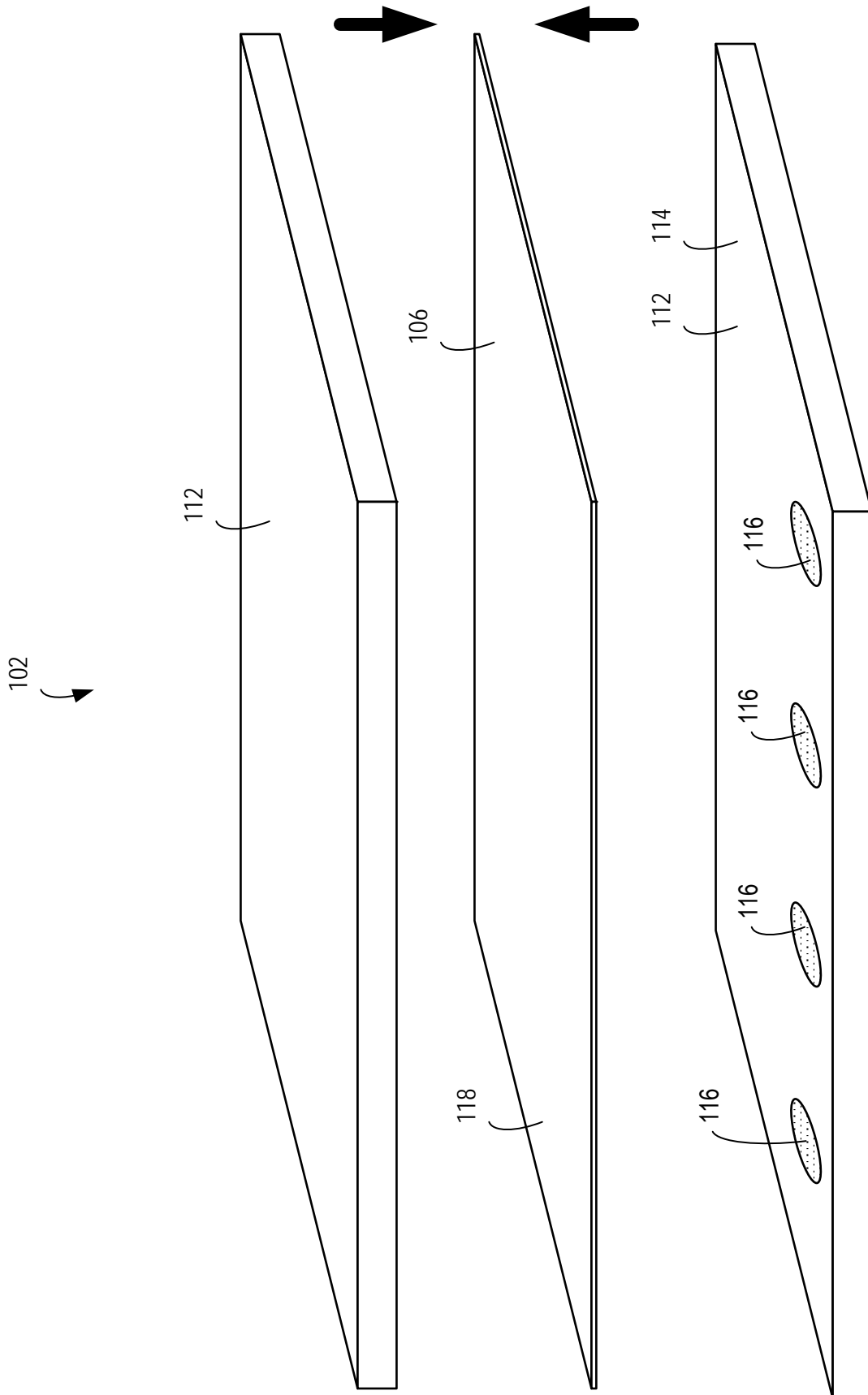


FIG. 2

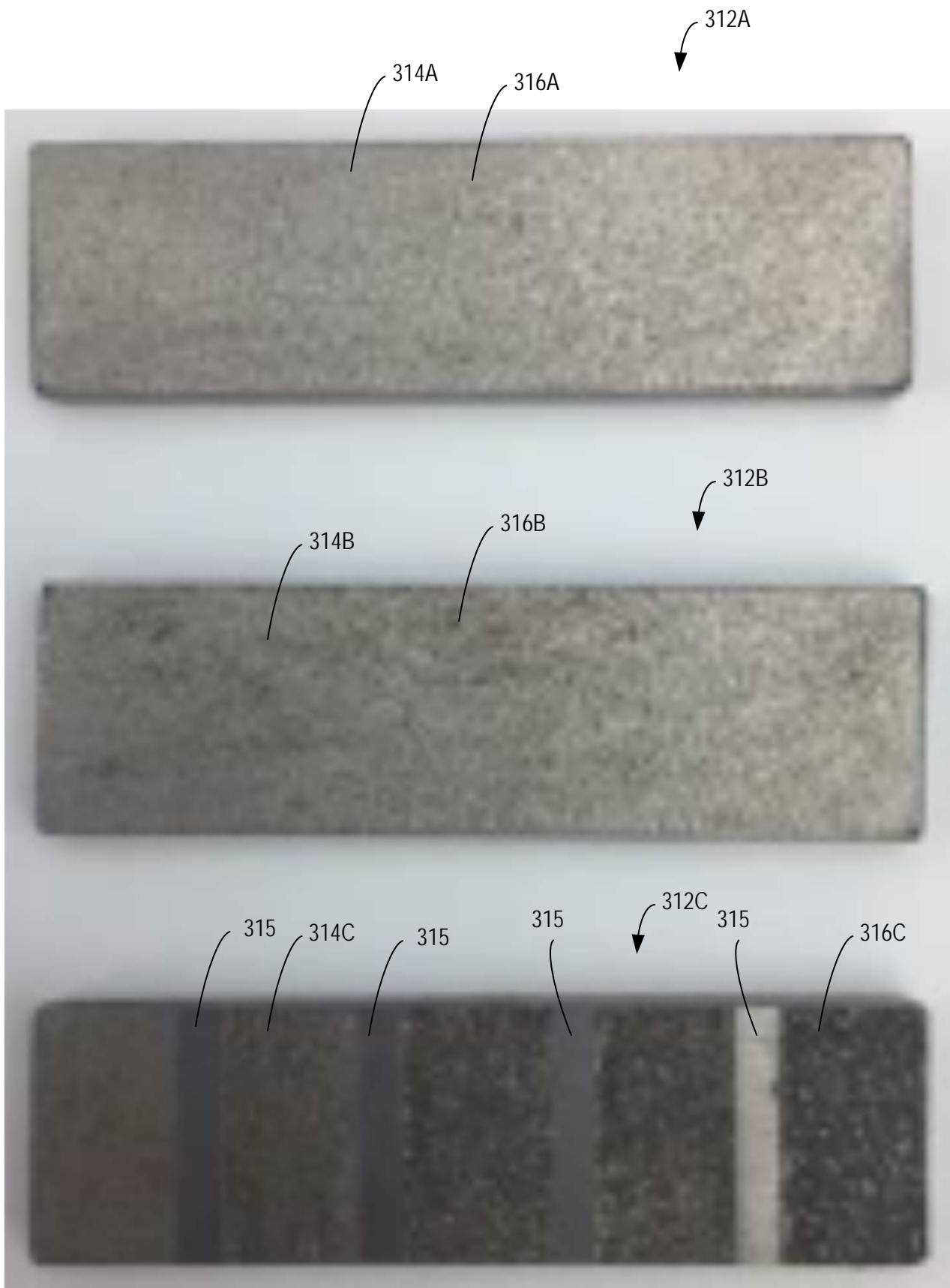


FIG. 3

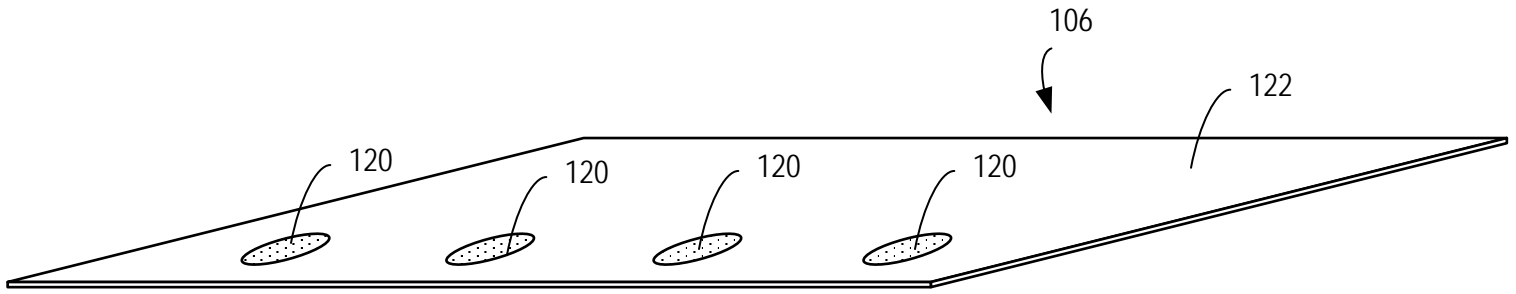


FIG. 4

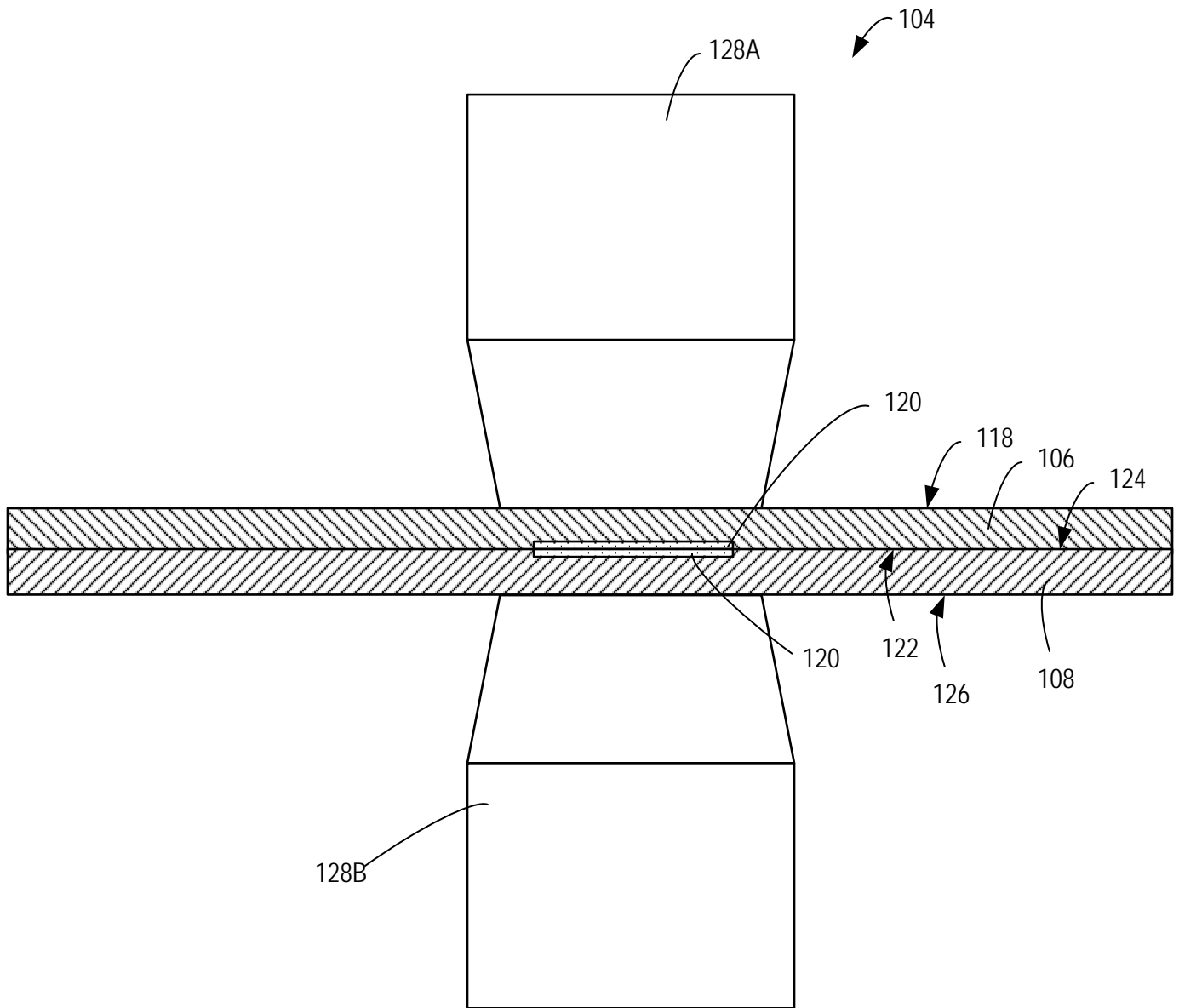


FIG. 5

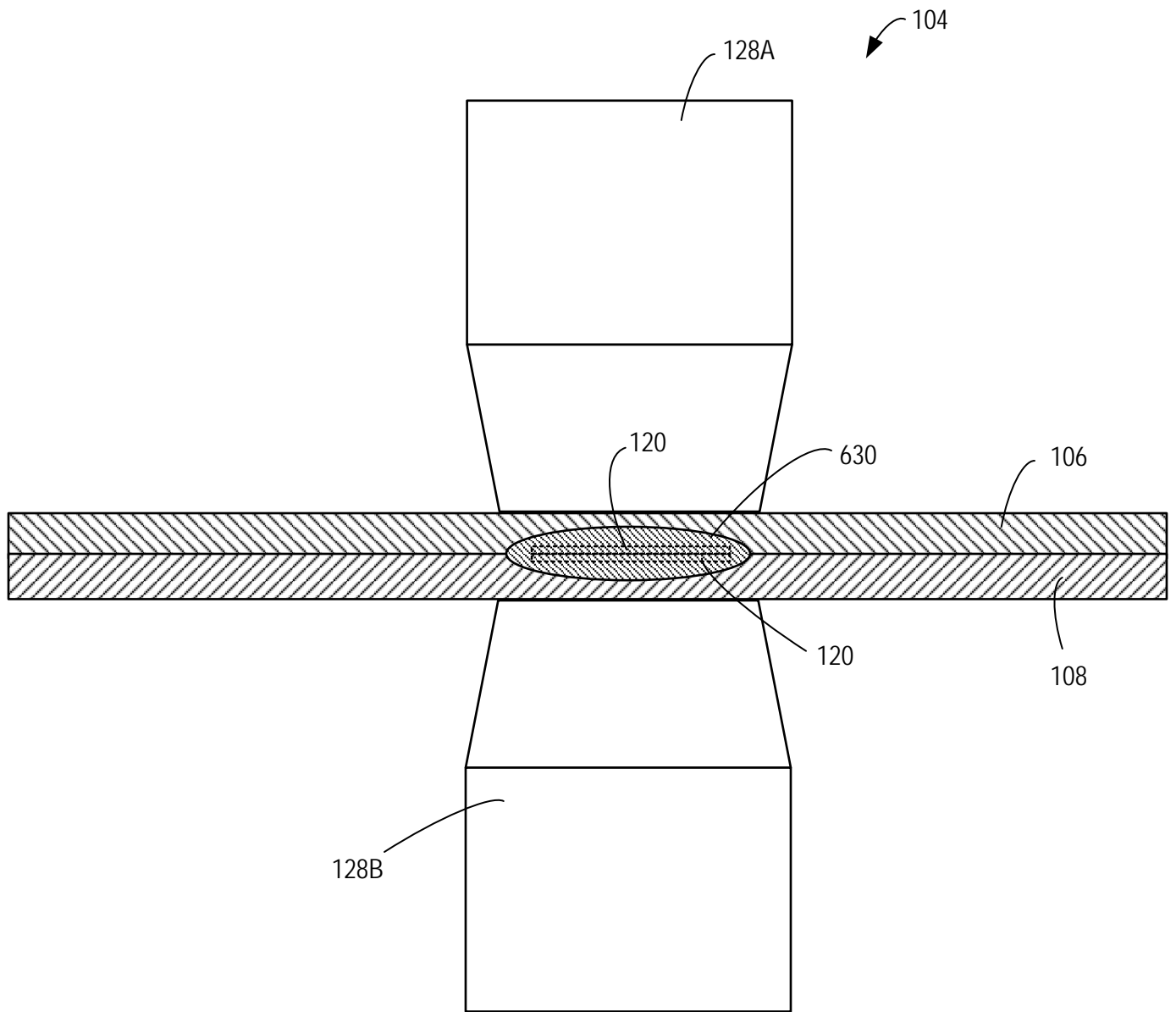


FIG. 6

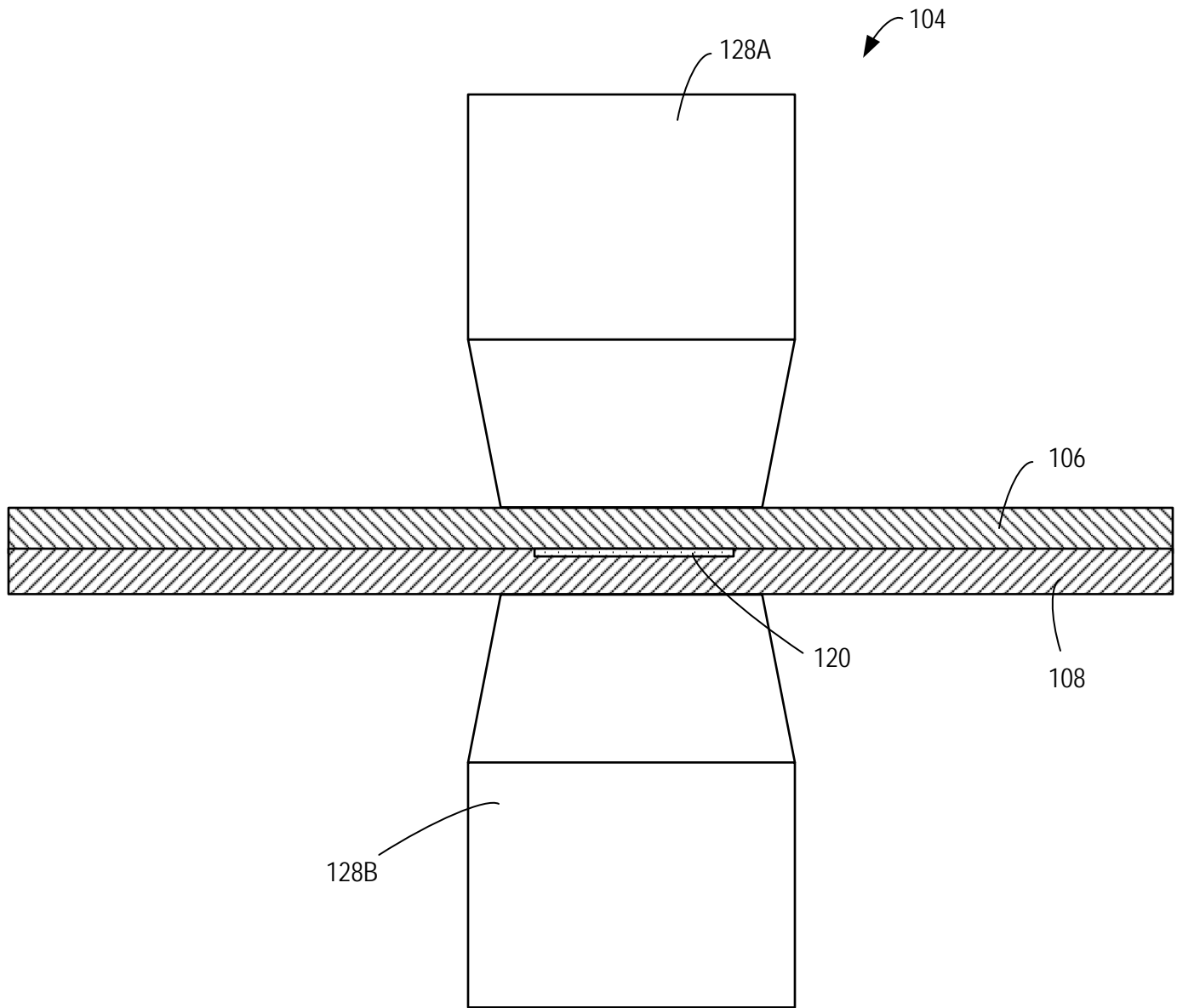


FIG. 7

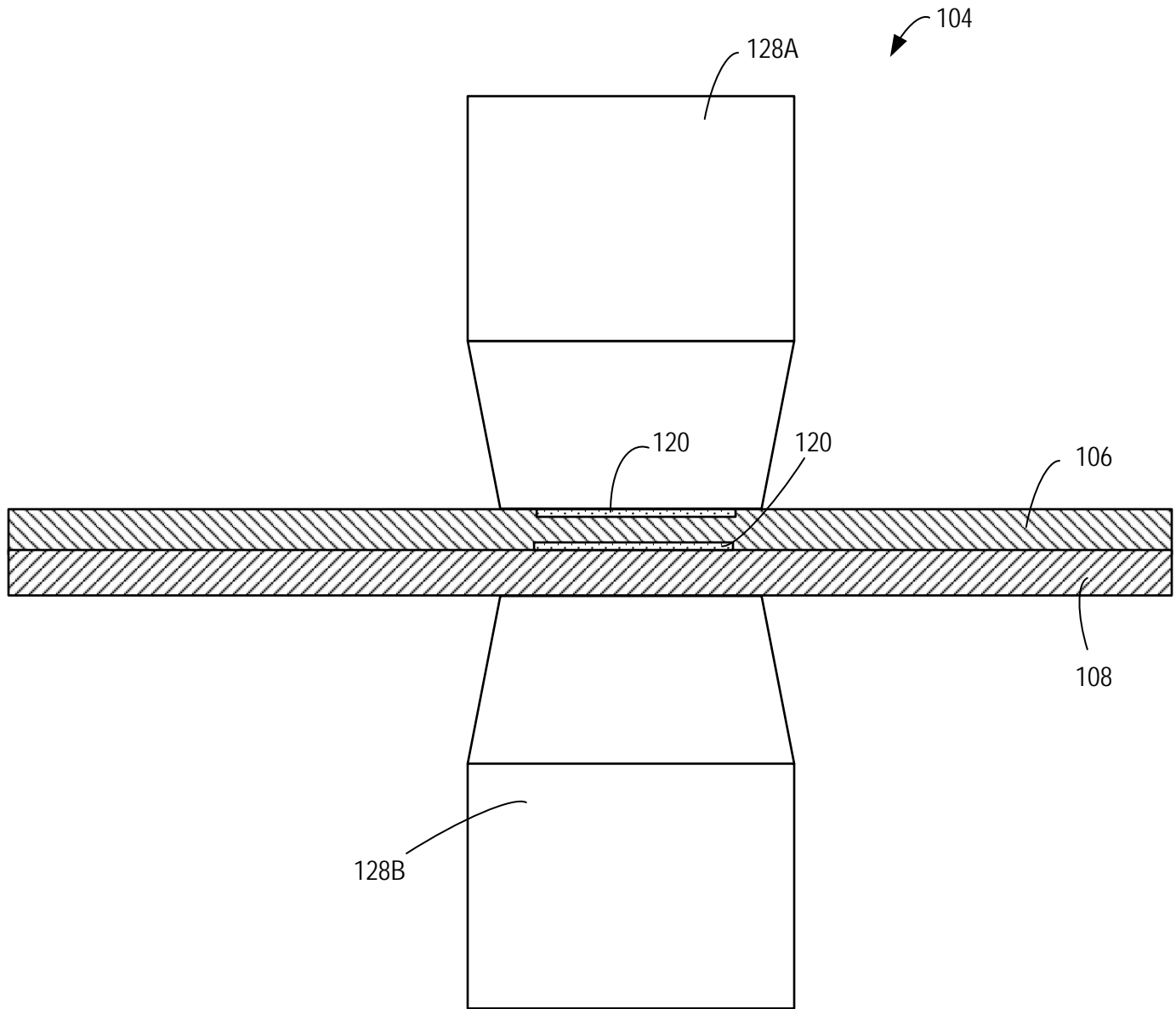


FIG. 8

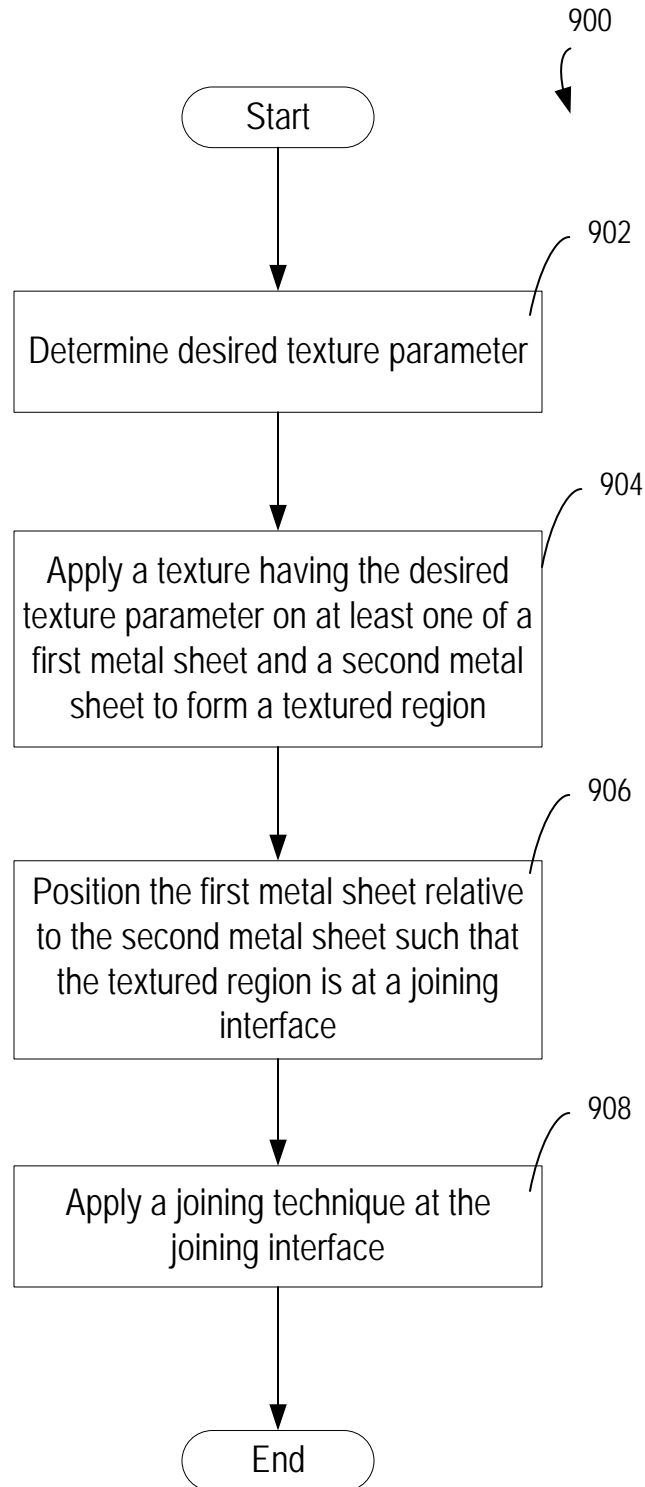


FIG. 9