June 22, 1971 R. J. JACCODINE ET AL 3,585,668

BRUSH CLEANING APPARATUS FOR SEMICONDUCTOR SLICES

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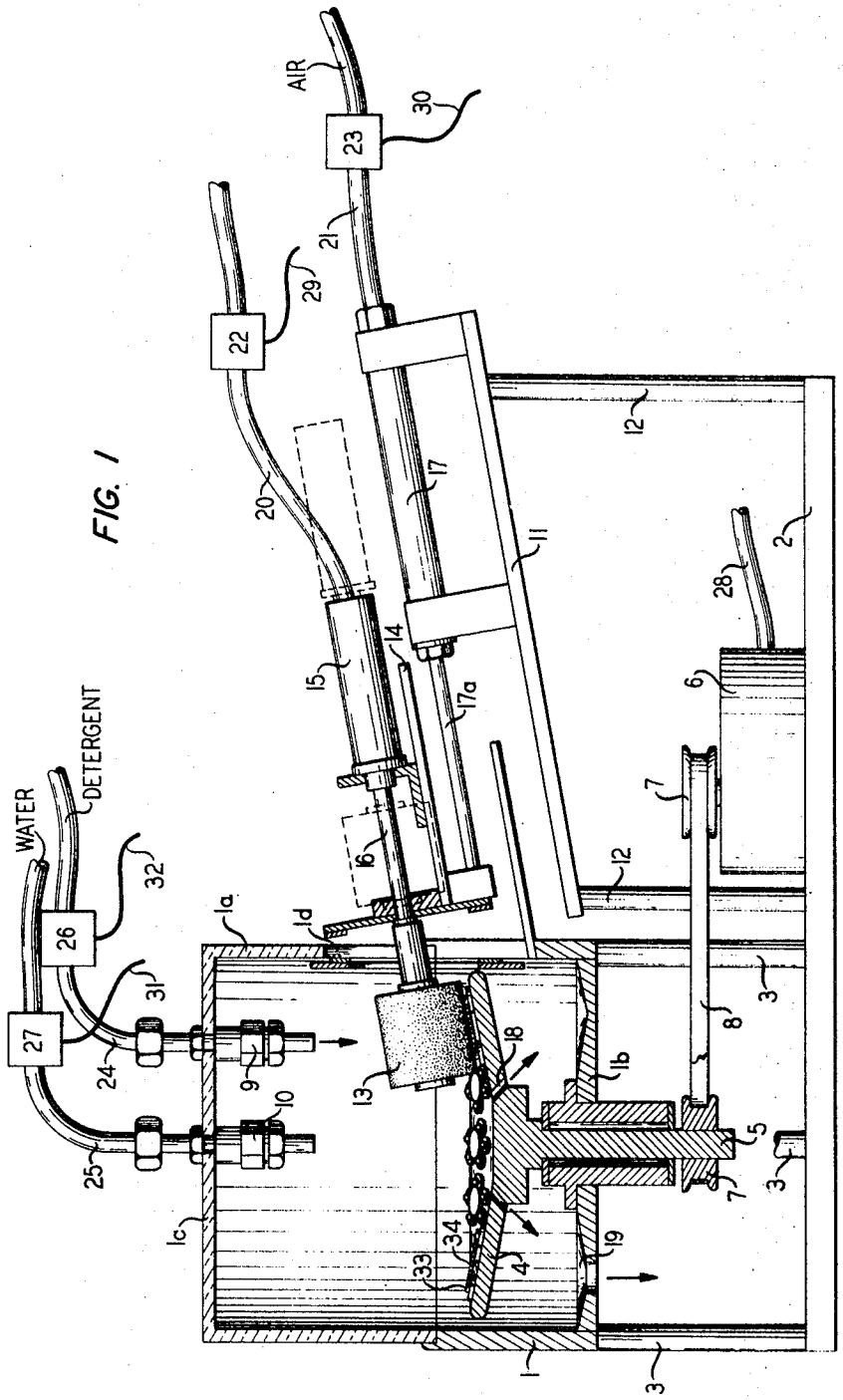
FIG. 1



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BRUSH CLEANING APPARATUS FOR SEMICONDUCTOR SLICES

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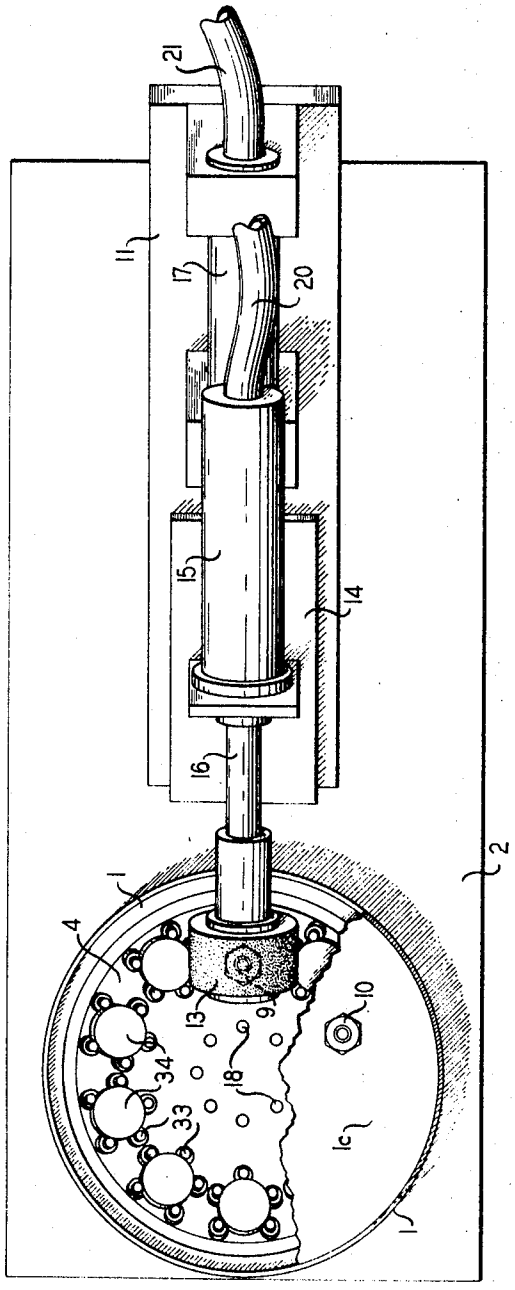

FIG. 2

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BRUSH CLEANING APPARATUS FOR SEMICONDUCTOR SLICES

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ABSTRACT OF THE DISCLOSURE

Semiconductor slices are cleaned in an apparatus which performs the operations of brushing with a cleaning agent, impact rinsing, and spin-drying. A plurality of slices are mounted on a rotating disc near its periphery so that they pass under a rotating scrubbing brush and under nozzles which successively dispense cleaning solution and rinsing water onto the slices. The brush is movably mounted so that it may retract along its axis of rotation to a position away from the slices during rinsing and drying. Drying is accomplished by substantially increasing the speed of the rotating disc so as to fling residual matter therefrom. The resulting slices are substantially free of dirt particles, stains and fingerprints, making them suitable for use in various semiconductor devices.

BACKGROUND

Field

This invention relates to an apparatus for cleaning the surfaces of semiconductors, prior to or during fabrication into semiconductor devices.

Prior art

In order to provide long-term stability of a semiconductor device, it is advantageous to clean the surface of the semiconductor slice prior to the performance of any processing step whose effectiveness may be lessened by the presence of surface contaminants. Such steps might include, for example, the formation of epitaxial layers on the slice, the controlled diffusion of impurities into the slice, or thermal treatment or final encapsulation of the device.

Efficient and effective cleaning of semiconductor slices has long remained an elusive goal. This is evidenced by the fact that in the highly automated art of semiconductor device fabrication, cleaning is often accomplished by manual scrubbing of individual slices.

Such a procedure is obviously undesirable in that it is time-consuming, and leads to low yields due to breakage and variation in the degree of treatment from slice to slice.

SUMMARY OF THE INVENTION

According to the invention, semiconductor slices are cleaned in an apparatus which performs the operations of scrubbing with cleaning agent, impact rinsing and non-evaporative drying. Slices cleaned in the apparatus are substantially free of dust particles, stains and fingerprints, making them suitable for use in various semiconductor devices.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a front elevation view, partly in section, of one embodiment of the inventive apparatus.

FIG. 2 is a plan view of the apparatus of FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, there is shown a front elevation view, partly in section, of one embodiment of the

inventive apparatus. Housing **1**, having an upper removable portion, or housing cover **1***a*, is mounted on one side of a base plate **2**, by supporting members **3**. Disc **4**, upon which slices to be cleaned are placed, and shaft **5** are rotatably mounted in housing **1** on bottom member **1***b*. Variable speed motor **6** supplies rotation to disc **4** through shaft **5**, pulleys **7**, and belt **8**. Disc **4** is sloped gradually from the central portion to the edges, so as to provide support against lateral movement of the slices during rotation of the disc. Nozzles **9** and **10** are mounted in top member **1***c* of cover **1***a*. Brush **13** is movably and rotatably mounted on carrier plate **11** adjacent to an aperture **1***d* in housing **1**. Carrier plate **11** is mounted on base plate **2** by supporting members **12**. More specifically, brush **13** is rotatably mounted on carrier plate **14**. Motor **15**, also mounted on plate **14**, supplies rotation to brush **13** through shaft **16**. Carrier plate **14** is rigidly connected to the shaft **17***a* of air cylinder **17**. Air cylinder **17** is in turn rigidly mounted to carrier plate **11**, so that operation of air cylinder **17** will result in motion of brush **13** along its axis of rotation, and thus, into or out of the housing **1** through aperture **1***d*. Holes **18** in disc **4** and hole **19** in bottom member **1***b* of housing **1** allow removal of liquid from the disc and housing respectively. Lead **20** supplies current to motor **15** through relay **22**, while tube **21** supplies air to cylinder **17** through solenoid valve **23**, while tubes **24** and **25** supply cleaning solution and rinse water respectively to nozzles **9** and **10**, through solenoid valves **26** and **27**. Leads **28**, **29**, **30**, **31**, and **32** are connected to control means, not shown, which means actuates motors **6** and **15** and solenoid valves **23**, **26**, and **27** according to a predetermined schedule.

Referring now to FIG. 2, there is shown a plan view of the apparatus of FIG. 1. Slices **34** to be cleaned are located between pins **33** of rotating disc **4**, and thus pass under brush **13**. Rotation of brush **13** will ordinarily be such that the motion of the bristles across the slices is opposite in direction to the motion of the slices, in order to obtain a generous scrubbing action. Brush **13** advances toward the center of the disc **4** in a direction along the axis of rotation of the brush **13**. Cleaning solution is sprayed from nozzle **9** onto brush **13** during scrubbing. After completion of scrubbing, rinse water is sprayed directly onto the slices from nozzle **10**. At some time either at the end of scrubbing or during rinsing, the brush **13** ceases to rotate and retracts along its axis of rotation to a point beyond the periphery of disc **4**. After rinsing, the speed of rotation of disc **4** is substantially increased to effect spin drying.

It is important to the successful practice of the invention that the degree of scrubbing achieved is sufficient for removal of tenacious particles, but not so vigorous as to result in scratching of the polished slice surfaces or dislodging them from the disc **4**. While the proper degree of scrubbing is to some extent dependent upon such factors as time of scrubbing, speed of rotation of the brush, speed of rotation of the disc, and speed of advancement of the brush across the disc, it may generally be achieved in large measure by the proper choice of brush and distance between brush and slice surface. It will be appreciated that such factors as brush stiffness or brush quality are difficult of description, being dependent upon the type, density, length, cross-section and width of the bristles, and upon the size and shape of the brush. By way of example only, it has been found satisfactory to use a cylindrical nylon brush, having a circular cross-section of from 1 to 4 inches, and bristles ½ to 1½ inches in length, having a circular cross-section of from .006 to .012 inch, and to choose a brush to slice distance such that from 1/16 to ¼ inch of the ends of the bristles come in contact with the slice surfaces.

Rinsing is most advantageously carried out by subjecting the slices to the direct impact of a fast-flowing and continuous stream of chemically pure water for a time sufficient to substantially remove from the surface all physical contaminants detectible under a magnification of at least 100×, with special techniques such as dark field illumination or interference contrast optics, or alternatively, detectible with the unaided eye under extremely intense illumination. For example, placing about a 1000 foot-candle light source about 6 inches away from a slice enables the unaided eye to detect the presence of particles as small as ¼ micron in size that are ordinarily detectible only at a magnification of from 100× to 200×. These particles are substantially completely removable by the above technique. Ordinarily, impact of the water stream on the slice is most advantageously at about an angle from 30° to 90°, below which the slices could become dislodged from the disc. Ordinarily, rinsing with an impact of from 1 to 20 p.s.i. on the surface of the slice for from 10 to 60 seconds is adequate. While rinsing should follow scrubbing immediately for best results, substantially clean surfaces may still be obtained by commencing rinsing with sufficient promptness to prevent substantially evaporation of cleaning agent.

With regard to drying, the essential requirement for achievement of clean, stain-free slices is that the drying be nonevaporative. This has been found to be most easily accomplished by rapidly moving the slices in a curved path, to fling the residual water away by centrifugal force. Of course, this should be effected before substantial evaporative drying can occur, to prevent staining. By way of example, rotation of about ten 1.25-inch slices located about the periphery of a 7-inch diameter disc at a speed of at least 1000 r.p.m. for from 10 to 60 seconds results in substantially complete water removal without staining.

By way of example only, a typical cleaning procedure is described. The apparatus used was similar to that depicted in the drawing. A 2-inch nylon cylindrical brush, having bristles ⅞-inch long and .008 inch thick, was mounted above the slice surfaces with its axis of rotation parallel thereto at a height such that about 1/16 inch of the bristles came in contact therewith. The brush was rotated at about 350 r.p.m., while a 7-inch diameter disc, supporting ten 1.25-inch polished silicon slices about the periphery of the disc, was rotated at about 150 r.p.m. Scrubbing with a detergent solution was carried out for about 20 seconds, after which rinsing was carried out under an impact pressure of about 10 p.s.i. for about 20 seconds. About half-way through the rinse cycle, the brush was retracted from the housing. Immediately after rinsing, the speed of rotation of the disc was increased to about 2000 r.p.m. for about 20 seconds to effect nonevaporatory drying. The slices so cleaned exhibited up to only 10 particles per slice, from about .25 to 5 microns in size, making them suitable for use in semiconductor devices. With special conditions such as well-filtered rinsing water and a particle-free environment, it has been possible to achieve slice surfaces completely free of particles detectible as described above.

It is emphasized that cleaning of semiconductor surfaces in the inventive apparatus may be carried out one or more times at any stage of the fabrication process, regardless of the condition of the surface prior to cleaning.

The invention has been described in terms of a limited number of embodiments. Alternative embodiments are contemplated to effect cleaning of semiconductor slices as described herein. For example, the slices may be secured to the disc by means of depressions rather than pins. Sloping of the disc upward from the central portion to the edges may be modified or eliminated. The brush need not rotate independently of the disc, where sufficient scrubbing is otherwise obtainable, such as by prolonging the cycle, or increasing the speed of rotation of the disc. The brush may be replaced by other types or shapes of brushes. Slices may be moved under the brush by means

of an endless belt, rather than a disc, in which case the housing may, of course, be modified to the extent necessary to accommodate the moving belt while maintaining the clean slices safe from ambient dust and other contaminants. The housing need not be apertured to accommodate the brush, if the brush is removable to a position in the housing away from the vicinity of the slices during some portion of rinsing and drying. For some applications, it may be found that such a protective housing is unnecessary. However, it should be understood that in the obtaining of substantially clean semiconductor surfaces as herein described, the ordinary precautions should be taken to insure a clean environment, such as the establishment of clean room conditions or the use of a laminar flow clean hood.

Finally, it is pointed out that separate nozzles for cleaning agent and rinse water are unnecessary. Any solution inlet means, such as an apertured tube or pipe, through which cleaning agent and rinse water may be successively admitted is satisfactory. Conversely, it may be found advantageous to employ a plurality of solution inlet means, and such is also contemplated.

It is, of course, essential that the apparatus perform the successive functions of scrubbing, impact rinsing and nonevaporative drying. Control means for actuating these functions according to a predetermined schedule are well-known, and are not a necessary part of this description. For example, relays actuated by timer cams, together with appropriate circuitry are satisfactory.

What is claimed is:

1. An apparatus for cleaning semiconductor slices comprising:

a base plate,

at least one brush movably mounted in a first position on said base plate,

means for moving the slices under the brush,

at least one means for successively directing streams of cleaning agent solution and rinse water onto the slices,

means for removing the brush to a second position away from the vicinity of the slices,

means for rapidly moving the slices in a curved path so as to cause water removal therefrom by centrifugal force,

and means for successively actuating (1) the slice moving means and cleaning agent directing means, (2) the brush moving means and the rinse water directing means and (3) the water removal means.

2. The apparatus of claim **1** which includes

a housing surrounding at least a portion of the apparatus including the first position of the brush and the water removal means

so as to protect the clean slices from the ambient.

3. The apparatus of claim **2** in which

(1) the housing is apertured, is mounted on a portion of said base plate, and includes a lower portion and removable upper portion,

(2) means are included for moving said brush through the aperture to its first position in the housing and to its second position outside the housing,

(3) said means for successively directing streams onto the slices comprises

at least one cleaning agent nozzle, together with means for admitting the agent into the nozzle, said nozzle mounted in the upper removable portion of said housing above the first position of the brush, and at least one rinse water nozzle, together with means for admitting water into the nozzle, said nozzle mounted in the upper removable portion of said housing, adjacent to the cleaning agent nozzle.

4. The apparatus of claim **1** in which the brush is rotatably mounted on said base plate, and means are included for rotating the brush during motion of the brush between its first and second positions.

5. The apparatus of claim 1 in which the brush is nylon.

6. The apparatus of claim 5 in which the brush is cylindrical, having a circular cross-section of from one to four inches.

7. The apparatus of claim 6 in which the bristles of the brush are .006 to .012 inch in cross-sectional diameter and ½ to 1½ inches long.

8. The apparatus of claim 7 in which only about 1/16 to ¼ inch of the ends of the bristles come in contact with the slice surfaces.

9. The apparatus of claim 1 in which the means for moving the slices and removing water from the slices comprise a rotatably mounted disc having a supporting surface, together with means for variably rotating said disc.

10. The apparatus of claim 9 in which the supporting surface of the disc is sloped gradually upward from the center of the edges of the disc, so as to provide support against lateral movement of the slices.

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