(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 806 267 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
12.11.1997 Bulletin 1997/46

(51) Int Cl.[6]: **B24B 37/04**

(21) Application number: **97302999.4**

(22) Date of filing: **01.05.1997**

(84) Designated Contracting States:
AT BE CH DE ES FR GB GR IE IT LI NL SE

(30) Priority: **02.05.1996 US 643054**

(71) Applicant: **APPLIED MATERIALS, INC.**
Santa Clara, California 95054-3299 (US)

(72) Inventors:
- **Cheng, Tsungnan**
Saratoga, California 95070 (US)
- **Tolles, Robert D.**
Santa Clara, California 95070 (US)

(74) Representative: **Bayliss, Geoffrey Cyril et al**
BOULT WADE TENNANT,
27 Furnival Street
London EC4A 1PQ (GB)

(54) **Cross-hatched polishing pad for polishing substrates in a chemical mechanical polishing system**

(57) A chemical mechanical polishing apparatus (30) including a platen (42) having a polishing surface (44) having a plurality of grooves (330,302) defining a plurality of polygonal projections (330). The grooves are uniformly spaced over the entire area of the polishing surface. A carrier head holds the substrate against the polishing surface.

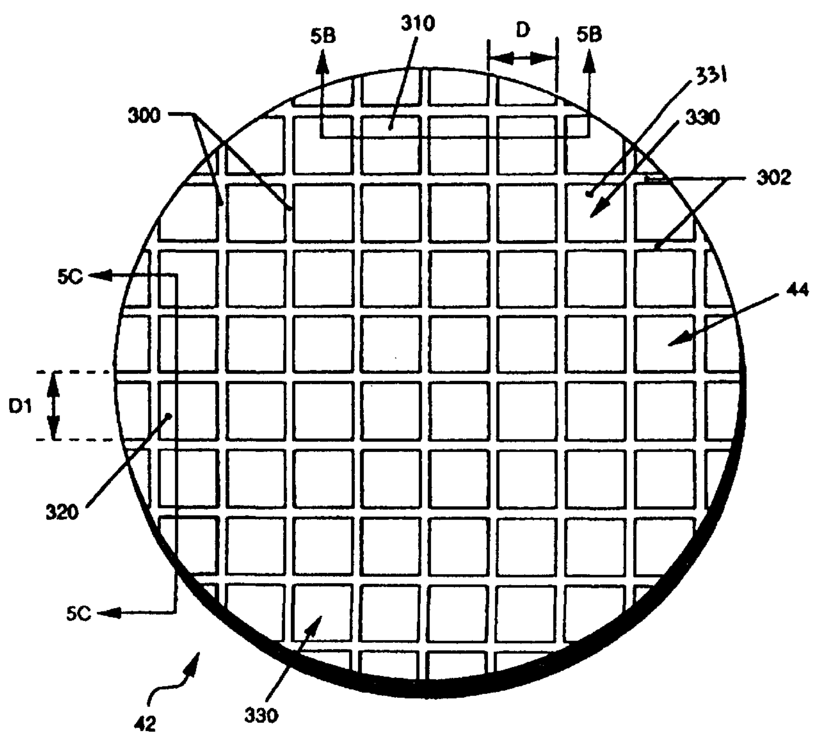

FIGURE 5A

EP 0 806 267 A1

Description

The invention relates to chemical mechanical polishing of substrates, and more particularly to a polishing pad having a cross-hatched groove pattern for polishing a substrate in a chemical mechanical polishing system.

Integrated circuits are typically formed on substrates, particularly silicon wafers, by the sequential deposition of conductive, semiconductive or insulative layers. After each layer is deposited, the layer is etched to create circuitry features. As a series of layers is sequentially deposited and etched, the outer or uppermost surface of the substrate, i.e., the exposed surface of the substrate, becomes increasingly more non-planar. This occurs because the distance between the outer surface and the underlying substrate is greatest in regions of the substrate where the least etching has occurred, and least in regions where the most etching has occurred. With a single patterned layer, this non-planar surface comprises a series of peaks and valleys wherein the distance between the highest peak and lowest valley may be on the order of 7000 to 10,000 Angstroms. With multiple patterned layers, the height differences between the peaks and valleys become even more severe, and can reach several microns.

FIGS. 1A-1E illustrate the process of depositing a layer onto a planar surface of a substrate. As shown in FIG. 1A, a substrate 10 might be processed by coating a circular, flat, silicon wafer 12 with a metal layer 14, such as aluminum. Then, as shown in FIG. 1B, a layer of photoresist 16 may be placed on metal layer 14. Photoresist layer 16 can then be exposed to a light image, as discussed in more detail below, to produce a patterned photoresist layer 16' shown in FIG. 1C. As shown in FIG. 1D, after the patterned photoresist layer is created, the exposed portions of metal layer 14 are etched to create metal islands 14'. Finally, as shown in FIG. 1E, the remaining photoresist is removed.

FIGS. 2A-2B illustrate the deposition of subsequent layers on a substrate. As shown in FIG. 2A, an insulative layer 20, such as silicon dioxide, may be deposited over metal islands 14'. The outer surface 22 of insulative layer 20 almost exactly replicates the underlying structures of the metal islands, creating a series of peaks and valleys so that outer surface 22 is non-planar. An even more complicated outer surface would be generated by depositing and etching multiple layers on an underlying patterned layer.

This non-planar outer surface presents a problem for the integrated circuit manufacturer. If, as shown in FIG. 2B, outer surface 22 of substrate 10 is non-planar, then a photoresist layer 25 placed thereon is also non-planar. A photoresist layer is typically patterned by a photolithographic apparatus that focuses a light image onto the photoresist. Such an imaging apparatus typically has a depth of focus of about 0.2 to 0.4 microns for sub-half-micron sized features. If photoresist layer 25 is sufficiently non-planar, i.e., if the maximum height difference h between a peak and valley of outer surface 22 is greater than the depth of focus of the imaging apparatus, then it will be impossible to properly focus the light image onto the entire outer surface 22. Even if the imaging apparatus can accommodate the non-planarity created by a single underlying patterned layer, after the deposition of a sufficient number of patterned layers, the maximum height difference will probably exceed the depth of focus.

It may be prohibitively expensive to design new photolithographic devices having an improved depth of focus. In addition, as the feature size used in integrated circuits becomes smaller, shorter wavelengths of light must be used, resulting in further reduction of the available depth of focus.

Therefore, there is a need to periodically planarize the substrate surface to provide a planar layer surface. As shown in FIG. 2C, planarization polishes away a non-planar outer surface, whether a conductive, semiconductive, or insulative layer, to form a relatively flat, smooth outer surface 22. As such, a photolithographic apparatus can be properly focused. Following planarizaticn, additional layers may be deposited on the outer layer to form interconnect lines between features, or the outer layer may be etched to form vias to lower features. Planarization may be performed only when necessary to prevent the peak-to-valley difference from exceeding the depth of focus, or it may be performed each time a new layer is deposited over a patterned layer.

Chemical mechanical polishing is one accepted method of planarization. This planarization method typically requires that the substrate be mounted on a carrier or polishing head. The exposed surface of the substrate is then placed against a rotating polishing pad. The carrier head provides a controllable load, i.e., pressure, on the substrate to push it against the polishing pad. In addition, the carrier head may rotate to provide additional motion between the substrate and polishing surface. A polishing slurry, including an abrasive and at least one chemically-reactive agent, is spread on the polishing pad to provide an abrasive chemical solution at the interface between the pad and substrate.

Chemical mechanical polishing is a fairly complex process, and differs from simple wet sanding. In a polishing process, a reactive agent in the slurry reacts with outer surface 22 (FIG. 2B) of top layer 20 and with the abrasive particles to form reactive sites. The interaction of the polishing pad, abrasive particles and reactive agent with the outer substrate layer results in polishing.

Factors that determine throughput in the chemical mechanical polishing process are: the desired finish (roughness) and flatness (lack of large scale topography) of the substrate surface after polishing, and the polishing rate. The pad and slurry combination, the relative speed between the substrate and pad, and the force pressing the pad against the substrate determine the polishing rate, finish and flatness. The polishing rate sets the time needed to polish a layer. Because inadequate flatness and finish can create defective substrates, the selection of a polishing pad and slurry combination is usually dictated by the required finish and flatness. Given these constraints, the polishing time needed to achieve the required finish and flatness sets the maximum throughput of the polishing apparatus.

Problems inherent to the chemical mechanical polishing process can limit the overall effectiveness of the polishing process and substrate yields. One such problem is referred to as the "edge effect" and relates to the amount of surface area of the substrate which becomes unusable due to the polishing process. The edge effect describes the portion about the periphery of the substrate which becomes unusable due to excessive polishing. It occurs due to discontinuities in the compressibility of the polishing pad over the surface of the substrate, resulting in non-uniform removal (polishing) across the substrate. Non-uniform removal describes the condition where portions of the substrate are polished at different removal rates. For example, the portion about the periphery of the substrate experiences excessive polishing (over polishing) as compared to other regions on the substrate surface due to the compressibility of the polishing pad. Typically, for a 200mm substrate, 10mm of over polished region is generated about the periphery of the substrate.

Another problem limiting the effectiveness of the chemical mechanical polishing process relates to slurry distribution. As was indicated above, the chemical mechanical polishing process is fairly complex, requiring the interaction of the polishing pad, abrasive particles and reactive agent with the substrate to obtain the desired polishing results. Accordingly, ineffective distribution of the slurry about the surface of the polishing pad will result in less than optimal polishing results. In the past, slurry distribution was accomplished by perforations provided in the polishing pad. Specifically, prior art polishing pads included perforations about the pad, which, when filled, would distribute slurry in their respective local region as the polishing pad was compressed. This method of slurry distribution has limited effectiveness because each perforation acts independently. Thus, some of the perforations may have too little slurry, while others have too much slurry.

Furthermore, there is no way in these prior art structures to directly channel the excess slurry to where it is needed.

Another related problem is waste removal. Polishing pads wear after use, causing "glazing". Glazing occurs when the polishing pad is heated and compressed in regions where the substrate is pressed against it. The peaks of the polishing pad are pressed down and the pits of the polishing pad are filled up, so the surface of the polishing pad becomes glazed (smoother and less abrasive). As a result, the polishing time required to polish a substrate increases. Therefore, the polishing pad surface must be periodically returned to an abrasive condition, or "conditioned", to maintain a high throughput. During the conditioning process, waste materials associated with abrading the surface of the pad may fill or clog the perforations in the prior art polishing pads. Filled or clogged perforations can not hold (and subsequently distribute) slurry, thereby reducing the effectiveness of the polishing process.

Yet another problem associated with filled or clogged perforations relates to the separation of the polishing pad from the substrate surface after polishing has been completed. The polishing process results in a high degree of surface tension between the polishing pad surface and the substrate being polished. In addition to slurry distribution, the perforations minimize the surface tension by reducing the contact area between the polishing pad and the substrate. Accordingly, as the perforations become filled or clogged with waste materials, the surface tension increases, making it more difficult to separate the polishing pad and the substrate, and may result in damage to the substrate during the separation process.

Another problem limiting the effectiveness of the chemical mechanical polishing process is referred to as the "planarizing effect". The "planarizing effect" refers to the simultaneous polishing of peaks and valleys in the topography of the substrate. Ideally, a polishing pad only polishes peaks, which after an predefined amount of polishing will eventually be level with the valleys, resulting in a planar surface. When both the peaks and valleys of the substrate are polished, no effective change in the topography of the substrate occurs. The "planarizing effect" results from the compressible nature of the polishing pad in response to point loading. Accordingly, systems to minimize the "planarizing effect" have been used, including methods for more evenly distributing the load on the polishing pad.

Finally, another problem limiting the effectiveness of the chemical mechanical polishing process is referred to as the "center slow effect". It has been observed that portions of the substrate are polished faster than others in the chemical mechanical polishing process. Specifically, the center portion of the substrate typically takes a longer time to achieve the same levels of flatness and finish as the outer portions, hence the use of the term "center slow effect". The dissimilarity in the time required to effectively polish different areas on a substrate may be due to the ineffective distribution of slurry in these regions, or the non-uniformity of the polishing pad surface. In the past, a back pressure was applied to the wafer, causing the wafer to bow with its center toward the polishing pad to help minimize this problem. Unfortunately, the back pressure solution has lead to inconsistent results.

In view of the foregoing, there is a need for a chemical mechanical polishing apparatus which optimizes polishing throughput, flatness, finish, slurry distribution, and waste disposal while minimizing edge effect, planarizing effect, surface tension build-up, and center slow effect conditions.

In general, in one aspect, the invention features a chemical mechanical polishing apparatus. The apparatus includes a platen having a polishing surface including a plurality of grooves defining a plurality of polygonal projections. The grooves are uniformly spaced over the entire area of the polishing surface. A carrier head holds the substrate against the polishing surface.

Embodiments of the invention include the following features. The plurality of grooves comprises a first plurality of parallel grooves and a second plurality of parallel grooves intersecting the first plurality of parallel grooves. The first plurality of parallel grooves is perpendicular to the second plurality of parallel grooves. The grooves in the first and second plurality of parallel grooves are between about 0.015 and 0.50 inches wide, and spaced between about 0.040 and 0.175 inches apart, e.g. approximately 0.018 inches wide, and spaced approximately every 0.060 inches. The grooves have a substantially square cross-section. The grooves in the first and second plurality of parallel grooves are between about 0.015 and 0.50 inches deep, e.g. approximately 0.025 inches deep. The plurality of grooves account for between about 30 to 75 percent of a total surface area of the polishing surface, e.g. approximately 50 percent of the total surface area of the polishing surface. The polishing surface is polyurethane. The chemical, mechanical polishing apparatus includes a feed line for distributing slurry to the polishing surface.

In another aspect of the invention, an apparatus for for polishing a substrate includes a platen having an upper surface, a rotatable drive shaft connected to the platen, a drive motor to rotate the platen and a polishing pad attached to the upper surface of the platen. The polishing pad including an upper surface having a plurality of grooves defining a plurality of polygonal projections. The grooves are uniformly spaced over the entire area of the polishing surface.

Embodiments of the invention include the following features. The plurality of grooves includes a first plurality of parallel grooves and a second plurality of parallel grooves intersecting the first plurality of parallel grooves. The first plurality of parallel grooves is perpendicular to the second plurality of parallel grooves. The grooves in the first and second plurality of parallel grooves are between about 0.015 and 0.50 inches wide, and spaced between about 0.040 and 0.175 inches apart, e.g. approximately 0.018 inches wide, and spaced approximately every 0.060 inches. The grooves in the first and second plurality of parallel grooves are between about 0.015 and 0.50 inches deep, e.g. approximately 0.025 inches deep. The plurality of grooves account for between about 30 to 75 percent of a total surface area of the polishing surface, e.g. approximately 50 percent of the total surface area of the polishing surface. The grooves have a substantially rectangular cross-section.

In another aspect of the invention, an apparatus for polishing a substrate in a chemical mechanical polishing system includes a platen having an upper surface and a polishing pad attached to the upper surface of the platen. The polishing pad including an upper polishing surface having a plurality of grooves defining a plurality of polygonal projections. The grooves are uniformly spaced over the entire area of the polishing surface.

In another aspect of the invention, an apparatus for polishing a substrate in a chemical mechanical polishing system includes a polishing pad having an upper polishing surface including a plurality of grooves defining a plurality of polygonal projections. The plurality of grooves include a first plurality of grooves and a second plurality of grooves intersecting the first plurality of parallel grooves. The grooves in the first and second plurality of grooves are uniformly spaced over the entire area of the polishing surface.

Embodiments of the invention include the following features. Grooves in the first plurality of grooves are substantially parallel. Grooves in the second plurality of grooves are substantially parallel. The first plurality of grooves are generally perpendicular to the second plurality of grooves.

In another aspect of the invention, an apparatus for polishing a substrate includes a platen having a polishing surface including a first plurality of polygonal projections, a second plurality of polygonal projections and a groove region disposed therebetween. The first plurality of polygonal projections are located at a first radius on the polishing surface to contact an edge portion of the substrate during a polishing process. The second plurality of polygonal projections are located at a second radius on the polishing surface and are not in contact with the substrate during the polishing process. The first radius is less than the second radius. The grooved region allowing the first plurality of polygonal projections to act substantially independently from the second plurality of grooved regions such that over polishing at the edge portion of the substrate is reduced. A carrier head is included for holding the substrate against said polishing surface.

In another aspect of the invention, an apparatus for polishing a substrate includes a platen having a polishing surface including a plurality of polygonal projections uniformly spaced about a periphery of the polishing surface for interfacing with an edge portion of the substrate during polishing thereof and a carrier head for holding the substrate against the polishing surface.

Advantages of the invention include the following. The plurality of grooves in the polishing pad surface result in a minimal area which is overpolished at the periphery of the substrate. In addition slurry distribution and waste removal are augmented by the groove structure. Further, improvements in the planarizing and center slow characteristics for the chemical mechanical polishing device can be realized. The plurality of grooves in the polishing pad surface also result in a minimal surface tension build up between the polishing pad and the substrate to facilitate separation between the two.

Other advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The advantages of the invention may be realized by means of the instrumentalities and combinations particularly pointed out in the claims.

The accompanying drawings, which are incorporated in and constitute a part of the specification, schematically illustrate embodiments of the present invention, and together with the general description given above and the detailed description given below, serve to explain the principles of the invention.

FIGS. 1A-1E are schematic diagrams illustrating the deposition and etching of a layer on a substrate.

FIGS. 2A-2C are schematic diagrams illustrating the polishing of a non-planar outer surface of a substrate.

FIG. 3 is an schematic exploded perspective view of a chemical mechanical polishing apparatus.

FIG. 4 is a schematic cross-sectional view of a carrier head.

FIG. 5A is a schematic top view of a polishing pad in accordance with the present invention.

FIG. 5B is a cross-sectional view along line 5B-5B of the polishing pad of FIG. 5A.

FIG. 5C is a cross-sectional view along line 5C-5C of the polishing pad of FIG. 5A.

FIG. 6 is an enlarged schematic cross-sectional view of a portion of the carrier head including a substrate engaging a polishing pad during the polishing process in accordance with the present invention.

As shown in FIG. 3, a chemical mechanical polishing (CMP) apparatus 30 according to the present invention includes a lower machine base 32 with a table top 33 mounted thereon and a removable upper outer cover (not shown). Table top 33 supports a series of polishing stations 35a, 35b and 35c, and a transfer station 37. Transfer station 37 forms a generally square arrangement with polishing stations 35a, 35b and 35c. Transfer station 37 serves multiple functions, including receiving individual substrates 10 from a loading apparatus (not shown), washing the substrates, loading the substrates into carrier heads (to be described below), receiving the substrates from the carrier heads, washing the substrates again, and finally transferring the substrates back to the loading apparatus. A substrate is moved between the three polishing stations generally in order from 35a to 35c. Each polishing station is independently controllable by the user, allowing for any combination or sequence of polishing activities. The speed, duration and the intensity of the polishing may vary over the three polishing stations. In one embodiment, the first polishing station (i.e. polishing station 35a) performs a "primary" polish. Each subsequent polishing station further refines the primary polish performed at the first station. Finally, the third polishing station (i.e. polishing station 35c) performs a buffing operation.

Each polishing station 35a-3Sc includes a rotatable platen 40 having a polishing pad 42. A slurry 50 containing a reactive agent (e.g., deionized water for oxide polishing), abrasive particles (e.g., silicon dioxide for oxide polishing) and a chemically-reactive catalyzer (e.g., potassium hydroxide for oxide polishing) is supplied to the surface of polishing pad 42 by a slurry supply tube 52. Sufficient slurry is provided to cover and wet the entire polishing pad 42. Two or more intermediate washing stations 55a and 55b may be positioned between neighboring polishing stations 35a, 35b and 35c, and transfer station 37. The washing stations rinse the substrates as they pass from one polishing station to another.

A rotatable multi-head carousel 60 is positioned above lower machine base 32. Carousel 60 is supported by a center post 62 and rotated thereon about a carousel axis 64 by a carousel motor assembly (not shown) located within base 32. Center post 62 supports a carousel support plate 66 and a cover 68. Multi-head carousel 60 includes four carrier head systems 70a, 70b, 70c, and 70d. Three of the carrier head systems receive and hold a substrate, and polish it by pressing it against polishing pad 42 on platen 40 of polishing stations 35a-35c. One of the carrier head systems receives substrates from and delivers substrates to transfer station 37.

The four carrier head systems 70a-70d are mounted on carousel support plate 66 at equal angular intervals about carousel axis 64. The carousel motor assembly rotates the carousel support plate 66 about center post 62, orbiting the carrier head systems 70a-70d, and the substrates attached thereto, about carousel axis 64.

Each carrier head system 70a-70d includes a polishing or carrier head 100. Each carrier head 100 independently rotates about its own axis and independently laterally oscillates in a radial slot 72 formed in carousel support plate 66. A carrier drive shaft 74 connects a carrier head rotation motor 76 to carrier head 100 (shown by the removal of one-quarter of cover 68). There is one carrier drive shaft and motor for each head.

A rotary coupling at the top of drive motor 76 couples four fluid or electrical lines (not shown) into four channels 94 in drive shaft 74 (see FIG. 4 where only two channels are shown because it is a cross-sectional view). Angled passages 95 formed in a base flange 96 of drive shaft 74 connect the four channels 94 to receiving channels (not shown) in carrier head 100. A threaded perimeter nut 98 may be placed over flange 96 to connect drive shaft 74 to carrier head 100. Channels 94 are used to pneumatically power carrier head 100, to actuate a retaining ring 140 against the polishing pad and to vacuum-chuck the substrate to the bottom of the carrier head. Additional details of the construction and operation of CMP apparatus 30 including those relating to the conditioning of the polishing pads may be found in application Serial no. 08/549,336, filed October 27, 1995, entitled "Carousel Processing System for Chemical Mechanical Polishing" and assigned to the assignee of the subject application, the entire disclosure of which is hereby incorporated by reference.

During actual polishing, three of the carrier heads, e.g., those of polishing head systems 70a-70c, are positioned at and above respective polishing stations 35a-35c. As noted, each rotatable platen 40 supports a polishing pad having a top surface wetted by an abrasive slurry. Each carrier head lowers its substrate into contact with polishing pad 42. Slurry 50 acts as the media for both chemically and mechanically polishing the substrate.

If substrate 10 is an eight-inch (200 mm) diameter disk, then platen 40 and polishing pad 42 will be about twenty inches in diameter. Platen 40 may be a rotatable aluminum or stainless steel plate connected by a drive shaft (not shown) to a platen drive motor (not shown). The drive shaft may be made of stainless steel. For most polishing processes, the drive motor rotates platen 40 at thirty to two-hundred revolutions per minute, although lower or higher rotational speeds may be used.

Carrier head 100 positions substrate 10 against polishing pad 42 and uniformly loads the substrate's outer surface against the polishing pad. The carrier head is vertically-fixed relative to the surface of the polishing pad by drive shaft 74. Drive shaft 74 provides a fixed bearing location from which head may extend to provide a desired load on the substrate.

Carrier head 100 may apply a force of approximately four to ten pounds per square inch (psi) to substrate 10 when the substrate is positioned at a first polishing station (for example station 35a). At subsequent stations, carrier head 100 may apply more or less force. For example, when the substrate is positioned at the third polishing station, for example at station 35c, carrier head 100 may apply about three psi. As noted, carrier motor 76 (see FIG. 3) may rotate each carrier head 100 at about thirty to two-hundred revolutions per minute. Platen 40 and carrier head 100 may rotate at substantially the same rate.

Each carrier head 100 includes a housing assembly 102, a carrier assembly 104 and a retaining ring assembly 106. Housing assembly 102 provides for connection to drive shaft 74. Carrier assembly 104 is attached to housing assembly 102 and acts to hold the substrate against the polishing pad exerting a downward pressure to load the substrate against the polishing surface. Retaining ring assembly 106 ensures that the substrate does not slip out from under carrier assembly 104 during polishing operations.

As the polishing pad rotates, it tends to pull the substrate out from underneath the carrier head. Therefore, retaining ring assembly 106 may be constructed with, as noted, downwardly-projecting retaining ring 140 which extends circumferentially around the edge of the substrate. The retaining ring forms a recess which contains the substrate. More specifically, an inner edge 142 of retaining ring 140 prevents the substrate from being dragged out from underneath carrier assembly 104.

As shown in FIGS. 4 and 5B-5C, polishing pad 42 may comprise a hard composite material having a roughened polishing surface 44. Polishing pad 42 may have an upper layer 46 and a lower layer 48. Each layer may be 50 mils thick. Lower layer 48 may be attached to platen 40 by a pressure-sensitive adhesive layer 49. Upper layer 46 may be harder than lower layer 48. Upper layer 46 may be a material composed of polyurethane or polyurethane mixed with a filler. Lower layer 48 may be a material composed of compressed felt fibers leached with urethane. A two-layer polishing pad, with the upper layer composed of IC-1000 and the lower layer composed of SUBA-4, is available from Rodel, Inc., of Newark, Delaware (IC-1000 and SUBA-4 are product names of Rodel, Inc.).

Referring to FIG. 5A, disposed in polishing surface 44 of polishing pad 42 are a first plurality of parallel grooves 300. These grooves are preferably equidistant, spaced apart by a distance D. Between each groove is a partition 310 having a width Wp, as shown in FIG. 5B. Each groove 300 includes walls 304 having a height H, which terminate at a base 306 having a width Wb. In one embodiment, walls 304 are generally perpendicular to base 306. Each polishing cycle results in wear of polishing pad 42, generally in the form of thinning of the pad as the polishing surface is worn down. As the pad surface is worn down, the surface area available for polishing a substrate may change if walls 304 are not perpendicular to base 306. The generally perpendicular walls 304 (relative to base 306) of the present invention create a generally uniform surface area for polishing pad 42 over its operating life.

In one embodiment, the ratio of base width Wb to partition width Wp is between about 0.12 and 0.85, with approximately 0.42 preferred. Walls 304 may have a height H between about .010 and .050 inches, with approximately .025 inches preferred. Base 306 may have a width Wb between about 0.015 and 0.050 inches, with approximately 0.018 inches preferred. Partition 310 may have a width Wp between about 0.025 and 0.125 inches, with approximately 0.042 inches preferred. Accordingly, distance D between adjacent grooves may be between about 0.040 and 0.175 inches, with approximately 0.060 inches preferred.

Referring again to FIG. 5A, also disposed in polishing surface 44 of polishing pad 42 is a second plurality of parallel grooves 302. Grooves 302 may be generally perpendicular to grooves 300. Grooves 302 are also preferably equidistant, spaced apart by a distance D1. Each groove 302 includes walls 314 having a height H1 which terminate at a base 316 having a width Wb1 as shown in FIG. 5C. In one embodiment, walls 314 are generally perpendicular to base 316 so that as polishing pad 42 is worn down over numerous polishing cycles, the surface area presented for polishing substrate 10 does not vary. Between each groove is a partition 320 having a width Wp1.

In one embodiment, the ratio of base width Wb1 to partition width Wp1 is between about 0.12 and 0.85, with approximately 0.42 preferred. Walls 314 may have a height H1 between about 0.010 and 0.050 inches, with approximately 0.025 inches preferred. Base 316 may have a width Wbl between about 0.015 and 0.050 inches, with approximately 0.018 inches preferred. Partition 320 may have a width Wp1 between about 0.025 and 0.125 inches, with approximately 0.042 inches preferred. Accordingly, distance D1 between adjacent grooves may be between about 0.040 and 0.175 inches, with approximately 0.060 inches preferred.

Referring again to FIG. 5A, first and second plurality of parallel grooves 300 and 302 form a cross-hatched pattern defining a plurality of polygonal islands or projections generally indicated at 330, in polishing surface 44. Polygonal projections 330 include a polygonal shaped uppermost surface 331 for contacting the substrate during polishing operations. The surface area presented for polishing a substrate is between about 30% and 75% of the total surface area of polishing pad 42, with approximately 50% preferred. Accordingly, first and second plurality of grooves 300 and 302 combine to occupy between about 25% and 70% of the total surface area of polishing pad 42, with 50% also preferred. As a result of the large amount of surface area occupied by grooves 300 and 302, the surface tension between the substrate and the polishing pad is reduced facilitating separation of the polishing pad from the substrate at the completion of a polishing cycle. This is due to the open-ended structure created by grooves 300 and 302 which reduces any vacuum build-up between the polishing pad and the substrate. However, as the surface area available to polish substrate 10 decreases, an accompanying increase in the polishing time may be required to achieve the same polishing results.

In one embodiment, the spacing D1 between grooves 300 and the spacing D2 between grooves 302 is approximately equally, resulting in a plurality of islands having uniform spacing and a generally square-shaped uppermost surface 331 of projections 330 for contacting substrate 10 during polishing operations. Alternatively, the spacing D1 and D2 may be different resulting in a generally rectangular-shaped uppermost surface 331 of projections 330 for contacting substrate 10 during polishing operations. In one embodiment, first and second plurality of grooves are angled (not perpendicular to each other) resulting in a generally parallelogram-shaped uppermost surface 331 of projections 330 for contacting substrate 10 during polishing operations.

The grooves may be introduced into polishing surface 44 by cutting or milling. Specifically, a saw blade on a mill may be used to cut grooves in polishing surface 44. Alternatively, grooves may be formed by embossing or pressing polishing surface 42 with a hydraulic or pneumatic press.

As was described above, slurry supply tube 52 provides slurry 50 to polishing surface 44. Grooves 300 and 302 facilitate the migration of slurry 50 about entire polishing pad 42. Excess slurry 50 in any region of polishing pad 42 may be transferred to adjacent regions by the groove structure resulting in more uniform coverage of slurry 50 over polishing surface 44. Accordingly, slurry distribution performance is improved and any center slow effect condition attributable to poor slurry distribution to the substrate center will be reduced.

In addition, grooves 300 and 302 reduce the possibility that waste materials generated during the polishing and conditioning cycles may become trapped and interfere with slurry distribution. First, the grooves facilitate the migration of waste materials away from the polishing pad surface (i.e. uppermost surface 331 of projections 330), reducing the possibility of clogging. Grooves 300 and 302 will collect waste during the polishing and conditioning processes, reducing the amount of waste which will remain on the polishing surface(i.e. uppermost surface 331 of projections 330). In addition, the rotation of platen 40 allows waste materials to migrate in grooves 300 and 302 toward the outer edges of the polishing pad due to centripetal force. The waste materials may be expelled from the polishing pad via openings at the edge of the polishing pad created by grooves 300 and 302, reducing occurrences of waste build and clogging.

Referring now to FIG. 6, the present invention helps to reduce the edge effect for processed substrates by reducing the over polishing of the edge region. Polishing pad 42 is compressible (not rigid). At an outermost region 350 of polishing pad 42, where polishing pad 42 no longer contacts substrate 10, polishing pad 42 has a tendency to bow toward substrate 10. This occurs because of the compressible discontinuity that is present in this region of the polishing pad (nothing for the polishing pad to press against) as substrate 10 is pressed against polishing pad 42. Heretofore, over polishing of the periphery of substrate 10 would occur. Now, by utilizing a polishing pad 42 which incudes a cross-hatched groove pattern formed by grooves 300 and 302, over polishing is minimized.

Polishing pad 42 includes islands 330a which are in contact with substrate 10, islands 330b which are in an outermost region 350 of polishing pad 42 and not in contact with substrate 10, and groove region 300a disposed therebetween. For the purposes of this discussion, only, only a single groove (300a) is discussed. However, each of the grooves 300 and 302 act in a similar fashion in their respective localized regions while in contact with the periphery of the susbtrate. Groove region 300a includes a base 306a which connects islands 330a and 330b. Groove region 300a tends to minimize pressure exerted on the edge of substrate 10, by allowing adjacent islands to act independently of one another. While polishing pad 42 will still bow toward substrate 10 during the polishing process (because of the compressible nature of the pad), groove region 300a allows island 330b to bend toward island 330a while exerting a minimum force on island 330b through base portion 306a. Accordingly, over polishing of the edge region is minimized.

In addition, grooves 300 and 302 may also reduce the "planarizing effect". As was described, the planarizing effect results from the use of a compressible polishing pad. Grooves 300 and 302 permit adjacent islands to act independently, and may reduce the effects of point loading. The present invention has been described in terms of a preferred embodiment. The invention, however, is not limited to the embodiment depicted and described. Rather, the scope of the invention is defined by the appended claims.

Claims

1. An apparatus for polishing a substrate, comprising:

a platen having a polishing surface including a plurality of grooves defining a plurality of polygonal projections, said grooves uniformly spaced over the entire area of said polishing surface; and
a carrier head for holding said substrate against said polishing surface.

2. The apparatus of claim 1 wherein said plurality of grooves comprises a first plurality of parallel grooves and a second plurality of parallel grooves intersecting said first plurality of parallel grooves.

3. The apparatus of claim 2 wherein said first plurality of parallel grooves is perpendicular to said second plurality of parallel grooves.

4. The apparatus of claim 3 wherein said grooves in said first and second plurality of parallel grooves are between about 0.015 and 0.50 inches wide, and spaced between about 0.040 and 0.175 inches apart.

5. The apparatus of claim 4 wherein said grooves have a substantially square cross-section.

6. The apparatus of claim 4 wherein said grooves in said first and second plurality of grooves are approximately 0.018 inches wide, and spaced approximately every 0.060 inches.

7. The apparatus of claim 3 wherein said grooves in said first and second plurality of parallel grooves are between about 0.015 and 0.50 inches deep.

8. The apparatus of claim 7 wherein said grooves in said first and second plurality of parallel grooves are approximately 0.025 inches deep.

9. The apparatus of claim 1 wherein said plurality of grooves account for between about 30 to 75 percent of a total surface area of said polishing surface.

10. The apparatus of claim 9 wherein said plurality of grooves account for approximately 50 percent of said total surface area of said polishing surface.

11. The apparatus of claim 1 wherein said polishing surface is polyurethane.

12. The apparatus of claim 1 further including a feed line for distributing slurry to said polishing surface.

13. A chemical mechanical polishing system for polishing a substrate, comprising:

a platen having an upper surface;
a rotatable drive shaft connected to said platen and a drive motor to rotate said platen; and
a polishing pad attached to said upper surface of said platen and said polishing pad including an upper surface having a plurality of grooves defining a plurality of polygonal projections, said grooves uniformly spaced over the entire area of said polishing surface.

14. The apparatus of claim 13 wherein said plurality of grooves comprises a first plurality of parallel grooves and a second plurality of parallel grooves intersecting said first plurality of parallel grooves.

15. The apparatus of claim 14 wherein said first plurality of parallel grooves is perpendicular to said second plurality of parallel grooves.

16. The apparatus of claim 14 wherein said grooves in said first and second plurality of parallel grooves are between about 0.015 and 0.50 inches wide, and spaced between about 0.040 and 0.175 inches apart.

17. The apparatus of claim 16 wherein said grooves in said first and second plurality of grooves are approximately 0.018 inches wide, and spaced approximately every 0.060 inches.

18. The apparatus of claim 16 wherein said grooves in said first and second plurality of parallel grooves are between about 0.015 and 0.50 inches deep.

19. The apparatus of claim 18 wherein said grooves in said first and second plurality of parallel grooves are approximately 0.025 inches deep.

20. The apparatus of claim 13 wherein said plurality of grooves account for between about 30 to 75 percent of a total surface area of said polishing surface.

21. The apparatus of claim 20 wherein said plurality of grooves account for approximately 50 percent of said total surface area of said polishing surface.

22. The apparatus of claim 16 wherein said grooves have a substantially rectangular cross-section.

23. An apparatus for polishing a substrate in a chemical mechanical polishing system, comprising:

a platen having an upper surface; and
a polishing pad attached to said upper surface of said platen and said polishing pad including an upper polishing surface having a plurality of grooves defining a plurality of polygonal projections, said grooves uniformly spaced over the entire area of said polishing surface.

24. An apparatus for polishing a substrate in a chemical mechanical polishing system, comprising:
a polishing pad having an upper polishing surface including a plurality of grooves defining a plurality of polygonal projections, said plurality of grooves including a first plurality of grooves and a second plurality of grooves intersecting said first plurality of parallel grooves, and wherein said grooves in said first and said second plurality of grooves are uniformly spaced over the entire area of said polishing surface.

25. The apparatus of claim 24 wherein said grooves in said first plurality of grooves are substantially parallel, said grooves in said second plurality of grooves are substantially parallel and said first plurality of grooves are generally perpendicular to said second plurality of grooves.

26. An apparatus for polishing a substrate, comprising:

a platen having a polishing surface including a first plurality of polygonal projections, a second plurality of polygonal projections and a grooved region disposed therebetween, said first plurality of polygonal projections located at a first radius on said polishing surface to contact an edge portion of said susbtrate during a polishing process, said second plurality of polygonal projections located at a second radius on said polishing surface and not in contact with said substrate during the polishing process, said first radius less than said second radius, said grooved region allowing said first plurality of polygonal projections to act substantially independently from said second plurality of grooved regions such that over polishing at the edge portion of said substrate is reduced; and
a carrier head for holding said substrate against said polishing surface.

27. An apparatus for polishing a substrate, comprising:

a platen having a polishing surface including a plurality of polygonal projections uniformly spaced about a periphery of said polishing surface for interfacing with an edge portion of said substrate during polishing thereof; and
a carrier head for holding said substrate against said polishing surface.

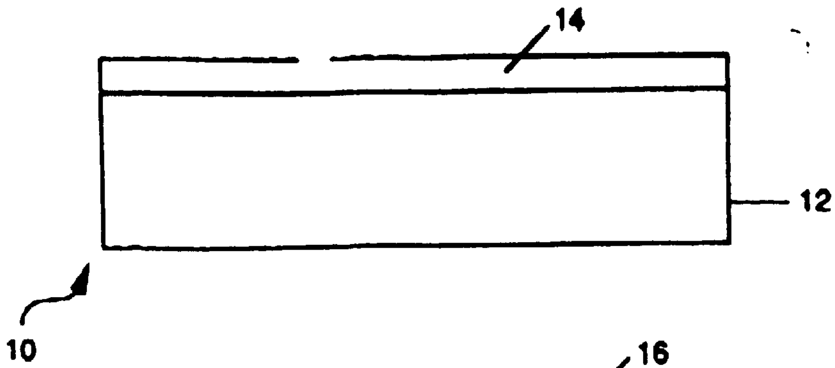

FIGURE 1A

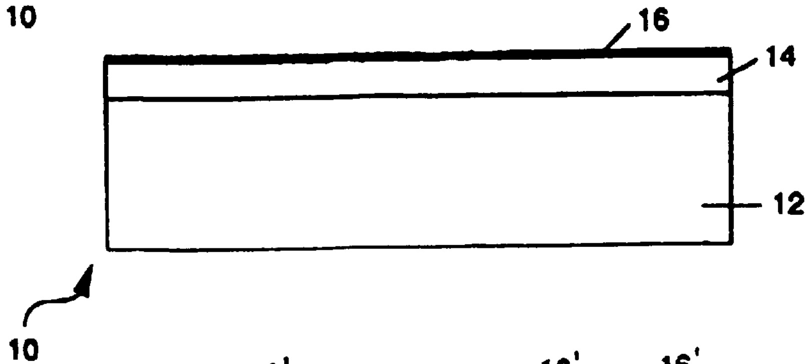

FIGURE 1B

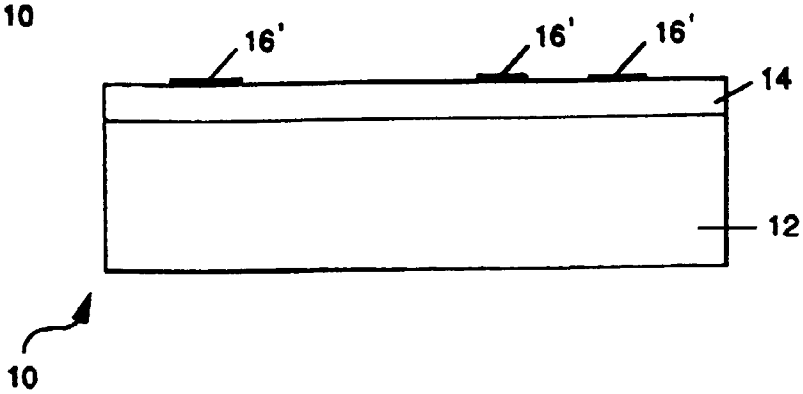

FIGURE 1C

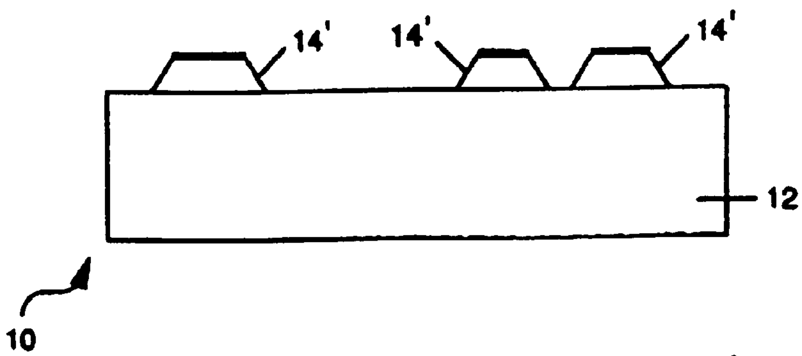

FIGURE 1D

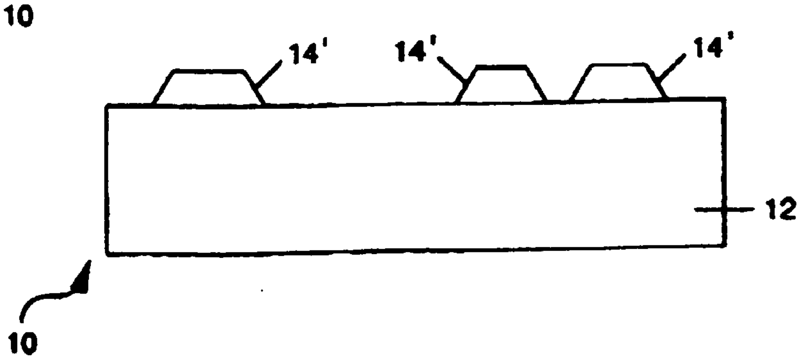

FIGURE 1E

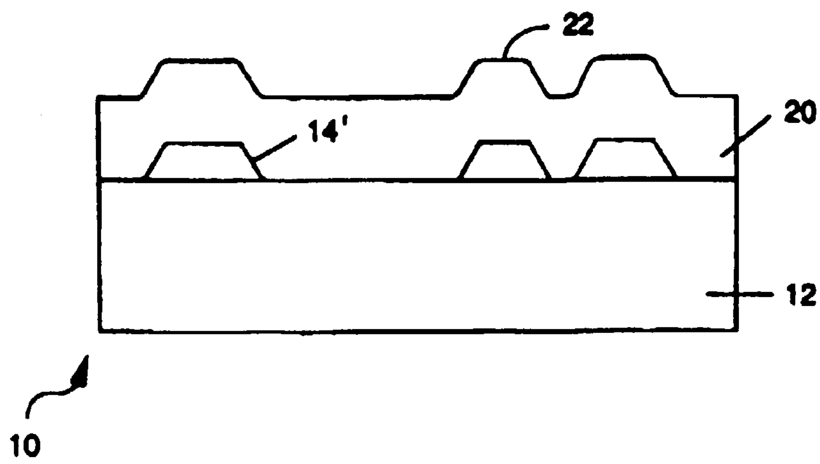

FIGURE 2A

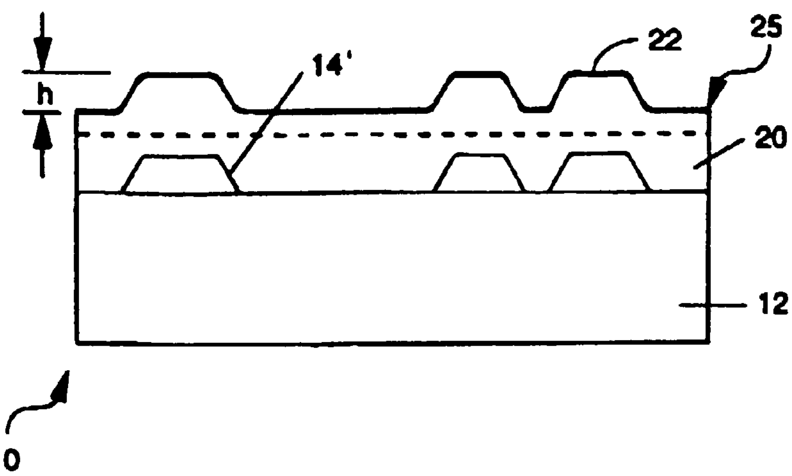

FIGURE 2B

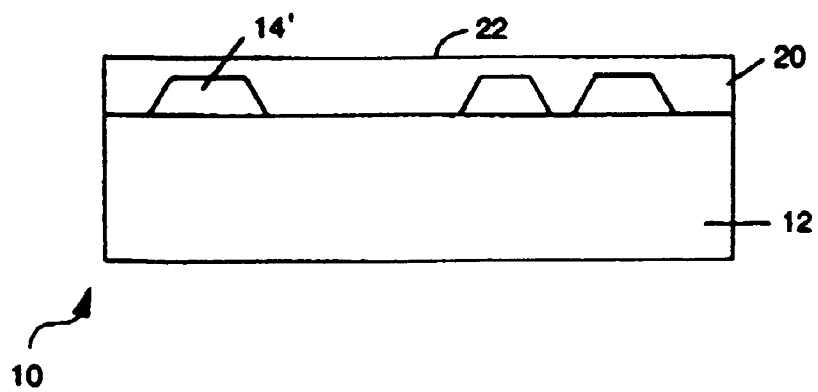

FIGURE 2C

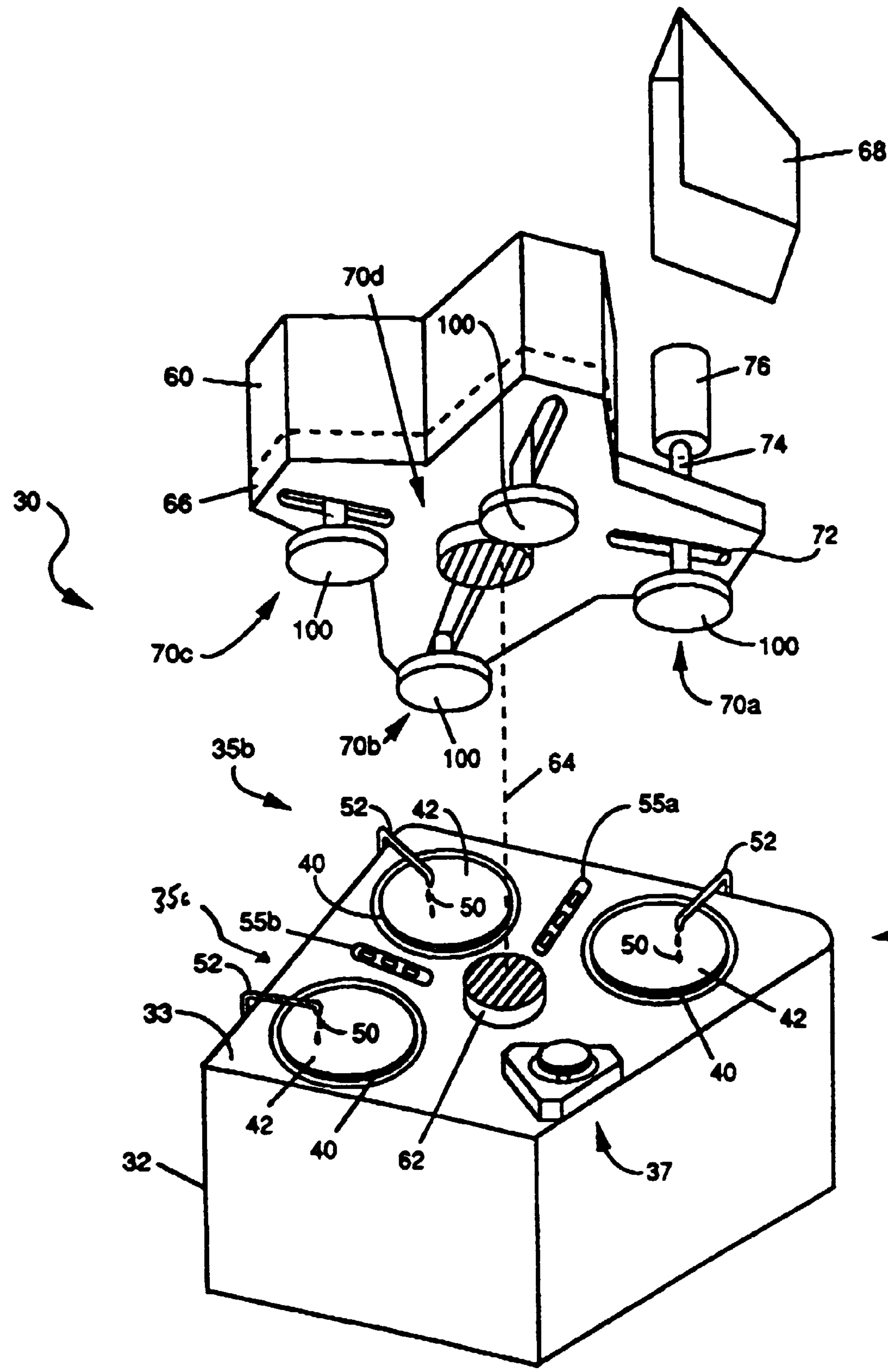
68
70d
100
60
76
74
30
66
72
100
100
70c
100
70a
70b
100
35b
64
52
42
55a
52
35a
40
50
35c
55b
50
52
42
50
33
40
42
42
40
62
37
32

FIGURE 3

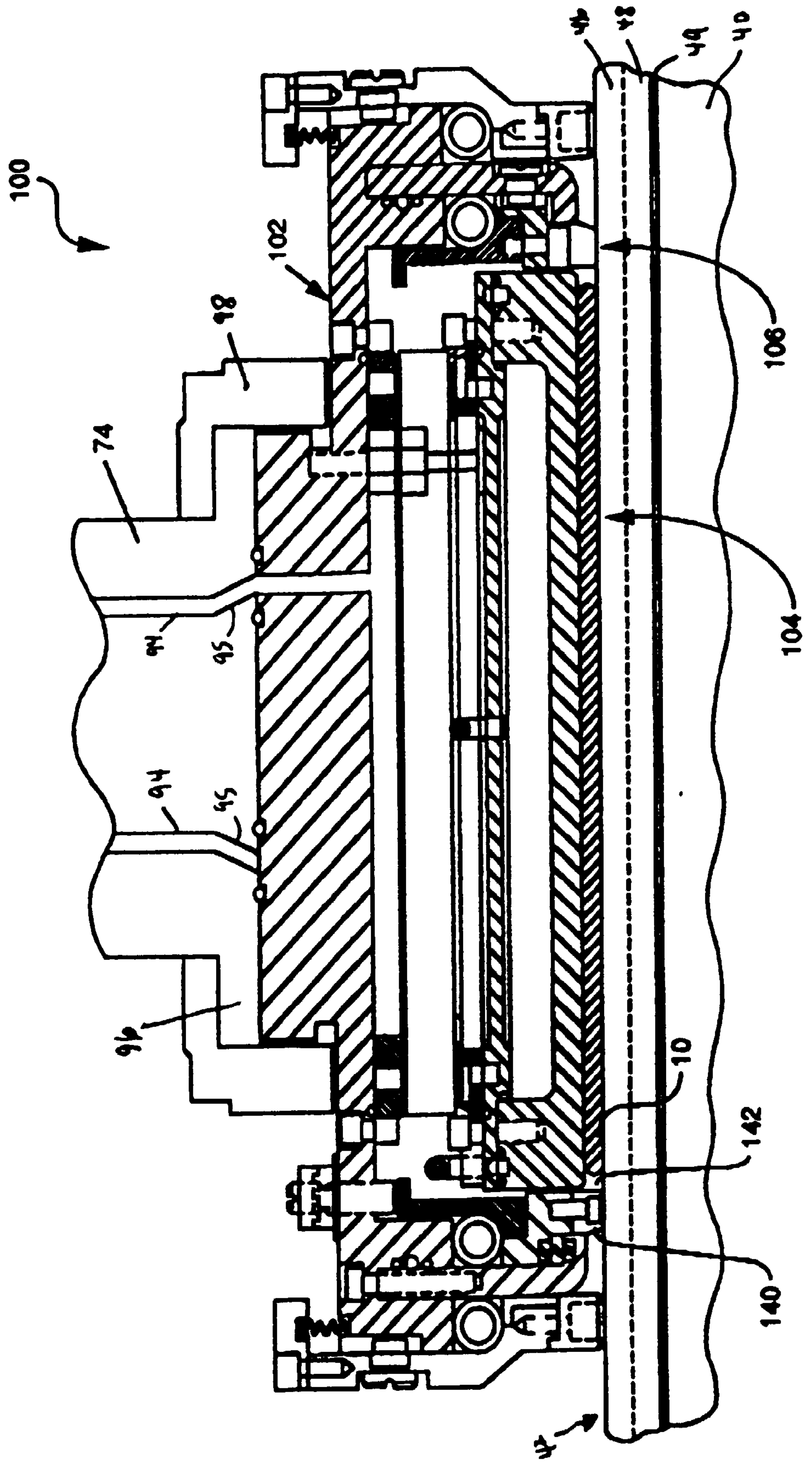

FIGURE 4

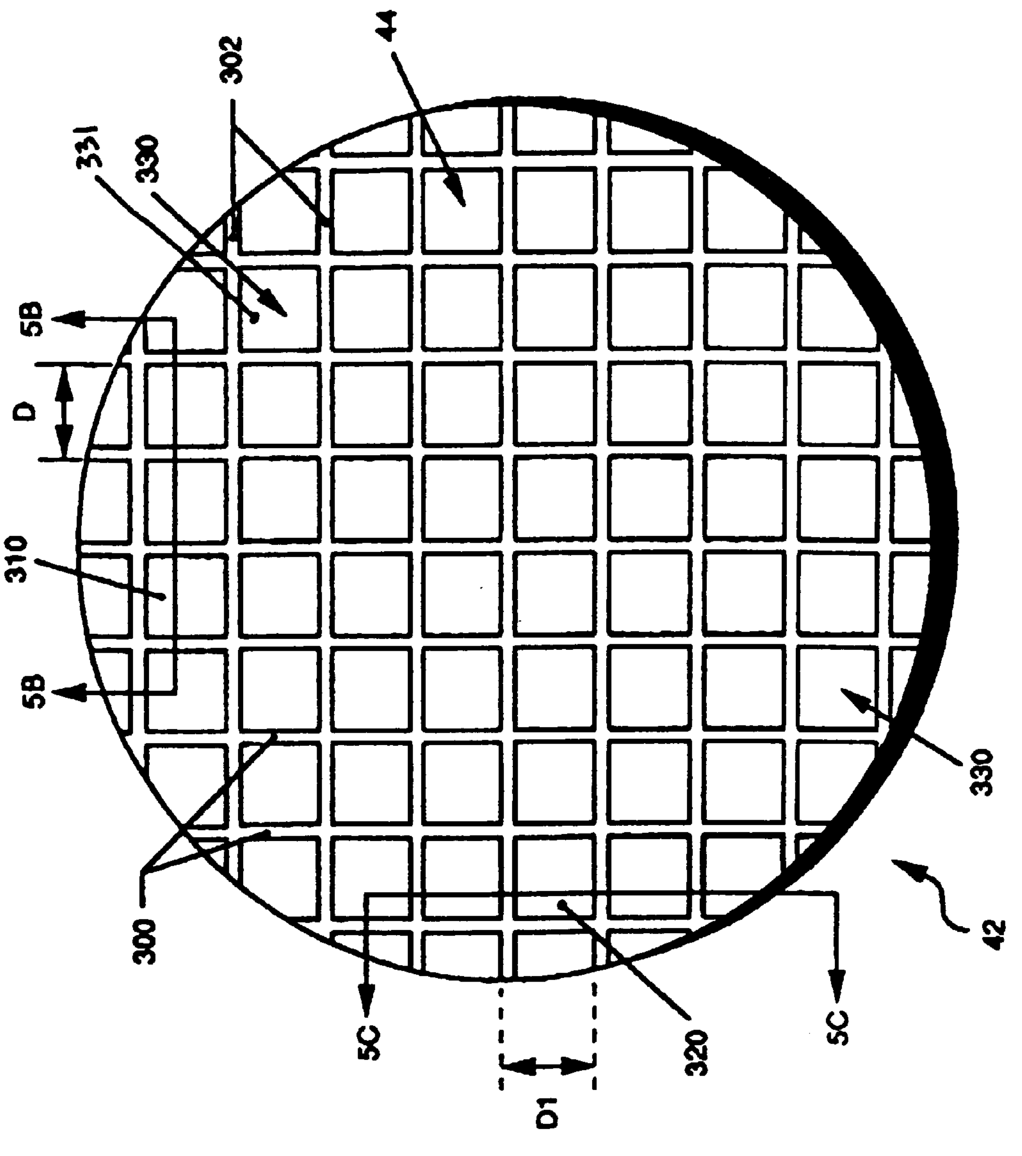

FIGURE 5A

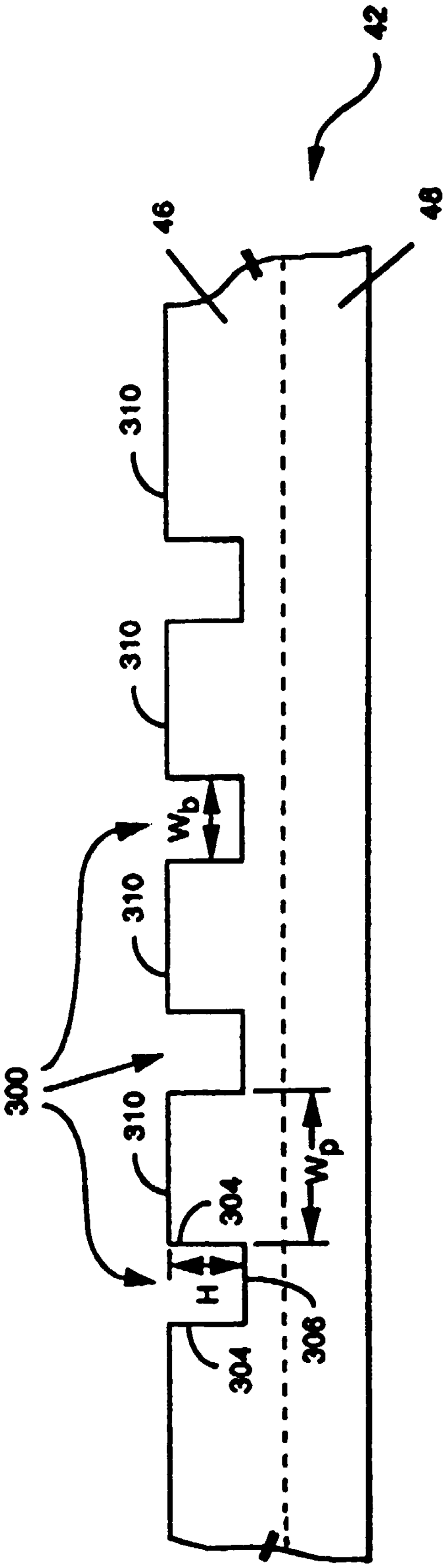

FIGURE 5B

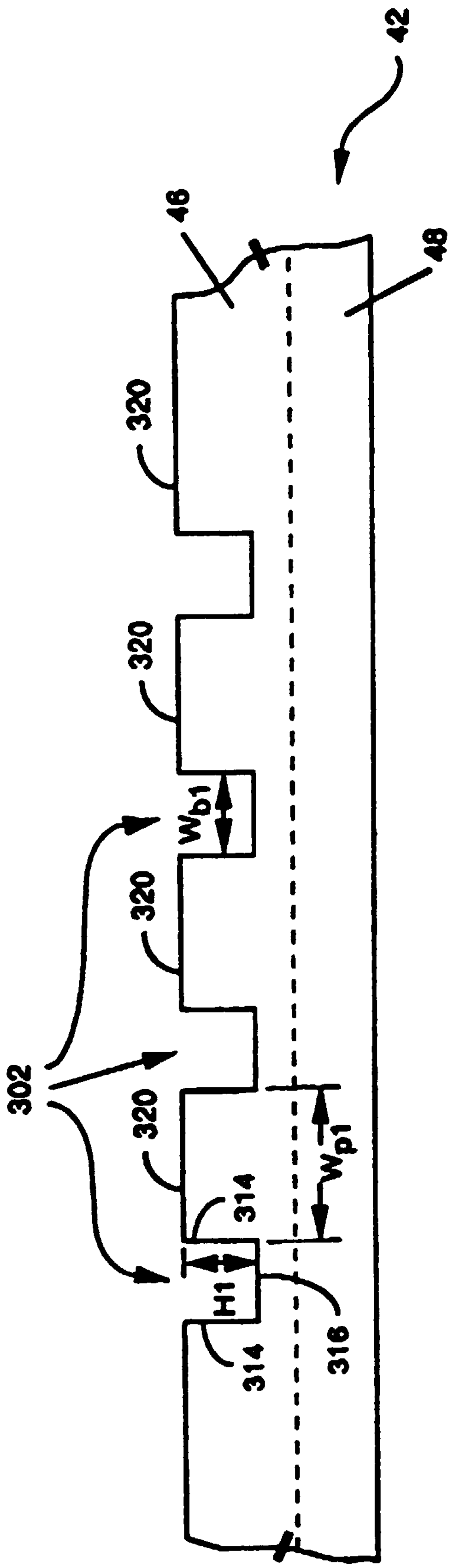

FIGURE 5C

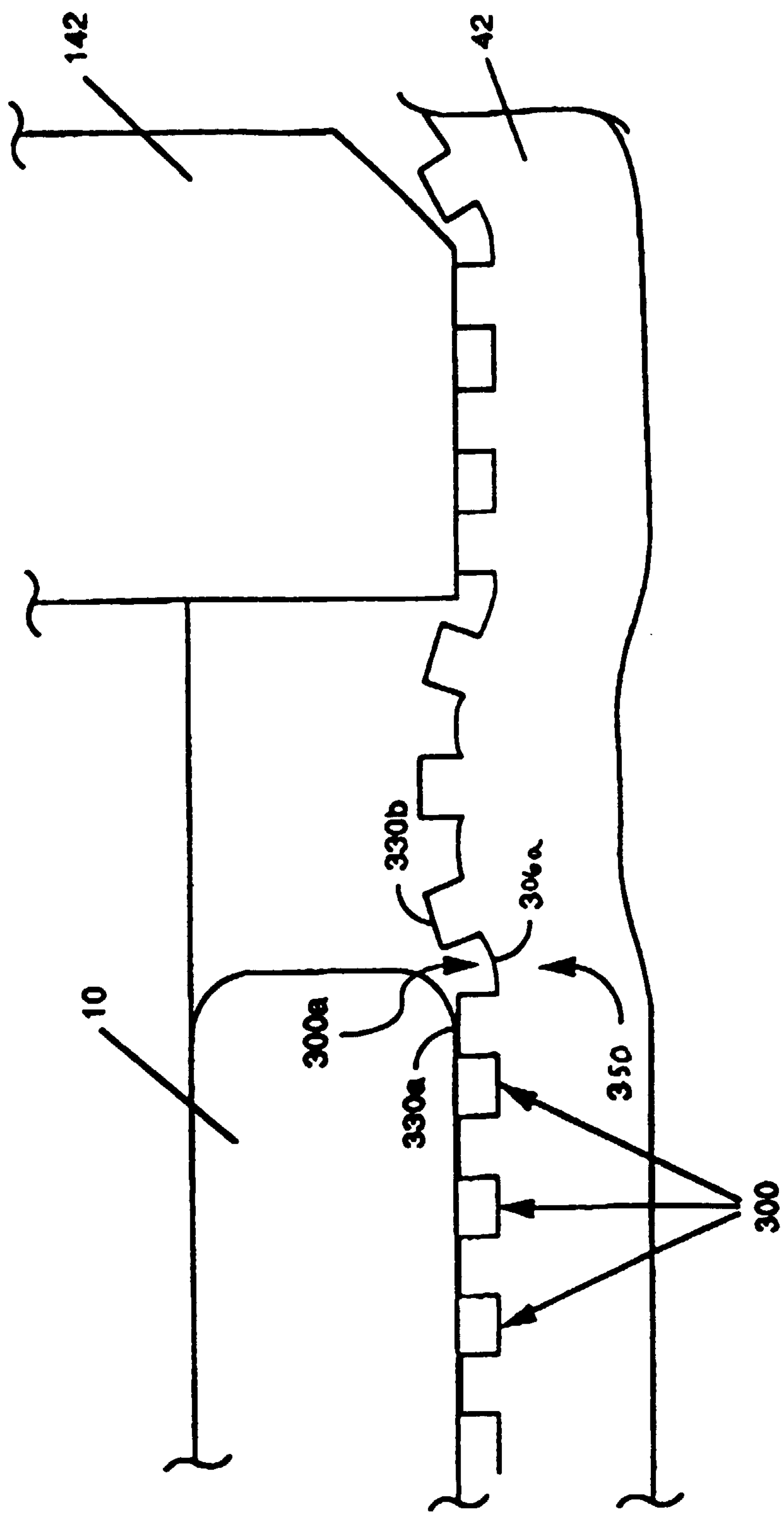

FIGURE 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 30 2999

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 5 212 910 A (BREIVOGEL ET AL) 25 May 1993 * column 4, line 52 - line 69; figures 6-9 *	1-27	B24B37/04
X	WO 94 04599 A (RODEL INC) 3 March 1994 * page 19, line 4 - page 20, line 31; figures 7,8 *	1,13,23, 24,26,27	
X	US 5 022 191 A (BROIDO) 11 June 1991 * column 3, line 44 - line 50; figures 3,4 *	1,13,23, 24,26,27	
X	EP 0 562 718 A (SHINETSU HANDOTAI KK) 29 September 1993 * column 13, line 12 - line 31; figures 21,22 *	1,13,23, 24,26,27	
X	EP 0 439 124 A (MICRON TECHNOLOGY INC) 31 July 1991 * column 3, line 25 - line 51; figure 3 *	1,13,23, 24,26,27	TECHNICAL FIELDS SEARCHED (Int.Cl.6) B24B
X	WO 96 07508 A (STRUERS A/S) 14 March 1996 * abstract; figures *	1,13,23, 24,26,27	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	6 August 1997	Garella, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)