Applications Note

NV10 Disks at Innovion

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Introduction

Innovion is the premier supplier of ion implantation foundry services. A major segment of our business is providing high dose implantation for 2 inch through 6 inch wafers. Innovion supplies much of this market segment with its stable of Eaton/Axcelis NV-10 series of implanters. To meet the varied requirements of its customers' applications, Innovion maintains an extensive inventory of disks for NV10 implanters. These disks provide a mix of features that promote the optimal implantation of our customers' diverse processes, from thin/fragile wafers through those sensitive to sputtered metal. Innovion customers and our engineering staff work closely together to select the most appropriate disk to meet their needs. This Application Note highlights the design features associated with each disk.

The NV10 End Station

The NV10 Implanter from Eaton (now Axcelis) was the first commercially successful high dose implanter with high productivity. It uses 2 alternating disks (1 and 2 in the graphic to the right) for a single implant chamber (4 in the graphic). While one disk is being processed (location 4), the second disk is being unloaded and loaded (location 1). Innovion uses manually loaded disks in its processing. The exchange arms (3 in the graphic) serve to move the 2 disks between the Load/Unload area and the Chamber area.

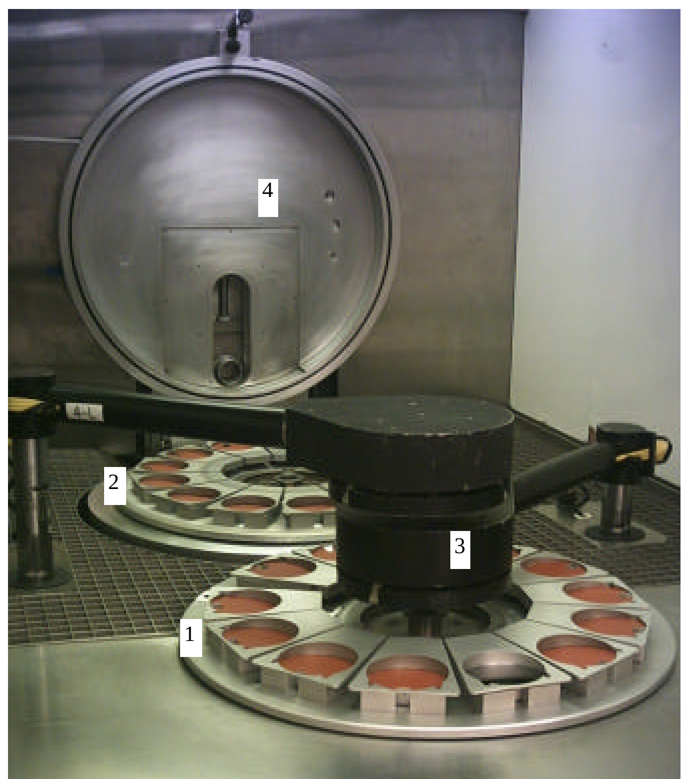

Figure 1 The Eaton NV10 End Station showing the 2 disks, exchange arms, and the implant chamber

In this graphic at location 1, a 4 inch 7 degree tilt Full Ring Clamp Disk is shown. This has pedestals for 13 wafers. Note that only one of the pedestals is loaded with a wafer. The rest of the pedestals are empty and the thermally conductive "Red Elastomer" can be seen.

At location 2, the disk is installed onto the Chamber door. Prior to implant the disk and chamber door assembly tilts up vertically, closing against the chamber (4) to form a vacuum compartment. The actual implant starts when the disk reaches a spin speed of 953 rpm and the vacuum goes below a pressure of 2e-5 torr.

On completion of the implant, the spin speed drops to zero, the chamber vents to atmsopheric pressure, and the chamber door and disk assembly opens and lowers to the horizontal position. At this point the Exchange Arms will exchange the positions of the 2 disks. The newly loaded disk will be placed onto the Chamber Door for implantation and the implanted disk placed onto a cooling pedestal for unloading and reloading with additional wafers.

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Disk Designs for the NV10

Innovion has an extensive inventory of disks to meet the specialized requirements of its customers. Innovion provides size capability ranging from 2 to 6 inch wafers. There are four major designs. Three types designed by Axcelis are: 1) Full Ring Clamp, 2) 2 Point Clamp, and 3) Clampless. A fourth, engineered by Innovion in direct response to the specific needs of a market segment, is the Converted Disk.

In the more heavily utilized disk designs, Innovion provides both 0 degree tilt and 7 degree tilt capability. Other tilts are possible but require discussion with Innovion Engineering.

These disks come into direct contact with the product wafers. As such they deserve and receive care necessary to maintain them in pristine condition. To this end, these disks are stored in a horizontal laminar flow.

Figure 2 The Eaton NV10 Disk Storage – Horizontal Laminar Flow Cabinet to protect the disks and to keep them clean

The Full Ring Clamp Disk and the Underlying Concepts of Disk Design

The Full Ring Clamp Disk (Innovion commonly calls this the Standard Wheel) is the original disk design for use on the NV10. It met the key design goal of delivering uniform heat transfer from the wafer through the back of the wafer. This design feature limits the increase in wafer temperature with the higher implant doses and energies, thereby preserving the integrity of the photoresist on the wafers.

Heat transfer is proportional to the degree of contact between the disk and the wafer back surface. While direct wafer contact to metal is theoretically ideal for thermal conduction, in practice wafers are not flat enough to form good thermal contact with the pedestal. Wafer fabrication causes varying degrees of warpage throughout the process. Even if the wafer is completely flat, the metal surface of the disk has, on a microscopic basis, ridges and valleys resulting from the machining process. Additionally, wafer back surface roughness is often times engineered intentionally to facilitate backside defect gettering. Even when the wafer backside is not designed for gettering, that surface continues to be rough. Thus, the combination of the microscopically rough metal and silicon surfaces in contact with each other results in minimal contact surface area for thermal transfer.

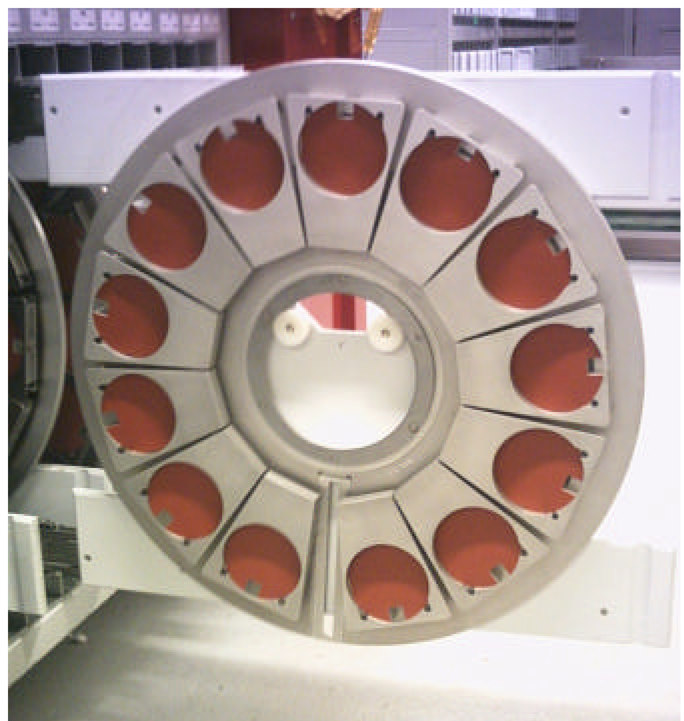

Figure 3 A 4 Inch Full Ring Clamp Disk

The commercial implanter manufacturers resolved this problem by casting a thin layer of elastomer on the metal surfaces of the disk pads where the wafers are loaded. The elastomer chosen by Eaton was an iron oxide filled RTV (Room Temperature Vulcanized Silicone Rubber). The iron oxide both enhances the heat transfer characteristics of the elastomer and imparts a red color to the polymer, hence the term “Red Elastomer”. Once a wafer is loaded onto this Red Elastomer and pressed down onto it, the elastomer becomes a thin film sandwiched between the metal and the silicon. This elastomer deforms to conform to the microscopic peaks and valleys of both the metal and silicon, vastly increasing the surface area for heat transfer between the metal and the silicon.

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The wafer is pressed against the elastomer by 2 mechanisms: 1) The Full Ring clamp gently applies force along the entire circumference of the wafer and 2) the centrifugal force resulting from the disk rotation at 953 rpm and the wafer tilt at 7 degrees.

Eaton designed this wafer pad with a slight spherically convex curvature (approximately 2 degrees of curvature) in all directions. When a wafer is first loaded onto the wafer pad, this curvature results in the center of the wafer contacting the elastomer and the wafer edges floating slightly above the elastomer. Mechanically, silicon bends slightly. When the Full Ring clamp pushes against the wafer edge, the wafer bends to conform to the shape of the wafer pad. This combination of shape, force, mechanical strength and flexibility results in uniform force across the entire back surface of the wafer against the elastomer. This leads to uniform levels of conformance of the elastomer into the peaks and valleys of the rough wafer backside, in turn leading to uniform heat transfer from the wafer to the elastomer and the underlying metal.

The second mechanism that works to improve elastomer conformality to the wafer is the rotation of the disk at 953 rpm. The wafer pedestal is tilted 7 degrees from the plane of the disk and towards the central hub of the disk. The centrifugal force due to the 7 degree tilt and the rotation forces 1) the clamp down against the wafer and 2) the wafer against the elastomer. This combination of mechanisms allows sufficient heat transfer between the wafer and the disk such that Eaton specifies the system to allow 800 watts of beam power. Innovion in working with its customers and the variety of resist processing uses a beam power limit of 600 watts. This limit provides a process that is sufficient for meeting the needs of the vast majority of our customers. Some resists and resist processing are more sensitive and may require lower beam currents to prevent heat damage to the resist.

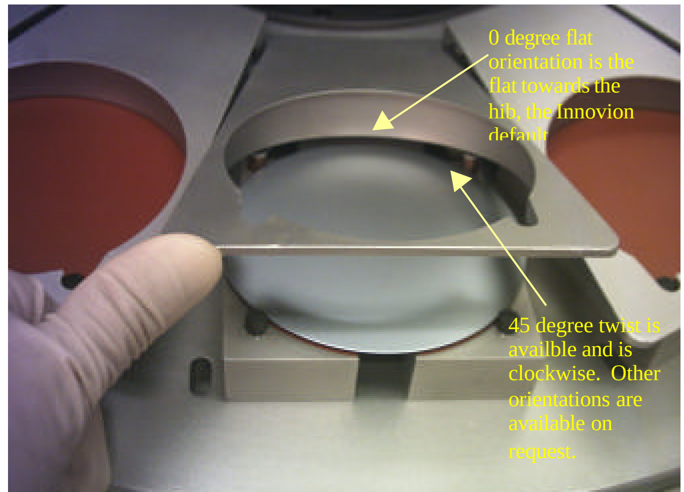

Figure 4 The Full Ring Clamp on a 4 inch disk.

When loaded onto the wafer pad, the wafer is centered under the clamp by four pins. The Full Ring clamp will occlude 4mm of wafer edge from the ion beam on a wafer centered under the clamp. However, due to the allowed tolerance in the wafer diameters (indiscernable to the naked eye), the centering pins are spaced to center a wafer with the maximum wafer diameter. Thus, on a wafer with the minimum wafer diameter, there can be misalignment of the wafer to the clamp, resulting in more occlusion on one edge than the opposite edge.

Ion implantation is performed at multiple steps throughout the wafer fabrication process. Due to the processing of the wafers at elevated temperatures and with a variety of deposited and grown thin films, the wafers can become warped. The level and direction of the warpage depends on the prior history of the wafer. Each process technology presents a different mix of process temperatures and films, hence, the level of warpage and its impact on wafer temperature during implant will be dependent on the customer's process technology. The Full Ring clamp with its mixture of force and elastomer shape is able to transcend the warpage and establish good contact across the wafer backside in spite of the warpage.

One final consideration in the use of high current implanters is neutralization of accumulated surface charge. In the case of the Full Ring clamp, when the ion beam strikes the clamp, secondary electrons are generated. These electrons are attracted to the accumulated positive charge from the ions, neutralizing them. This mechanism is effective for charge neutralization for wafer sizes up to 4 inch. Secondary Electron Flood Gun operation is recommended for larger wafer sizes.

The pedestal and clamp of a 4 inch Full Ring Clamp Disk is shown in Figure 4. The clamp is lifted up to allow the wafer to be inserted onto the pedestal under the clamp. The wafers are handled using vacuum wands. As some customer product does not allow the use of vacuum wands, the use of tweezers is available on request.

The operator will load the wafer with the flat towards the hub unless otherwise instructed. This is defined as 0 degree orientation. This Innovion default flat orientation on NV10 implanters is applied across all of the disk designs. Other orientations are available on request. Innovion uses a clockwise convention for flat orientation as indicated in Figure 4.

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The 2 Point Clamp Disk

The NV10 with the Full Ring Clamp Disk provided a tremendous productivity improvement for ion implantation. Prior to the introduction of this implanter onto the marketplace, high dose implantation was performed on single wafer implanters, those that are currently dedicated to medium current doses. However, the Full Ring Clamp resulted in loss of die yield due to the shadowing of the implant by the Clamp Ring. Process concerns were also raised over the potential for sputtering of the clamp ring material by the ion beam onto the underlying wafer.

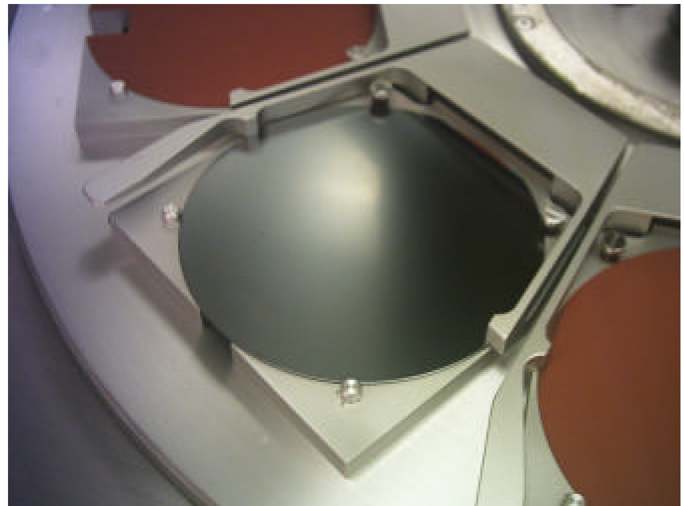

Figure 5 The 2 Point Clamp on a 5 inch disk

To address those concerns, the 2 Point Clamp Disk was designed. The clamp contacts the wafer only on 2 opposing sides, greatly reducing the area of clamp contact to the front of the wafer compared to the Full Ring Clamp. Since the wafer is held against the elastomer by just the 2 fingers of the clamp, the implant shadow is limited to the 2 small areas of the clamp fingers.

Where the Full Ring Clamp Disk has a spherical section as the surface of the elastomer, the 2 Point Clamp has a cylindrical section for its elastomer surface. Due to this surface shape the 2 Point Clamp is unable to apply as uniform a force across the wafer backside against the elastomer. Therefore, the manufacturer's original specification is for a beam power of 600 watts. Innovion has determined that a 400 watt limit meets the needs of the bulk of its customers using the 2 Point Clamp disks. In all other respects the 2 Point Clamp Disk is the same as the Full Ring Clamp Disk.

The Clampless Disk

The gain in wafer area for improved die yield proved to be a strong benefit for using the 2 Point Clamp Disk. However, IC manufacturers continued to press for eliminating all contact to the front surface of the wafer. Moreover, the reduction in the Beam Power Limit reduced the productivity of the NV10. Additionally, though no yield loss had been directly attributed to the iron oxide fill of the Red Elastomer, it was designed out of the future generation of disks.

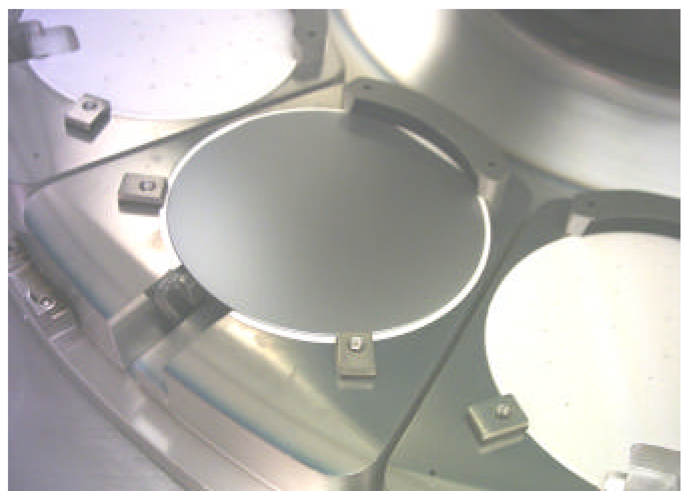

Figure 6 The Clampless pedestal on a 4 inch disk

Eaton addressed these requirements in the Clampless Disk, and as the name suggests it functions without a clamp to hold the wafer. Without a clamp to hold the wafer against the elastomer, centrifugal force became the lone mechanism for forcing the wafer backside against the elastomer. Without a clamp to force the wafer to conform to a curved elastomer surface, the elastomer surface became flat.

The iron oxide's role in heat transfer is now satisfied by silicone oil. The elastomer lost it's reddish color and became white, leading to the name "White Elastomer". The manufacturers of the Clampless Disk have specified the disk for a maximum beam power limit of 1600 watts. Innovion has adopted a limit of 800 watts to address the needs of its broad spectrum of clients.

The silicone oil also serves to enhance the conformality of the elastomer to the microscopic roughness of the wafer backside. The White Elastomer was developed to be slightly adhesive so that once the wafer has been pulled down onto the elastomer surface, the elastomer would continue to adhere to the wafer until the wafer is removed. The silicone oil is key to this feature. Hence, the silicone oil serves 1) to enhance the thermal conductivity of the elastomer and 2) to enhance the conformality of the elastomer to the microscopic roughness of the wafer backside for increased heat transfer surface area.

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The wafers are first loaded onto the disk with a vacuum wand. The wafers are then pulled down onto the elastomer using a special appliance designed expressly for this function. This tool applies a vacuum to the back of the wafer via passages inside the Clampless Pedestal and through tiny holes in the elastomer (can be seen on the elastomer of the pedestal in upper left hand corner of Figure 6). At the end of the implant, this same tool applies gentle nitrogen pressure through the same passages and openings, easing the wafer off of the elastomer, hence the name "Suck and Puff Wand". The wafer is then removed with a vacuum wand.[a]

The clamps of the two earlier disk designs also served to hold the wafers onto the disk when the disk was brought to the vertical orientation for implantation, preventing the wafers from falling off. To serve this same function, a finger was added to push the wafer by the edge against a rail. This finger retracts with the rotation of the disk to 953 rpm, at which point centrifugal force holds the wafer in place. Moreover, the adhesive nature of the elastomer also serves to hold the wafer on the pedestal and prevent it from falling off.

The combination of centrifugal force and tacky elastomer will overcome most of the typical wafer warpage problems. However, more severe levels of wafer warpage cannot be overcome and can lead to some heat damage to localized resist.

Note that the White Elastomer can leave low levels of silicone oil residue on the back of the wafers. This is easily cleaned off of the wafer using a hot sulfuric peroxide clean. The typical cleaning processes used to remove resist or at a diffusion step utilize this cleaning solution. Some care needs to be taken in the integration of this type of disk into the process flow. More discussion on this point can be found in "Applications Note, Notes on the Processing of Photoresist for Ion Implantation Applications".

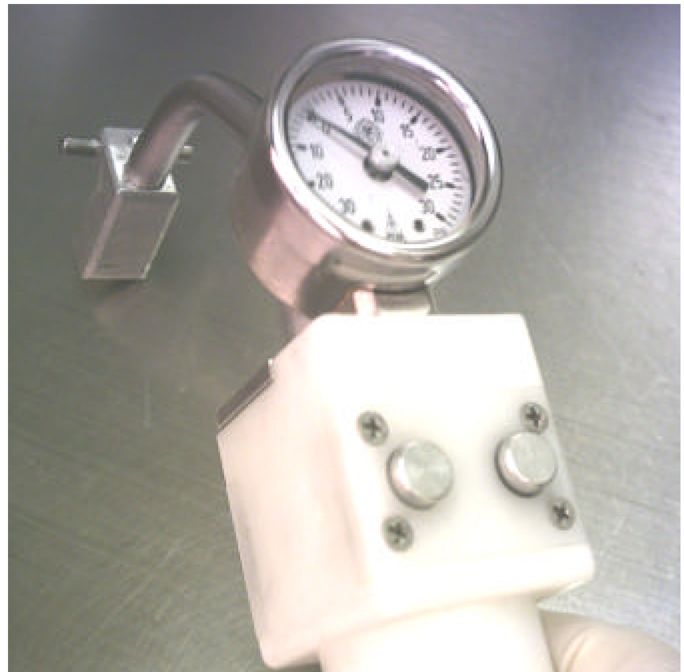

Figure 7 Suck and Puff Wand used with Clampless Disks – One button applies vacuum to the wand tip and the other applies nitrogen. The gauge measures both vacuum and pressure.

The Converted Disk

The converted disk was developed by Innovion to address the problems of those Innovion customers with more fragile wafers. This includes thin wafers and MEMS type wafers with cavities. These devices cannot withstand the bending associated with the Full Ring Clamp or 2 Point Clamp Disks. Nor can they withstand the puffing process attendant to unloading of the Clampless Disks.

The converted disk has all the same features as the Full Ring Clamp Disk except that the elastomer surface is flat instead of convex with a spherical section shape. Due to the clamping at the wafer circumference and the flat surface of the elastomer, the backside force against the elastomer is non-uniform. Therefore, Innovion has implemented a beam power limit of 300 watts to offset the potential for resist burning associated with hot spots.

Conclusion

Innovion meets the needs of the semiconductor industry with the broadest selection of commercially available disks for the NV10 implanter. Additionally, Innovion is able to provide innovative designs for specialty applications. From 2 inch to 6 inch wafers, Innovion is able to address the implant requirements of technologies ranging over standard silicon ICs, thin wafers, MEMS, and power devices. Innovion works with our customers to select the implant technology best suited to their needs. On the NV10 implanters, Innovion will work with you to identify key process parameters for the selection of the disk most suitable for your application.

[a] On customer specification, Innovion will also use tweezers for those applications that cannot withstand handling with vacuum wands. For example, wafers with cavities or thin wafers cannot be handled with vacuum wands. The pressure difference across the wafer may rupture the thin membranes of the cavities or thin silicon wafer.

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Appendix A
NV10 Disks used at Innovion

Property	Full Ring Clamp	2 Point Clamp	Clampless	Converted
Description	The wafer is held against an elastomer coated pedestal with a surface that is a spherical section of +/-2 degrees in each direction. The clamp applies force around the entire circumference of the wafer. With the spherical shape of the pedestal, this results in uniform force of the wafer backside against the elastomer. The elastomer conforms to the rough surface of the wafer backside, facilitating heat transfer to the elastomer. The clamp ring occludes roughly a 4mm edge of the wafer from implantation. This exclusionary area is not concentric to the wafer.	The wafer is held against an elastomer coated pedestal with a surface that is a cylindrical section of +/-2 degrees in the direction perpendicular to the radius of the disk. (The axis of the cylinder is roughly co-linear with the radius of the disk.) The clamp has 2 fingers that are roughly 2 mm wide that holds down 2 opposing edges of the wafer against the pedestal. If the flat is pointed to the hub of the disk, then the clamp holds the left and right edges of the wafer against the pedestal. This design minimizes the area that is occluded from the beam. It also minimizes the sputtering of the clamp material onto the wafer surface by the ions of the beam.	The wafer is held against the elastomer coated pedestal that has a flat surface. The rotation of the disk at 953 rpm combined with the 7 degree tilt of the pedestal results in a force that holds the wafer against the pedestal. The wafers are loaded onto the disk in a horizontal position. The disk is tilted up vertically for the implantation. The elastomer is formulated to be slightly tacky in order to hold onto the wafer while the disk is being tilted up and before the rotation begins. The pedestal has a distribution of holes for sucking the wafer against the elastomer during the loading operation. This causes the elastomer to come into close conformity with the wafer. During the unload operation, nitrogen is puffed through these same holes to puff these wafers off of the elastomer. There is no edge occlusion from the ion beam. This design minimizes the sputtering of metals onto the wafer surface.	Innovion Design This is similar to the Full Ring Clamp except that the pedestal surface is flat. The force of the wafer backside against the elastomer is reduced, thereby reducing the heat transfer characteristics of this design. See Disk Beam Power Limit. This design is available for both 4 inch and 6 inch wafers.

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Property	Full Ring Clamp	2 Point Clamp	Clampless	Converted
Historical Introduction Design Criteria	 Original design ~ 1980 Part of the original design. Focus was on heat transfer to prevent overheating of resist.	 Introduced ~ 1984. Designed in response to concerns for 1) lost silicon area due to the edge exclusion and 2) sputtered aluminum from the clamp structure of the Full Ring Clamp Disk.	 Introduced ~ 1988. Designed in response to lost productivity from the 2 Point Clamp Disk.	 Introduced ~ 1984. Innovion development for those customers with more fragile wafers such as thin wafers and wafers with cavities. The wafer contact surface is flat to avoid mechanical strain on the wafer.
Elastomer	Red[b]	Red	White[c]	Red
Flood Optional Required[d] Innovion Default[e]	 5 inch and smaller wafers. 6 inch wafers for high doses. Flood on.	 4 inch and smaller wafers. 5 and 6 inch wafers for high doses. Flood on.	 N/A All wafer sizes for high doses. Flood on.	 5 inch and smaller wafers. 6 inch wafers for high doses. Flood on.
Disk Beam Power Limit[f] OEM Spec Innovion default[g]	 800 watts of beam power. 600 watts for the typical resist process.	 600 watts of beam power. 400 watts for the typical resist process.	 1600 watts of beam power. 800 watts for the typical resist process.	 N/A 300 watts for the typical resist process.
Tilt[h] Default 0 Degree[i] Other tilts[j] Comment	 7 degrees. Call for availability. Call for discussion. The spherical section of the pedestal adds variation to the implant angle depending on the location on the wafer.	 7 degrees. Call for availability. Call for discussion. The cylindrical section of the pedestal adds variation to the implant angle depending on the location on the wafer.	 7 degree tilt is a requirement for Clampless disks. Not currently available. Call for discussion. Call for discussion. All locations on the wafer receive the same implant angle.	 7 degrees. None currently available. Call for discussion. Call for discussion. All locations on the wafer receive the same implant angle.

[b] This is an iron oxide filled RTV. This formulation promotes 1) good elastomer conformality to the wafer backside to maximize thermal transfer from the wafer to the elastomer and 2) good thermal conductivity from the wafer contact surface to the metal of the disk.

[c] This was developed in response to the need for an elastomer that would hold onto the wafer until the disk is brought up to speed, at which time centrifugal force would hold the wafers onto the disk. Additionally, this met the concern regarding the iron oxide fill of the Red elastomer. The iron oxide filler is replaced by a silicone oil. This silicone oil has been observed to leave a “waffle” pattern on the back of the wafers. This pattern is due to a trace level of silicone oil transferred from the elastomer to the wafer. This is easily cleaned off of the wafer by the hot sulfuric cleans that are typical for post implant stripping of resist or the pre-clean for a furnace operation.

[d] Electron flood is not necessary for the typical application with doses less than 1e14. For these doses Innovion defaults to Flood Gun off.

[e] Innovion defaults to a setting of 10 times the beam current with a 5mA minimum.

[f] Beam Power is defined as the product of the beam energy and beam current. An 80KeV beam with current of 5mA has a beam power of 400 watts.

[g] The Innovion Default for beam power will protect the typical process from resist burning and/or cracking. Some resist processing will require that the beam power be lower. Innovion applies this limit unless the customer specifies that there is no resist on the wafers.

[h] This is defined as the edge of the wafer furthest from the hub of the disk tilting upward from the disk (or towards the beam).

[i] This is available for a variety of wafer sizes and applications. Innovion has developed other tilt capabilities based upon customer requirement.

[j] Innovion can work with customers to develop specialized tooling.

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Property	Full Ring Clamp	2 Point Clamp	Clampless	Converted
Orientation (Twist)[k]				
Default	0 degree.	0 degree.	0 degree.	0 degree.
Other orientations[l]	Available on request.	Available on request with certain limitations.	Available on request.	Available on request with certain limitations.

[k] The flat orientation with the flat closest to the hub of the disk is defined as zero degree orientation. Positive twist is defined as clockwise from the loading operators perspective.

[l] There are no indicators for orientations other than 0. The repeatability is subject to operator judgement. Specialized fixtures can be developed to enhance the reproduction of orientations other than 0, call for discussion.

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