MEMBRANE FRAME FOR ELECTRODEPOSITION TOOL

BACKGROUND

[0001] Electrodeposition can be used in integrated circuit manufacturing processes to deposit electrically conductive films onto substrates. Electrodeposition involves the electrochemical reduction of dissolved ions of a selected metal to an elemental state on a substrate to form a film of the selected metal. Electrodeposition systems comprise a cathode chamber through which a catholyte solution circulates, and an anode chamber through which an anolyte solution circulates. An ion-exchange membrane is positioned between the cathode chamber and anode chamber. The ion-exchange membrane selectively allows some ions to pass from the anolyte to the catholyte while preventing the passage of other ions and organic additives.

SUMMARY

[0002] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all disadvantages noted in any part of this disclosure.

[0003] Examples are disclosed that relate to efficiently draining catholyte solution from a volume between a high-resistance virtual anode (HRVA) and an ion-exchange membrane in an electrodeposition system. In one example system, an electrodeposition tool comprises an anode chamber and a cathode chamber. A HRVA is positioned within the cathode chamber. An ion-exchange membrane is positioned between the anode chamber and the cathode chamber. The ion-exchange membrane is supported by a membrane frame. The electrodeposition tool further comprises an aspiration flow path configured to drain a volume between the HRVA and the ion-exchange membrane. The aspiration flow path is defined by the ion-exchange membrane and a groove in the membrane frame.

[0004] In some such examples, the groove is formed at least partially around a perimeter of the membrane frame.

a pressure differential between the membrane frame 128 and an evacuation system 132. In other examples, a pump 130 or other mechanism (e.g. a compressed gas source) can be used to provide a positive pressure differential. For example, the pump 130 can pump water (e.g. deionized water) into the electrodeposition cell 102. In this manner, the pump 130 is configured to remove the catholyte from the volume between the ion-exchange membrane 108 and the HRVA 109.

[0070] As illustrated in FIG. 4, one or more of the baffles 206 can comprise at least one opening 214. Each opening 214 is configured to permit flow of a catholyte through the baffle. In this manner, the opening(s) 214 and the grooves 210A, 210B together enable aspiration of the volume above the ion-exchange membrane.

[0071] In some examples, the opening(s) 214 can be relatively small compared to the baffle 206. Accordingly, catholyte flow through the opening(s) 214 can have a substantially higher impedance than the catholyte solution flow 208 across a substrate. In this manner, the opening(s) 214 can help to maintain a suitably high impedance to catholyte solution flow to avoid disrupting catholyte solution flow 208 across the substrate.

[0072] FIGS. 5-6 show another example of a membrane frame 500. The membrane frame 500 can serve as the membrane frame 128 of FIG. 1. Like the membrane frame 200 of FIGS. 2-4, the membrane frame 500 comprises a grid structure 502 comprising a plurality of frame cells 504. The membrane frame 500 also comprises a plurality of baffles 506 and a groove 510. The groove 510 is formed around at least a portion of a perimeter of the grid structure 502.

[0073] The membrane frame 500 further comprises a plurality of additional grooves 512A-512D. Each of the additional grooves 512A-512D is formed in one of the baffles 506. Furthermore, each of the additional grooves 512A-512D is in fluid communication with the groove 510 at the perimeter of the grid structure 502. As described in more detail below, the additional grooves 512A-512D further help to aspirate the volume between the HRVA and the ion-exchange membrane.

[0074] As illustrated in FIG. 6, one or more of the baffles 506 comprises a pair of openings 514A, 514B. Like the openings 214 in the baffles 206 of FIGS. 2-4, the openings 514A, 514B permit catholyte to flow into groove 512A.

[0075] In some examples, the openings 514A, 514B are located on opposite sides of the baffle. Additionally or alternatively, the openings 514A, 514B can be offset along a length of the baffle 506. In this manner, as illustrated in FIG. 6, the openings 514A,

514B are staggered. The staggered openings 514A, 514B impede bulk flow of a catholyte under the HRVA or between the membrane and the HRVA. In this manner, the opening(s) 514A, 514B enable aspiration while maintaining a suitably high impedance to catholyte solution flow to avoid disrupting catholyte solution flow across the substrate.

[0076] In the example of FIGS. 5-6, a plurality of baffles 506 divide the volume between the HRVA and the ion-exchange membrane into a plurality of differently sized volumes. Eight volumes formed by the baffles 506 are indicated by brackets 516A-516H in FIG. 5. The volumes 516A and 516B are at least partially bounded by the perimeter of the membrane frame 500 and the groove 512A. The volumes 516C and 516D are at least partially bounded by the perimeter of the membrane frame 500 and the groove 512B. The volumes 516E and 516F are at least partially bounded by the perimeter of the membrane frame 500 and the groove 512C. The volumes 516G and 516H are at least partially bounded by the perimeter of the membrane frame 500 and the groove 512D. Volumes 516D and 516E are larger than volumes 516C and 516F. Volumes 516C and 516F are larger than volumes 516B and 516G. Volumes 516B and 516G are larger than volumes 516A and 516H. Volumes 516D and 516E are located closer to the aspiration port than volumes 516C and 516F. Volumes 516C and 516F are located closer to the aspiration port than volumes 516B and 516G. Volumes 516B and 516G are located closer to the aspiration port than volumes 516A and 516H. Accordingly, the larger volumes can be aspirated at a relatively faster rate than the smaller volumes due to less flow restriction within the aspiration grooves. In this manner, each of plurality of volumes 516A-516H can be drained in substantially the same amount of time.

[0077] FIG. 7 shows yet another example of a membrane frame 700. The membrane frame 700 can serve as the membrane frame 128 of FIG. 1. As illustrated in FIG. 7, the membrane frame 700 includes at least one tube 702A, 702B extending from a perimeter of the membrane frame 700. The tubes 702A, 702B can be used in addition to or as an alternative to the grooves 210A, 210B of FIG. 3, the groove 510 of FIG. 6, and/or the grooves 512A-512D of FIG. 6.

[0078] Each tube 702A, 702B is in fluid communication with an aspiration port 704A, 704B, respectively. The aspiration ports 704A, 704B can be analogous to the aspiration ports 212A, 212B described above with reference to FIG. 4. In this manner the tubes 702A, 702B can aspirate a volume between an HRVA and ion-exchange membrane.

catholyte via the aspiration flow path. In some examples, as discussed above, the aspiration port may further be used to backfill deionized water (or another suitable liquid) into the grooves 906, 908, and the frame cells 904, to flush remaining catholyte from the electrodeposition tool.

[0088] One or more of the plurality of the frame cells may include openings that enable fluid communication between the frame cell and the intersecting groove. For instance, in FIG. 9, an opening 912 enables fluid communication between the intersecting groove 908 and a neighboring frame cell of the plurality of frame cells 904. Any or all of the frame cells neighboring the intersecting groove may in some cases include openings to the intersecting groove, to thereby enable flow of catholyte from the frame cells into the intersecting groove.

[0089] In some examples, the membrane frame may have a sloping profile. In other words, the perimeter groove 906 may define a plane parallel to the page, as depicted in FIG. 9. As the intersecting groove 908 extends from an opening in the perimeter groove towards the center of the membrane frame, the intersecting groove is not parallel to the plane of the perimeter groove, but rather extends into the page. In this manner, the center of the intersecting groove may be relatively more distal from the plane of the perimeter groove than other points along the intersecting groove. When installed in the electrodeposition tool, this sloping profile may cause liquid to drain toward the center of the intersecting groove, as aided by gravity.

[0090] When the membrane frame has a sloping profile, the degree of the slope may vary depending on the implementation. As one non-limiting example, the membrane frame 900 may have a slope inclination of one degree. As one non-limiting example, the membrane frame 1000 of FIG. 10 may have a slope inclination of seven degrees. Membrane frames with different slope inclinations may in some cases be used for different types of electrodeposition processes.

[0091] In some cases, openings may be defined between different frame cells of the plurality of frame cells 904, such that a given frame cell may be in fluid communication with one or more of its neighboring frame cells. FIG. 9 includes a zoomed-in view of a group of frame cells, one of which is labeled as first frame cell 914. It will be understood that the specific arrangement of openings between frame cells shown in FIG. 9 is non-limiting. In general, different frame cells of the plurality of frame cells 904 may have different numbers of openings to their orthogonally and/or diagonally neighboring frame cells. Furthermore, different membrane frames may have

1004. The membrane further includes an intersecting groove 1008A that extends between openings in the perimeter groove 1006.

[0096] In this example, the intersecting groove 1008A is one of several intersecting grooves that divide the plurality of frame cells into different cell volumes. Specifically, in this example, there are a total of seven intersecting grooves 1008A-1008G, each extending between different respective pairs of openings in the perimeter groove 1006. In this manner, the perimeter groove and the intersecting grooves together define a portion of the aspiration flow path that enables aspiration of the catholyte.

[0097] In this example, the intersecting grooves divide the plurality of frame cells into separate cell volumes 1010A-H. Each intersecting groove includes one or more openings to a different respective cell volume. FIG. 10 includes a zoomed-in view of a frame cell 1012 of the plurality of frame cells 1004. Frame cell 1012 is included in cell volume 1010C, and includes an opening 1014 to intersecting groove 1008C. Frame cell 1012 additionally includes openings to other frame cells in the same cell volume 1010C. For instance, frame cell 1012 includes an opening 1016 to a diagonally adjacent frame cell 1018. This enables catholyte within frame cells of the cell volume 1010C to drain into the intersecting groove 1008C, and eventually be aspirated from the electrodeposition tool via an aspiration port.

[0098] Similarly, intersecting groove 1008B may include one or more openings to frame cells in cell volume 1010B, intersecting groove 1008A may include one or more openings to frame cells in cell volume 1010A, etc. In this manner, catholyte within each cell volume may be aspirated separately through the different intersecting grooves into the perimeter groove. Furthermore, in the example of FIG. 10, different frame cells of the plurality of frame cells lack openings to their orthogonally adjacent neighboring frame cells. As discussed above, the membrane frame 1000 of FIG. 10 may have a sloped profile with a steeper inclination (e.g., a seven degree inclination), as compared to the membrane frame 900 of FIG. 9. This steeper slope may improve draining of catholyte toward the center of the membrane frame, which enables omission of openings between orthogonally adjacent frame cells while still providing for effective catholyte aspiration. To the contrary, it is believed that inclusion of openings between orthogonally neighboring frame cells in a membrane frame with a relatively steeper sloping profile, as is the case in FIG. 10, can “short circuit” and reduce the efficacy of the aspiration process.