

BLENDING CONTACT FINGERS FOR PREVENTING CRACKS DURING THIN SUBSTRATE HANDLING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/018,039, filed on April 30, 2020. The entire disclosure of the application referenced above is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to electroplating systems and more particularly to blended contact fingers for electroplating systems.

BACKGROUND

[0003] The background description provided here is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0004] In some applications, a substrate such as a semiconductor wafer is thinned using a grinding wheel to a desired thickness prior to downstream processing. The substrate may be too thin to sufficiently support the substrate during grinding, subsequent handling and/or downstream processing. In this situation, the substrate is bonded to a carrier substrate, which acts as a support structure, and later detached from the carrier substrate when processing is complete. Even with the additional support provided by the carrier substrate, the substrate is prone to cracking and chipping during downstream processing.

SUMMARY

[0005] A contact for providing a connection to a substrate in a substrate plating system includes a body having an arcuate shape. The arcuate shape of the body is configured to conform to a shape of at least a portion of a substrate arranged on a lip seal and a cup of the substrate plating system. A plurality of first contact fingers extend a first distance from the body. A plurality of second contact fingers extend a second distance from the body. The first distance is greater than the second distance.

[0006] In other features, the plurality of first contact fingers are configured to contact a seed layer arranged above a substrate bonded to a carrier substrate during plating. The plurality of second contact fingers are configured to contact the carrier substrate at a location outward from a radially outer edge of the substrate during plating. Ones of the plurality of first contact fingers alternate with ones of the plurality of second contact fingers. P of the plurality of first contact fingers are arranged immediate adjacent to one another and Q of the plurality of second contact fingers are arranged immediately adjacent to one another. P and Q are integers greater than or equal to 1. P and Q are equal, greater than one and less than twenty. P is greater than Q. Q is greater than P.

10 **[0007]** In other features, a plurality of third contact fingers extend a third distance that is different than the first distance and the second distance. A plurality of "U"-shaped cutouts are located between the plurality of first contact fingers and the plurality of second contact fingers. The plurality of first contact fingers are connected together at radially outer ends thereof.

15 **[0008]** In other features, radially inner ends of at least one of the plurality of first contact fingers has a "V"-shaped profile. The first distance is in a range from 0.6mm to 4.2mm and the second distance is in a range from 0.2mm to 1.0mm. The first contact fingers have a thickness in a range from 0.001" to 0.0045" and the second contact fingers have a thickness in a range from 0.0035" to 0.007". The body of the contact is annular.

20 **[0009]** In other features, the contact includes N ones of the body, each of the N ones spans $360^\circ/N$, and the N ones are arranged in a contiguous manner around a periphery of the lip seal. A plating system includes the contact, a cup, and a lip seal arranged on the cup. The contact is arranged between the lip seal and the substrate during plating.

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[0010] A contact configured to rest on a lip seal of a cup includes a first body having an arcuate shape and including a plurality of first contact fingers extending a first distance from the first body and a plurality of first spaces located between selected ones of the plurality of first contact fingers. A second body has an arcuate shape and includes a plurality of second contact fingers extending a second distance from the second body and a plurality of second spaces located between selected ones of the plurality of first contact fingers. The second distance is greater than the first distance. The first body and the second body are configured to overlap with the plurality of first

contact fingers aligned with the plurality of second spaces and with the plurality of second contact fingers aligned with the plurality of first spaces.

5 [0011] In other features, the plurality of second contact fingers are configured to contact a seed layer of a substrate bonded to a carrier substrate. The plurality of first contact fingers are configured to contact the carrier substrate radially outwardly from the substrate. The plurality of first contact fingers are configured to contact a seed layer outwardly from a radially outer edge of the substrate.

[0012] A plating system includes the contact, a cup and a lip seal arranged on the cup.

10 [0013] A contact providing an electrical connection to a substrate in a substrate plating system comprises a first body and a second body. The first body has an arcuate shape and includes N first contact fingers extending a first distance from the first body, where N is an integer greater than 1. The second body has an arcuate shape and includes M second contact fingers extending a second distance from the second body, where M is an integer greater than 1, and a ratio of N:M is 1:P, where P is a positive integer. The second distance is greater than the first distance. The N first contact fingers and the M second contact fingers have the same width. The first body and the second body are configured to overlap, with the N first contact fingers aligned with and stacked on top of at least a plurality of the M second contact fingers.

[0014] In another feature, $P=1$, $P=2$, or $P=3$.

20 [0015] In another feature, the M second contact fingers are configured to contact a seed layer of a substrate bonded to a carrier substrate.

[0016] In another feature, the N first contact fingers are configured to contact the carrier substrate radially outwardly from the substrate.

25 [0017] In another feature, the N first contact fingers are configured to contact a seed layer outwardly from a radially outer edge of the substrate.

[0018] Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims and the drawings. The detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

5 **[0020]** FIGs. 1A to 1F illustrate a method for attaching a substrate to a carrier substrate;

[0021] FIGs. 2A to 2D illustrate problems that may arise when attaching the substrate to the carrier substrate;

[0022] FIG. 3 is a side cross-sectional view of a substrate holder used during plating of the substrate;

10 **[0023]** FIGs. 4A and 4B are enlarged views illustrating contact fingers during plating;

[0024] FIGs. 5A and 5B are plan views illustrating a contact including an arcuate body and contact fingers;

[0025] FIG. 5C is a plan view illustrating an example of a contact including blended contact fingers according to the present disclosure;

15 **[0026]** FIG. 5D is a side view illustrating the blended contact fingers in contact with the substrate;

[0027] FIGs. 6A to 6E are plan views illustrating other examples of contacts including blended contact fingers according to the present disclosure;

20 **[0028]** FIGs. 7A to 7C are plan views illustrating other examples of overlapping contacts including blended contact fingers according to the present disclosure;

[0029] FIG. 7D is a side view illustrating overlapping contacts including blended contact fingers in contact with the substrate;

[0030] FIGs. 8A to 8D are side views illustrating variations of the blended contact finger profiles according to the present disclosure;

25 **[0031]** FIGs. 9A to 9C illustrate width variations for the blended contact fingers;

[0032] FIGs. 10A and 10B illustrates a contact finger with a "V"-shaped end profile on a radially-inner end of the blended contact finger according to the present disclosure;

[0033] FIGs. 11A to 11C are side views illustrating the effect of different blended contact finger profiles on spring force against the substrate surface;

[0034] FIGs. 12A to 12C illustrate various types of contacts according to the present disclosure;

[0035] FIGs. 13A to 13C are plan views illustrating other examples of overlapping contacts including blended contact fingers according to the present disclosure;

5 **[0036]** FIGs. 14A to 14C are plan views illustrating other examples of overlapping contacts including blended contact fingers according to the present disclosure; and

[0037] FIG. 15 is a side view illustrating overlapping contacts of FIGs. 13A-14C including stacked contact fingers in contact with the substrate.

10 **[0038]** In the drawings, reference numbers may be reused to identify similar and/or identical elements.

DETAILED DESCRIPTION

[0039] The present disclosure relates to contacts used during substrate processing such as plating. The contacts according to the present disclosure include blended contact fingers. A first group of the blended contact fingers is designed to contact a
15 radially outer edge of the substrate bonded to the carrier substrate. The first group of contact fingers provides electrical connections to a seed layer on the substrate during plating. A second group of the blended contact fingers is designed to contact the carrier substrate radially outside of the substrate. The second group of contact fingers help break a seal formed by a lip seal to the substrate.

20 **[0040]** Referring now to FIGs. 1A to 1F, a method for attachment of a substrate 14 such as an active Si wafer to a carrier substrate 10 is shown. In FIG. 1A, an adhesive layer 12 is applied to a first surface on one side of a carrier substrate 10. In FIG. 1B, a first surface of the substrate 14 is arranged in contact with the adhesive layer 12. In FIG. 1C, the second surface of the substrate 14 is ground by a grinding wheel to reduce
25 a thickness of the substrate 18 to a desired thickness.

[0041] In FIG. 1D, a thinned substrate 18 is supported by the carrier substrate 10 during and after grinding to prevent damage during handling or other downstream processing. In FIG. 1E, the handling and/or other downstream processing such as deposition, etching, patterning, plating and/or other substrate treatments are performed
30 (generally on the side of the substrate that was ground). In FIG. 1E, the substrate 18 is eventually separated from the carrier substrate 10 to produce a thinned and processed substrate.

[0042] Referring now to FIGs. 2A to 2D, several problems may arise when attaching the substrate 14 to the carrier substrate. In the example in FIG. 2A, a bonded substrate assembly 200 includes the carrier substrate 10 and other layers 204 including the adhesive layer 12, a substrate 210 and a seed layer 214. In some examples, the seed layer 214 is a copper (Cu) seed layer. In some examples, the carrier substrate 10 is made of glass or silicon and has a thickness in a range from 400-700 μm , although other thicknesses can be used. In some examples, the thickness of the substrate 18 after grinding is in a range from 10 to 150 μm , although other thicknesses can be used.

[0043] In FIG. 2B, the seed layer 214 may also cover a portion of the carrier substrate as shown at 230. In FIG. 2C, the adhesive layer 12 may not extend fully under the substrate 210, which may make the substrate prone to cracking or breaking. In FIG. 2D, the adhesive layer 12 may also extend beyond the substrate 210 as shown at 250.

[0044] Referring now to FIG. 3, a plating assembly 300 includes a cup 312 and a cone 314. While a specific assembly is shown for discussion purposes, other types of assemblies, handling equipment or processing equipment can be used. The cup 312 is supported by a top plate 310 and struts 316. Generally, a bonded substrate 320 rests on the cup 312 which provides support. The cup 312 includes an opening through which electrolyte from a plating cell contacts the substrate 320. The substrate 320 has a front/working side 322 where plating occurs. An outer periphery of substrate 320 rests on a lip seal 330 of the cup 312. A spindle 334 causes the cone 314 to press against a cone seal 336 to hold the substrate 320 in place and to seal the substrate 320 against the lip seal 330. A contact ring 350 including contact fingers is located between an upwardly facing surface of the lip seal 330 and a downwardly facing surface of the substrate 320. The contact ring 350 provides an electrical connection to the substrate 320 during plating.

[0045] Referring now to FIGs. 4A and 4B, contact fingers of a contact are shown during plating or other substrate treatment. In FIG. 4A, a contact finger 414 rests on a lip seal 412 supported by a cup (not shown). A radially inner end 416 of the contact finger 414 acts as a spring as a bonded substrate 418 is compressed against the lip seal 412. In FIG. 4B, pressure from the radially inner end 416 of the contact finger 414 against the substrate 210 may cause the substrate 210 to crack and/or one or more layers may break away as shown at 204-1.

[0046] The contact fingers serve as an electrical connection from a power supply to the substrate. Some of the contact fingers need to make good electrical contact with the seed layer 214 on the substrate 210. Generally, longer, flatter contact fingers make better electrical contact. Contacts also serve a secondary purpose by providing lift on the substrate after plating to free the substrate from suction against the lip seal 414. Steep angle contacts with more spring force provide better lift, whereas flatter contacts are more prone to sticking to the lip seal 412. Contact fingers (particularly those that provide strong lift) are a key source of wafer cracking/chipping on thin substrates such as active Si wafers.

[0047] Systems and methods discussed herein to provide a contact design that makes good electrical contact with the seed layer on the substrate, provides strong lift to prevent wafer sticking to the lip seal after plating, and does not crack or chip the substrate. The present disclosure relates to contacts including blended contact fingers and/or other features addressing the foregoing problems. In some examples, the blended contact fingers include two or more types of contact fingers that are used to contact a single substrate.

[0048] Referring now to FIGs. 5A and 5B, a contact 500 including a plurality of contact fingers is shown. In FIG. 5A, the contact 500 includes an outer portion 510 and an inner portion 514 extending radially inwardly from the outer portion 510. The inner portion 514 includes contact fingers projecting radially inwardly (examples shown in FIGs. 5B, 5C and 6A to 6E). While the inner portion 514 of the contact 500 includes the contact fingers, the contact fingers can be arranged on the outer portion 510. In FIG. 5B, the contact fingers 530 extend radially inwardly by the same distance.

[0049] In FIGs. 5C and 5D, the contact fingers have different lengths and are blended. First contact fingers 540 extend inwardly more than second contact fingers 550. In some examples, the first contact fingers 540 alternate with the second contact fingers 550. However, different patterns may be used. For example, F of the first contact fingers 540 can be arranged between G of the second contact fingers, where F and G are integers greater than or equal to one.

[0050] This blended contact finger arrangement has several advantages. The second contact fingers 550 make physical contact with the carrier substrate and typically not with the substrate, which minimizes risk of cracking/chipping. The second contact fingers 550 provide lift to prevent the substrate from sticking to the lip seal.

[0051] In some examples, the second contact fingers 550 have a length in a range from 0.2mm to 1.0mm (e.g. 0.4mm). In some examples, the second contact fingers 550 have steeper angle than the first contact fingers 540. In some examples, the angle of a second bend of the second contact fingers 550 closest to the substrate is in a range from 45° to 135° (e.g. 105°).

[0052] In some examples, the second contact fingers 550 are stiffer than the first contact fingers 540. For example, the second contact fingers may use a material having a thickness in a range from 0.0035" to 0.007" (e.g. 0.004"). In some examples, the second contact fingers 550 can also make electrical contact with the seed layer if the seed layer extends beyond the substrate as shown in FIG. 2B.

[0053] The first contact fingers 540 make electrical contact with the substrate. Characteristics include longer length for good electrical contact. In some examples the length is in a range from 0.6mm to 4.2mm (e.g. 1.3mm). In some examples, the second bends of the first contact fingers 540 have a shallower angle in a range from 45° to 135° (e.g. 115°). In some examples, the first contact fingers 540 are made of a thinner material than the second contact fingers 550. In some examples, the thickness of the first contact fingers 540 is in a range from 0.001" to 0.0045" (e.g. 0.002") to reduce thin wafer cracking and chipping

[0054] In some examples, the first contact fingers 540 and the second contact fingers 550 are made of a conductive material. For example, the conductive material may include stainless steel (SS), platinum coated SS, Paliney® 7, beryllium copper, and/or other alloys or metals.

[0055] The blended contact fingers described herein enable shallower, gentler electrical contact (using longer length contact fingers) to minimize cracking risk, while reducing sticking risk (using shorter contact fingers) as shown in FIG. 5D.

[0056] Referring now to FIGs. 6A to 6E, other examples of contacts including blended contact fingers are shown. In FIG. 6A, the contact 600 is shown to include an outer portion 606 and an inner portion 602 including contact fingers 610, 614 and 620 having increasing lengths, respectively. Instead of alternating between two types of contacts, the contact 500 includes 3 or more radial lengths, circumferential widths, material thicknesses and/or material types.

[0057] In FIGs. 6B, 6D and 6E, the contact ring portion 630 is shown to include an outer portion 606 and an inner portion 608 including a group of P contact fingers 634

having the same first length arranged adjacent to one another. The contact ring portion 630 includes a group of Q contact fingers 638 having the same second length arranged adjacent to one another where the first length is shorter than the second length. The group of P contact fingers 634 is arranged adjacent to the group of Q contact fingers 638. P and Q are integers greater than or equal to 1 where at least one of P or Q is greater than or equal to 1. In some examples, P and Q are less than or equal to 30, 20, 10, 8, 6 or 4. In some examples, P and Q are equal. In FIG. 6B, P=Q=6 for the contact ring portion 630. In FIG. 6D, P=1 and Q=2 for a contract ring finger 670. In FIG. 6E, P=1 and Q=3 for a contract ring finger 680. While specific examples are shown, other combinations are contemplated.

[0058] In FIG. 6C, a contact ring portion 640 includes “U”-shaped cutouts 652 defining first contact fingers 650 and second contact fingers 654. Two or more of the second contact fingers 654 are connected together and extend further than the first contact fingers 650. In some examples, two, three, four or more of the second contact fingers 654 are joined together to make a circumferentially longer contact, which maximizes contact area on the seed layer. In some examples, additional cutouts (not shown) may be made between selected ones of the second contact fingers 654 to separate the second contact fingers 654 to a desired number of connected second contact fingers 654. In other examples, all of the second contact fingers 654 remain joined together. This design may be beneficial for thin seed layers and/or marginally distributed seed layers.

[0059] Referring now to FIGs. 7A to 7D, overlapping contacts including blended contact fingers are shown. In FIG. 7A, a first contact 710 includes an outer portion 712 and an inner portion 714. Contact fingers 716 extend inwardly and are separated by spaces 718. A second contact 720 includes an outer portion 712 and an inner portion 714. Contact fingers 724 extend radially inwardly and are separated by spaces 728. The contact 710 is arranged in an overlapping manner on the second contact 720 with the contact fingers 716 aligned with spaces 728 and with the contact fingers 724 aligned with the spaces 718 as can be seen in FIG. 7C. The overlapping contacts can remain independent pieces that lay on top of one another and are held in place when assembled into the cup. Alternatively the overlapping pieces can be spot-welded, glued, or permanently attached to one another using other approaches.

[0060] In FIG. 7D, the contact fingers 724 provide electrical contact to the seed layer and the contact fingers 716 contact the carrier substrate to help break the seal after plating. FIGs. 7A to 7C show one of the contact fingers 716 from the first contact 710 between each of the contact fingers 724 from the second contact 720. Other patterns
5 may include groups of C contact fingers on the first contact ring arranged immediately adjacent to one another and separated by other groups by spaces and a group of D contact fingers on the second contact ring arranged immediately adjacent to one another and separated by spaces, where C and D are integers greater than one. In some examples, C=D. In other examples, C <> D and the widths are varied. For
10 example, C=2 and D=1 with the width of the D contact fingers being twice the width of the C contact fingers.

[0061] Referring now to FIGs. 8A to 8D variations of the blended contact finger profiles are shown. In FIG. 8A, a contact finger 810 includes a first bend 812 in a downward direction, a second bend 814 in an upward direction and a radially inner end 816. In
15 FIG. 8B, a contact finger 820 includes a first bend 822 in a downward direction, a second bend 824 in an upward direction and a radially inner end 826. Edges of the contact finger 820 are more rounded (as compared to FIG. 8A) to reduce damage to the substrate due to digging into the substrate and/or subsequent cracking.

[0062] In FIG. 8C, the contact finger 830 includes a first bend 832 in a downward
20 direction, a second bend 834 in an upward direction, a third bend 835 in a downward direction and a radially inner end 816. The third bend 835 provides a smoother contact surface that likewise reduces damage to the substrate due to digging into the substrate and/or subsequent cracking. In FIG. 8D, the contact finger 840 includes a first bend
25 842 in a downward direction, a second bend 844 in an upward direction and a radially inner end 816. Altering the angles at the bends (particularly the first bend 842) varies the loading of the contact finger and the pressure on the substrate.

[0063] Referring now to FIGs. 9A to 9C, a circumferential width of the blended contact fingers can be varied to adjust loading of the contact fingers. A wider circumferential width will have increased loading as compared to a standard circumferential width
30 whereas a narrower width will have less loading (assuming the same materials and thickness).

[0064] Referring now to FIGs. 10A and 10B, a profile of a radially inner end of the contact finger can be varied. A contact finger 1020 includes a first bend 1022, a

second bend 1024 and a radially inner end 1026. The radially inner end 1026 has a "V"-shaped profile. Bends in the "V"-shaped profile provide increased contact pressure on the substrate.

[0065] Referring now to FIGs. 11A to 11C, the effect of different blended contact finger profiles and force on the substrate surface are illustrated. The location and angle of second bend on the contact finger can have significant impact on contact force. In FIG. 11A, a cup 1110 includes a bottom surface 1112 and a lip seal 1114. A contact finger 1120 is supported on the lip seal 1114 and includes a first bend 1122, a second bend 1124 and a radially inner end 1126. As can be seen, the contact finger 1120 acts as a spring with an effective length L_1 from the second bend 1124 to the radially inner end 1126 of the contact finger 1120.

[0066] In FIG. 11B, a contact finger 1140 is supported on the lip seal 1114 and includes a first bend 1142, a second bend 1144 and a radially inner end 1146. As can be seen, the contact finger 1140 acts as a spring with an effective length L_2 from the second bend 1144 to the radially inner end 1146 of the contact finger 1140. As can be seen, the effective length of the spring changes the impacting force on the substrate. More particularly, the location and angle of the second bend on the contact finger changes the contact force.

[0067] In FIG. 11C, a contact finger 1150 is supported on a lip seal 1152 of a cup 1154. The contact finger 1150 includes a first bend 1152, a second bend 1154 and a radially inner end 1156. When the contact finger 1150 makes electrical contact with the substrate, a flatter contact/shallower angle of the second bend 1154 reduces force on substrate and minimizes likelihood of cracking. A flatter contact will also require less pressure to hold the wafer in place, thereby reducing the propensity of the wafer to stick to the lip seal.

[0068] Referring now to FIGs. 12A to 12C, the body of the contact can be a continuous annular ring or a group of arcuate portions combined to form an annular ring. In other examples, the contact ring can be segmented into A portions each spanning $360^\circ/A$, where A is an integer greater than or equal to one. In FIG. 12B, $A=2$ and the contact ring portions span 180° . In FIG. 12C, $A=4$ and the contact ring portions span 90° . In other examples, $A=3$ and the contact ring portions span 120° , $A=5$ and the contact rings span 72° , etc.

[0069] Referring now to FIGs. 13A to 14C, additional configurations of contacts including stacked contact fingers are shown. In FIGs. 13A-13C, the shorter contact fingers 716 are fewer in number than the longer contact fingers 530, and are aligned with and stacked on top of only some of the longer contact fingers 530. In FIGs. 14A-14C, the shorter contact fingers 716 are equal in number as the longer contact fingers 530, and are aligned with and stacked on top of the longer contact fingers 530.

[0070] In FIGs. 13A-13C, FIG. 13A is similar to FIG. 7A, and FIG. 13B is similar to FIG. 5B. In FIG. 13A, the first contact 710 includes the outer portion 712 and the inner portion 714. The contact fingers 716 extend inwardly and are separated by spaces 718. In FIG. 13B, the second contact 500 includes the outer portion 510 and the inner portion 514 extending radially inwardly from the outer portion 510. The inner portion 514 includes the contact fingers 530 projecting radially inwardly. While the inner portion 514 of the second contact 500 includes the contact fingers 530, the contact fingers 530 can be arranged on the outer portion 510. The contact fingers 716 are shorter in length than the contact fingers 530. The contact fingers 716 and 530 have the same width. The number of contact fingers 716 is less than the number of contact fingers 530. For example, a ratio of the number of contact fingers 716 to the number of contact fingers 530 may be 1:2, 1:3, and so on.

[0071] In FIG. 13C, the shorter contact fingers 716 are aligned with and are stacked on top of only some of the longer contact fingers 530 depending on the 1:N ratio between the contact fingers 716 and 530, where N is an integer greater than 1. The first contact 710 is arranged in an overlapping manner on the second contact 500 with the contact fingers 716 aligned with and stacked on top of some of the longer contact fingers 530.

[0072] In FIGs. 14A-14C, FIG. 14A differs from FIG. 13A in that a first contact 711 includes the contact fingers 716 that are not separated by spaces 718. Otherwise, the first contact 711 is similar the first contact 710 in all other respects. FIG. 14B is the same as FIG. 13B and is therefore not described again for brevity. The shorter contact fingers 716 are again smaller in length than the longer contact fingers 530. The contact fingers 716 and 530 again have the same width. However, the number of contact fingers 716 is equal to the number of contact fingers 530. That is, the ratio of the number of contact fingers 716 to the number of contact fingers 530 is 1:1.

[0073] In FIG. 14C, the shorter contact fingers 716 are aligned with and are stacked on top of the longer contact fingers 530, respectively. The first contact 711 is arranged in an overlapping manner on the second contact 500 with the contact fingers 716 aligned with and stacked on top of the longer contact fingers 530, respectively.

5 **[0074]** FIG. 15, which is similar to FIG. 7D, shows that the contact fingers 530 provide electrical contact to the seed layer 214, and the contact fingers 716 contact the carrier substrate 418 to help break the seal after plating. As described above with reference to FIG. 7D, the overlapping contacts can remain independent pieces that lay on top of one another and are held in place when assembled into the cup. Alternatively the
10 overlapping pieces can be spot-welded, glued, or permanently attached to one another using other approaches.

[0075] The foregoing description is merely illustrative in nature and is in no way intended to limit the disclosure, its application, or uses. The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure
15 includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims. It should be understood that one or more steps within a method may be executed in different order (or concurrently) without altering the principles of the present disclosure. Further, although each of the embodiments is
20 described above as having certain features, any one or more of those features described with respect to any embodiment of the disclosure can be implemented in and/or combined with features of any of the other embodiments, even if that combination is not explicitly described. In other words, the described embodiments are not mutually exclusive, and permutations of one or more embodiments with one another
25 remain within the scope of this disclosure.

[0076] Spatial and functional relationships between elements (for example, between modules, circuit elements, semiconductor layers, etc.) are described using various terms, including “connected,” “engaged,” “coupled,” “adjacent,” “next to,” “on top of,” “above,” “below,” and “disposed.” Unless explicitly described as being “direct,” when a
30 relationship between first and second elements is described in the above disclosure, that relationship can be a direct relationship where no other intervening elements are present between the first and second elements, but can also be an indirect relationship where one or more intervening elements are present (either spatially or functionally)

between the first and second elements. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A OR B OR C), using a non-exclusive logical OR, and should not be construed to mean “at least one of A, at least one of B, and at least one of C.”