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[Continued on next page]

(54) Title: APPARATUS AND METHOD FOR MEASURING TOOL DEGRADATION

(57) Abstract: A machining apparatus (10) comprises a material removing tool (12) movably mounted for removing material from a workpiece (14); means for illuminating (42, 54) a sample area upon a tool surface (34) with excitation radiation; means for receiving (42, 54) sample light emitted from the sample area; a spectral analyzer (54) for performing a spectral analysis of the sample light received; and means for determining (60) the condition of the tool at the sample area from the spectral analysis of the sample light. The wear of the tool (12) is determined as such a condition. Operation parameters of the machining apparatus (10) are adjusted according to the determined wear. An example application is a wafer dicing tool.

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APPARATUS AND METHOD FOR MEASURING TOOL DEGRADATION

Field of the Invention

5 The present invention generally relates to degrading tools, which wear during use.

Background of the Invention

10 Equipment for mechanical machining a workpiece often uses degrading tools to remove material from a workpiece, for example cutting tools or abrasive tools such as lapping or grinding or polishing tools. Usually the work layer of the tool is of a harder material than the workpiece, but nevertheless it degrades over its lifetime. Non-optimal work conditions result in an extended 15 machining time, in unnecessarily fast degradation of the tool, or in damage to the workpiece, all of which are economically unfavorable. Especially workpieces of a very hard material need very expensive tools. The actual optimal work condition depends on the actual condition criteria degradation of the tool.

20 US 4,786,220 discloses a cutting tool wear monitor for detecting tool wear failure of a drill by monitoring a voltage or current which is generated between drill and workpiece during drilling. It is detected when the tool is worn out.

US 5,934,974 describes In-situ monitoring of the wear of a polishing pad for polishing semiconductor wafers by laser triangulation. The polishing tool is 25 adjusted to compensate uneven wear of the tool.

Both US Patents employ effects for the measurement, which are application specific. There is a further need for more general measuring the degradation of a tool.

Now, a special field of degrading tools, which wear during use is cutting 30 (dicing) processed semiconductor wafers for die separation with blades, which wear during use. A processed semiconductor wafer has dies comprising electronic circuits thereupon in a rectangular pattern of rows and

columns. These dies are separated by a dicing blade for packaging into single housings. Typically, the blade thickness ranges from 0.015 mm to 1.3 mm. The dicing blade comprises particles of diamond as typical abrasive material within a carrier material and cut the wafer with a liquid present for
5 cooling and removing saw dust. Three types of dicing blades are commercially available:

Sintered Diamond Blade, in which diamond particles are fused into a soft metal such as brass or copper, or incorporated by means of a metallurgical process;

10 Plated Diamond Blade, in which diamond particles are held in a nickel bond produced by an electroplating process; and

Resinoid Diamond Blade, in which diamond particles are held in a resin bond to create a homogeneous matrix.

Silicon wafer dicing is dominated by the plated diamond blade and the
15 resinoid diamond blade. The resinoid diamond blade has the advantage that it is self-sharpening automatically by the cutting process.

Due to the abrasive nature of the process the dicing blade wears. A used-up or damaged dicing blade causes die damage as large particles break away from the die border. The operation parameters of the dicing blade are
20 adjusted so that a suitable compromise of high throughput, small die damage level and reasonable blade wear is reached and usually left constant.

Usually, the dicing blade is either checked from time to time and exchanged when a certain degradation is reached, or it is exchanged after a defined number of wafers cut or a defined operation time. This conception
25 can prevent die damage on the cost of labor for manual checking and/or too early exchange of the dicing blade, which means unnecessary blade costs and down time.

Several approaches have been undertaken to improve this compromise by detecting when the blade is considered used up. The detectable
30 operational conditions according to the art are when the load induced on the blade by the wafer substrate reaches a predefined value or the when the

blade cutting edge reaches a minimum separation distance from the work surface.

US 6,033,288 discloses an apparatus for accumulating dicing data having a spindle motor, a spindle with a blade, a spindle driver to drive the spindle at a predetermined rotation rate, and a sensor connected to the spindle motor to determine the rotation rate of the spindle. A controller controls the spindle driver responsive to the load induced on the blade by the substrate.

According to US 5,718,615 a semiconductor wafer dicing saw is controlled by monitoring blade exposure from a flange holding the blade during the wafer dicing process. A system measures the flange clearance using a height sensor to determine blade wear and a processor for monitors blade movement toward the wafer during the wafer dicing and stops the movement when the blade cutting edge reaches a minimum separation distance from the work surface.

Both conceptions provide unsufficient precision of the used-up condition of the blade.

Brief Description of the Drawings

FIG. 1 is a schematic view of a cutting machine employing an apparatus according to an embodiment of the invention;

FIG. 2 is a flow diagram of a method according to an embodiment of the invention;

FIG. 3 is a flow diagram of a method according to another embodiment of the invention;

FIG. 4 shows diagrams of measurements by the machine of FIG. 1;

FIG. 5 is a schematic view of a drilling machine employing an apparatus according to an embodiment of the invention; and

FIG. 6 illustrates schematically a polishing machine employing an apparatus according to an embodiment of the invention.

Detailed Description of a Preferred Embodiment

The present invention seeks to provide an apparatus and method for measuring the degradation of a tool and/or to detect when the tool is worn out. Further, the present invention seeks to provide a machine having a degrading tool, wherein machining parameters of the machine are controlled according to the determined condition of the tool, and a method therefore. Such apparatus and method allow to extend the lifetime of the tool and to reduce damage to a workpiece.

The wear of a material removing tool is accompanied by modified optical features of the material removing surface, i.e. work surface, of the tool. In accordance with the invention, these modifications of the optical features can be detected spectroscopically. Such optical features may show up and may be detected not only in the visual spectral range but also in neighboring spectral ranges of electromagnetic radiation including infrared and ultraviolet radiation.

Many material removing tools have a body giving structure to a work layer of the tool, which may comprise several distinct geometrical surfaces. The body provides form stability to the tool and the work layer interacts with the workpiece and comprises of or contains particles of an especially hard material. Commonly used materials for work layers are e.g. titanium nitride (TiN), cubic boron nitride (CBN) and diamond. For example surgical drills are made of surgical grade stainless steel or carbon steel coated by a thin layer of titanium nitride. Diamond is used in form of very small particles, which are embedded in a carrier material providing the work layer material. The carrier material is softer than the small diamonds and possibly also softer than the workpiece material. The carrier material on the work surface between the diamonds is abraded by the workpiece material, leaving the diamonds partly embedded and sticking out of the carrier material for removing the workpiece material. Such tools are widely used e.g. for stone saws and for semiconductor wafer backside polishing apparatuses.

For such tools, wear shows in a modified chemical composition of the work surface, which according to the invention is detectable by means of spectroscopy. Compared to a new tool comprising the chemical elements of the work surface, a tool in use comprises also a certain amount of atoms of the chemical elements of the workpiece. When the tool is worn out, i.e. the work layer is used up, the chemical elements of the tool body appear on the work surface. Thus, the wear of the tool is mapped in the ratio of chemical elements on the work surface and also in the optical features of the work surface.

According to the invention, the optical features of the work surface of a tool of a machining apparatus are detected spectroscopically. Further, the condition of the tool is determined from the optical features of its work surface. The condition of the tool contains at least one condition criteria of interest. Such condition criteria can be for example the wear of the tool, its tension or its temperature. The condition criteria can be quantified by a respective condition criteria value for each condition. For example, a condition criteria can be simply assume of the value good/bad to distinct between working tools and used up tools or can assume a range of numbers for finer specifying the degree of wear of a tool.

Also according to the invention, work parameters of the machining apparatus are determined with respect to the condition of the tool. Such work parameters can include the speed of moving parts and can be chosen to extend the lifetime of the tool, or to reduce the tension or the temperature of the tool.

The applicability of the invention is very broad and will be demonstrated by special examples representing applications showing different kinds of machining apparatus, different types of tools, different spectroscopes, and applications in different fields of the industry.

FIG. 1 shows schematically machining apparatus 10 having material removing tool 12 movably mounted for removing material from workpiece 14, and spectroscopic analyzer 16. Machining apparatus 10 is an wafer dicing apparatus used in the semiconductor industry for machining workpiece 14

which is here wafer 20, namely for separating integrated circuits 18 on wafer 20 into single chips which are packaged individually. Material removing tool 12 comprises so called dicing wheel 22 for dicing thin round wafer 20 rectangularity into single chips. Dicing wheel 22 is mounted on axis 24. Dicing 5 wheel 22 has body 26 giving structure to work layer 28 at the circumference of dicing wheel 22. Work layer 28 comprises diamond particles embedded in a carrier material. Work surface 30 of work layer 28 is the material removing surface section of dicing wheel 22, which dices wafer 20. Here, work surface 30 comprises distinct geometrical surfaces 32, 34, 36, which are in abrasive 10 contact with wafer 20. In this example, machining apparatus 10 has a fixed dicing wheel 22 and a movable slide (not shown) carrying wafer 20 moving the wafer along the direction of the dicing by a defined forward speed.

Spectroscopic analyzer 16 comprises detection head 38 having three microscope objectives 40, 42, 44 with lenses 46. Microscope objectives 40, 15 42, 44 are coupled to optical fibers 48, 50, 52, respectively. Microscope objectives 40, 42, 44 optically view or map defined sample areas of work surface 30 on geometrical surfaces 32, 34, 36, to optical fibers 48, 50, 52, respectively. When dicing wheel 22 is turning, the sample areas move along a path on geometrical surfaces 32, 34, 36. The area size of the sample areas 20 is adjustable by adjusting microscope objectives 40, 42, 44.

Detection head 38 is a measurement head for determining the condition of degrading cutting edge of dicing wheel 22. Geometrical surfaces 34, 32, 36 of dicing wheel 22 form front face 34 and first and second side faces 32, 36 substantially rectangular to the front face. Microscope objectives 42, 40, 44 25 form guiding means for guiding illuminating radiation onto a sample area upon a tool surface and simultaneously form sample means for receiving sample light emitted from the sample area, one for each of the front and first and second side sections of the sample area. Detection head 38 is adapted to the dicing wheel 22 such that a front and first and second side sections of 30 the sample area are upon the front and first and second side faces of dicing wheel 22, respectively. Microscope objectives 42, 40, 44 are adapted to optical fibers 50, 48, 52, respectively, one for each of the front and first and

second side sections of the sample area. Detection head 38 forms a block-like measurement head in the meaning that its parts are readily calibrated with respect to each other such that the measurement head can be adjusted to dicing wheel 22 as one piece. Detection head 38 is adapted for receiving
5 illuminating radiation via optical fibers 50, 48, 52 and for transmitting sample light via optical fibers 50, 48, 52. Such a block-like measurement head greatly improves the handling of the hole apparatus.

Spectroscopic analyzer 16 comprises Raman-spectrometer 54 coupled via optical fiber 56 to fiber selector 58. Fiber selector 58 is selectively coupled
10 to one of optical fibers 48, 50, 52. Fiber selector 58 is a switch for selectively feeding sample light of a chosen sample area to the spectral analyzer. This allows to use one spectral analyzer, here the Raman-spectrometer, for several distinct sample areas and thus reduces the costs of the apparatus significantly. Raman-spectrometer 54 comprises a laser for illuminating the
15 actual selected sample area on the tool surface with excitation radiation. Raman-spectrometer 54 is coupled via data bus 62 to personal computer (PC) 60. PC 60 is coupled via control line 64 to fiber selector 58.

In operation, the optical path between spectrometer and actual sample area is used in both directions. The illuminating light from the laser within
20 Raman-spectrometer 54 is fed through optical fiber 56 and behind fiber selector 58, optical fiber 48, 50, or 52, and through the actual microscope objective 40, 42, or 44 to the sample area under inspection. This light illuminates a sample area upon a tool surface 32, 34, or 36 with excitation radiation. Light emitted from the actual sample area is collected by the same
25 microscope objective 40, 42, or 44 and is fed through optical fibers to Raman-spectrometer 54. Raman-spectrometer 54 performs a spectral analysis of the sample light received and provides spectral data of the sample area under inspection, i.e. Raman spectral data. PC 60 controls Raman-spectrometer 54 via data bus 62 and controls fiber selector 58 via control line 64. Raman-
30 spectrometer 54 sends spectral data via data bus 62 to PC 60. PC 60 evaluates the spectral data and determines the condition of the tool at the sample area under inspection therefrom. PC 60 subsequently selects all

sample areas by switching fiber selector 58 and determines the condition of the tool at all sample areas. Therefrom, PC 60 determines a total condition of the tool. The condition of the tool is qualified by at least one condition criteria and can be quantified by a respective condition criteria value for each
5 condition criteria. A PC display shows the spectrum and the determined condition of the tool both at all sample areas and in total. Raman-spectrometer 54 contains also a camera, which can observe the sample area under inspection and whichs image can be displayed on a screen for visual checking.

10 Then, PC 60 uses the condition of the tool to determine optimal machining parameters of machining apparatus 10. PC 60 controls machining apparatus 10 to work a the determined optimal machining parameters. Here, the optimal machining parameters include the forward speed of the slide and the rotation frequency of dicing wheel 22. PC 60 is programmed to determine
15 the optimal machining parameters of machining apparatus 10 from condition criteria values representing the total condition of the tool according to a defined functional relationship. PC 60 is also programmed to detect differences in the condition of the tool between sample areas on geometrical surfaces 32 and 36 above a predetermined warning level. If such differences
20 are detected, a misalignment error between wheel and slide is assumed and an error procedure is initiated. A PC display shows the determined optimal machining parameters of machining apparatus 10, and indicates visually and audibly if a condition criteria value of the tool is above a predetermined warning level.

25 FIG. 2 shows of a method for determining the condition of a degrading tool according to an embodiment of the invention. This method comprises step 152 illuminating a sample area upon a tool surface with excitation radiation. Then in step 154 sample light emitted from the sample area is received. In step 156 the received sample light is spectrally analyzed. From
30 the spectrum of the received sample light, the condition of the tool at the sample area is determined in step 158. The determined condition of the tool can be displayed or can be used to provide a warning signal if it is bad. The

excitation radiation is chosen suitable such that its emission from the sample area is significantly dependent on the condition of the tool with respect to at least one condition criteria. Examples of such dependency is given below.

FIG. 3 shows flow diagram 160 of a method for controlling a machine
5 having a degrading tool according to an embodiment of the invention. In step 162 a sample area upon a tool surface is illuminated with excitation radiation. In step 164 sample light emitted from the sample area as a result of the excitation is received. The received sample light is spectrally analyzed in step 166. From the spectrum of the received sample light, the condition of the tool
10 at the sample area is determined in step 168. Here, this determining includes comparing a value representing the condition with a predetermined value. If the determined value is worse than the predetermined value then a warning is provided, step 170. Next, in both cases with or without warning, machining parameters of the machine are determined dependent on the determined
15 condition of the tool, step 172. Then, step 174, the tool is operated with the determined machining parameters. Additionally, the determined condition of the tool and the determined machining parameters are displayed, step 176.

Preferably, the wear of the tool is a condition criteria quantified with a condition criteria value, which changes significantly during the lifetime of the
20 tool. This change in the condition criteria value is evaluated from the spectrum of the received light according to a predetermined function. Another predetermined function is used to determine machining parameters of the machine which are optimized for a long lifetime of the tool and minimum damage to the workpiece according to the actual condition, here wear, of the
25 tool. Both predetermined functions can be combined to one resulting function such that the condition criteria value doesn't show up explicitly, but this is nevertheless understood as including determining the condition of the tool.

Those skilled in the art will know that all computing and controlling of the machine can be performed by a single computer such as a PC or an
30 integrated microprocessor within the machine. This includes performing a spectral analysis, computing condition criteria values, computing optimal machining parameters and controlling the machine, running machining

application programs, etc. Usually a spectrometer is computer controlled and this computer can take additional tasks of controlling the machine.

Currently, many machining apparatuses are operating a tool at a constant standard speed. Evaluation of many dicing and sawing situations have shown that a new sawing wheel or dicing wheel can advantageously be operated at a beginning speed greater than a standard speed for a short time, at the standard speed for a long time, and a reduced speed relative to the standard speed at the end of lifetime of the wheel with respect to the workpiece.

Here, during the lifetime of dicing wheel 22 work layer 28 will degrade and thus work surface 30 will change its condition. The carrier material of work layer 28 is softer than the small diamonds and also softer than the workpiece material of wafer 20. The carrier material on work surface 30 between the diamonds is abraded by the workpiece material, leaving the diamonds partly embedded and sticking out of the carrier material for removing the workpiece material. Diamonds show a certain size distribution and can be unevenly distributed in the work layer. During use and wear, diamonds can stick out of the carrier material unevenly and can be more or less strongly fixed within the carrier material. Such non-uniformities and mechanical imperfections of machining apparatus 10 as bearing and non-exact positioning of dicing wheel 22 contribute to a non-uniform material removal over the circumference of dicing wheel 22 during one turn. The non-uniform material removal can lead to damage to both wafer 20 and dicing wheel 22. Damage to wafer 20 includes chipping, i.e. breaking portions out of the wafer, which are much bigger than the size of the outsticking diamonds, and breaking of the wafer. Damage to dicing wheel 22 includes breaking portions out of work layer 28 which are much bigger than the size of the outsticking diamonds. Damage is done also by secondary effects due to temperature rising at the dicing track in both wafer 20 and dicing wheel 22.

From a different point of view, the condition of dicing wheel 22 changes during wear. Such condition can include condition criteria position of the actual work surface 30, thickness, degradation, temperature and contamination by small particles of work layer 28. These changed condition of

a used dicing wheel is typically worse than the condition of a new wheel with respect to cutting efficiency. According to the invention, the machining parameters of the machining apparatus such as rotational speed of the dicing wheel and speed of linear movement of the wafer relative to the wheel are set
5 to a values optimized for the actual state of degradation. The cutting efficiency, the risk of wafer damage, and the lifetime of the tool can be greatly improved by adjusting the machining parameters of the machining apparatus to the actual condition of the tool.

For such tools, wear shows in a modified chemical composition of the
10 work surface, which according to the invention is detectable by means of spectroscopy. Compared to a new tool comprising the chemical elements of the work surface, a tool in use comprises also a certain amount of atoms of the chemical elements of the workpiece. When the tool is worn out, i.e. the work layer is used up, the chemical elements of the tool body appear on the
15 work surface. Thus, the wear of the tool is mapped in the ratio of chemical elements on the work surface and also in the optical features of the work surface.

The condition of the tool may include condition criteria that are depending on the actual load such as temperature or stress. Any condition criteria which
20 shows in the spectrum is observable. Especially, the Raman spectrum information preferably contains at least one of the group intensity, position, polarization, and widths of Raman spectral lines. The distance of a Raman spectral line from the excitation frequency is characteristic for the surface material substance or chemical composition and the stress. Thus
25 contamination by small particles of a known substance as well as the appearance of dicing wheel carrier material on the work layer are detectable therewith. In particular, burning of the diamond dicing material due to insufficient cooling of the dicing blade gives rise to additional graphite signals in the Raman spectrum, which can be discriminated from the diamond signal.
30 The polarization of light from a Raman spectral line is dependent on mechanical stress that applies to the tool. Thus critical loads of the tool can be detected therewith.

In FIG. 1, the number of three microscope objectives 40, 42, 44 in detection head 38 has been chosen to observe sample areas on three geometrical surfaces 32, 34, 36, respectively. The number of sample areas may vary with the number of geometrical surfaces or other application specifics. One sample area and one light collecting element can be sufficient.

FIG. 4 shows diagrams of Raman measurements 68 by the machine of FIG. 1, namely Raman spectrum 70 of a new dicing wheel, and Raman spectrum 80 of a used dicing wheel near the end of it's lifetime. Raman spectrum 70 shows the intensity as function of the Ramanshift, which is the spectral distance of the observation wavelength from the excitation wavelength. Spectrum 70 shows ground line 72 having broad maximum 74 and peak line 76. Peak line 76 is a narrow Raman spectral line characteristic for diamond. The intensity ratio between the maximum of peak line 76 and broad maximum 74 is a measure of the amount of diamond particles at the area of observation at the surface of the dicing wheel.

Raman spectrum 80 shows the intensity as function of the Ramanshift. Spectrum 80 shows ground line 82 having broad maximum 84 and peak line 86 characteristic for diamond. Peak line 86 shows a comparatively small maximum because not many diamond particles are left on the surface of the dicing wheel. Additionally, peak lines 87 and 88 both characteristic for silicon rise significantly from ground line 82. This shows contamination from silicon particles on the dicing wheel. The ratio between the maximum of peak line 86 characteristic for diamond and the maximum of peak line 87 characteristic for silicon is a measure of the condition of the dicing wheel.

FIG. 5 shows schematically drilling machine 100 employing an apparatus according to an embodiment of the invention employing classical spectroscopy. Drilling machine 100 has drill 102 for drilling workpiece 104. Drill 102 is the degrading tool under observation. Drilling machine 100 has further drill frame 106 supporting drill head 107 which rotates and chucks drill 102. Drill frame 106 moves to and from workpiece 104 together with drill 102. Drill frame 106 carries laser diode unit 108 and photodetector 110. Laser diode unit 108 illuminates an area of observation 112 on the surface of the tip

of drill 102. Preferably, the cutting edge of drill 102 moves within area of observation 112. Photodetector 110 collects and receives light emitted from area of observation 112. Photodetector 110 has filter 114 for performing spectral analysis of light received. PC 116 controls laser diode unit 108 via diode control 118. PC 116 receives a signal from photodetector 110 via detector supply 119.

Drill 102 is surface coated with a hard material. Controlled by PC 116, laser diode unit 108 illuminates area of observation 112 with excitation light of a suitable predetermined excitation frequency. Photodetector 110 receives filtered reflected excitation light from the area of observation 112 but suppresses stray light. Filter 114 is chosen with respect to the hard material of the surface coating of drill 102 and to the carrier material of drill 102. For the excitation light the hard material of the surface coating of drill 102 has a high reflection coefficient and the carrier material of drill 102 has a small reflection coefficient. PC 116 acts as a comparator comparing the signal received from photodetector 110 to a predetermined value. When the surface coating is used up, the light received by photodetector 110 and thus the signal received by PC 116 decreases significantly and PC 116 provides a warning signal.

The invention is not limited to dicing, sawing, and cutting but also applicable to other abrasive machining including grinding and polishing.

FIG. 6 shows polishing machine 120 in accordance with an embodiment of the invention. Polishing machine 120 is a CMP machine for chemical mechanical polishing a semiconductor wafer. Polishing machine 120 includes a degrading tool consisting of belt 122 carrying polishing pads. Further, polishing machine 120 includes wafer carrier head 124 that positions the wafer against the polishing pads, support bearing 126 that supports belt 122 under wafer carrier head 124, a belt drive system including rollers 128 to move belt 122 and the polishing pads, and optical head 130 mounted on sensor drive system 132 that includes drive motor 134 and drive spindle 136. Optical head 130 is the optical head of Raman-spectrometer 138 and coupled

thereto by optical fiber 140. PC 142 controls Raman-spectrometer 138 and drive motor 134.

In operation, the belt drive system rotates belt 122 so that the polishing pads slide past an exposed surface of a wafer mounted on wafer carrier head
5 124. Support bearing 126 and wafer carrier head 124 co-operate to keep the polishing pads parallel to and uniformly in contact with the surface of the wafer. Raman-spectrometer 138 comprises a laser illuminating sample area 143 on the tool surface with excitation radiation via optical fiber 140 and optical head 130. Sample area 143 moves along on belt 122 on path 144 in
10 zigzag form resulting from the movement of belt 122 and optical head 130 moved by drive spindle 136. Raman light emitted from sample area 143 is collected by optical head 130 and via optical fiber 140 transmitted to Raman-spectrometer 138. PC 142 controls Raman-spectrometer 138, which provides spectral data to PC 142. PC 142 determines the condition of the tool at
15 sample area 143 as it moves along path 144, quantifies the degradation at sample area 143 as one condition criteria, and maps the determined condition with respect to the position of sample area 143 upon belt 122. A PC display shows the degradation of the tool at its different areas. A warning message is displayed if the degradation of the tool is too unevenly distributed
20 over the belt surface or if the degradation of the tool has reached a predefined value.

Those skilled in the art know further that a more simple machine can make use of the invention by employing a comparator for determining the condition of the tool. Such simple machine can just distinct between the tool
25 being good or bad by observing a spectral feature and comparing it's value to a predetermined value. For example an ordinary non-Raman-spectroscope can consist of a lamp for illuminating a sample area upon the tool surface with excitation radiation, a photodetector for receiving sample light emitted from the sample area, a spectral filter for performing a spectral analysis of the
30 sample light received, and a comparator. The comparator determines the condition of the tool at the sample area from the spectrally filtered sample light. The condition of the tool is good if the photodetector signal is lower or

bad if it is higher than a predetermined value. With a suitable spectral filter, the apparatus detects when material of the wheel body appears on the surface of the working layer and provides a warning signal that the tool is used up.

5 While the invention has been described in terms of particular structures, devices and methods, those of skill in the art will understand based on the description herein that it is not limited merely to such examples and that the full scope of the invention is properly determined by the claims that follow.

Reference numbers

machining apparatus 10	laser diode unit 108
tool 12	photodetector 110
workpiece 14	area of observation 112
analyzer 16	filter 114
circuits 18	PC 116
wafer 20	diode control 118
Dicing wheel 22	detector supply 119
axis 24	Polishing machine 120
body 26	belt 122
work layer 28	wafer carrier head 124
Work surface 30	support bearing 126
geometrical surfaces 32, 34, 36	rollers 128
detection head 38	optical head 130
Microscope objectives 40, 42, 44	sensor drive system 132
lenses 46	drive motor 134
optical fibers 48, 50, 52	drive spindle 136
Raman-spectrometer 54	Raman-spectrometer 138
optical fiber 56	optical fiber 140
fiber selector 58	PC 142
PC 60	sample area 143
data bus 62	path 144
control line 64	flow diagram 150
Raman measurements 68	ILLUMINATING SAMPLE AREA 152
Raman spectrum 70	RECEIVING LIGHT FORM SAMPLE AREA 154
ground line 72	SPECTRAL ANALYZING LIGHT RECEIVED 156
broad maximum 74	DETERMINING CONDITION FROM SPECTRUM 158
peak line 76	flow diagram 160

Raman spectrum 80	ILLUMINATING SAMPLE AREA 162
ground line 82	RECEIVING LIGHT FORM SAMPLE AREA 164
broad maximum 84	SPECTRAL ANALYZING LIGHT RECEIVED 166
peak line 86, 88	DETERMINING CONDITION 168
maximum of peak line 87	PROVIDING A WARNING 170
drilling machine 100	DETERMINING MACHINING PARAMETERS 172
drill 102	OPERATING MACHINE AT DETERMINED PARAMETERS 174
drilling workpiece 104	DISPLAYING CONDITION AND DETERMINED PARAMETERS 176
Drill frame 106	

Claims

1. An apparatus for determining the condition of a degrading tool having at least one condition criteria comprising

5 first means for illuminating a first sample area upon a tool surface with excitation radiation;

first means for receiving first sample light emitted from the first sample area;

a spectral analyzer for performing a spectral analysis of the first

10 sample light received; and

means for determining the condition of the tool at the first sample area from the spectral analysis of the first sample light.

2. The apparatus of claim 1, wherein the spectral analyzer is a Raman

15 spectral analyzer for providing Raman spectrum information of the first sample light.

3. The apparatus of claim 2, wherein the Raman spectrum information contains at least one of the group intensity, position, polarization, and widths

20 of Raman spectral lines.

4. The apparatus of claim 1, further comprising

second means for illuminating a second sample area upon a tool surface with excitation radiation;

25 second means for receiving second sample light emitted from the second sample area;

a spectral analyzer for performing a spectral analysis of the second sample light received;

means for determining the condition of the tool at the second sample

30 area from the spectral analysis of the second sample light.

5. The apparatus of claim 1, wherein the tool is moving and the first sample area is moving along a surface of the tool.

5 6. The apparatus of claim 1, further comprising a means for providing a warning signal if a predetermined condition criteria value is reached.

7. A method for determining the condition of a degrading tool comprising the steps

10 illuminating a first sample area upon a tool surface with excitation radiation;

receiving first sample light emitted from the first sample area;

spectral analyzing first sample light received; and

determining the condition of the tool at the first sample area from the

15 spectrum of the first sample light.

8. The method of claim 7, further comprising the steps

illuminating a second sample area upon a tool surface with excitation radiation;

20 spectral analyzing second sample light emitted from the second sample area;

determining the condition of the tool at the second sample area from the spectrum of the second sample light.

25

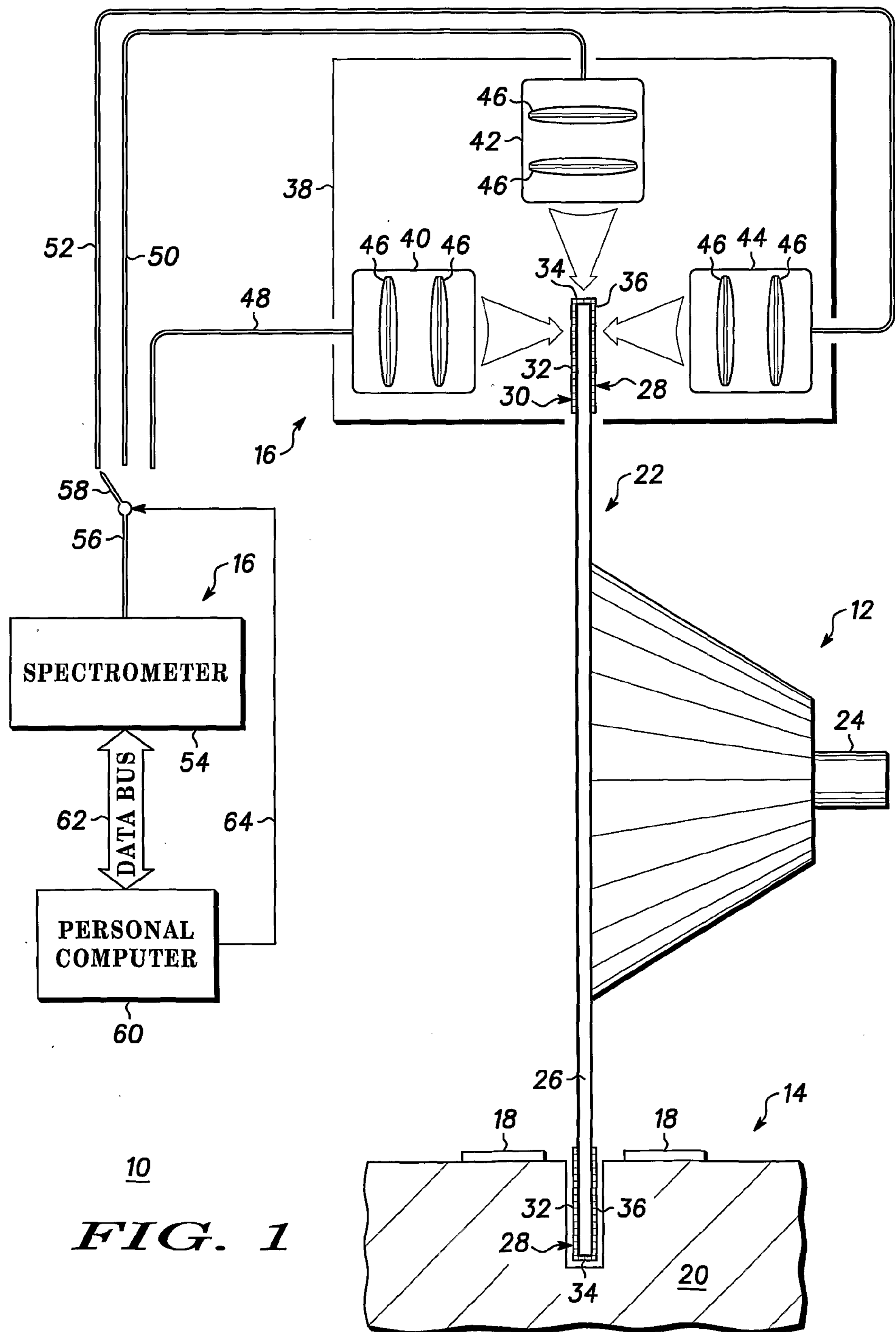

FIG. 1

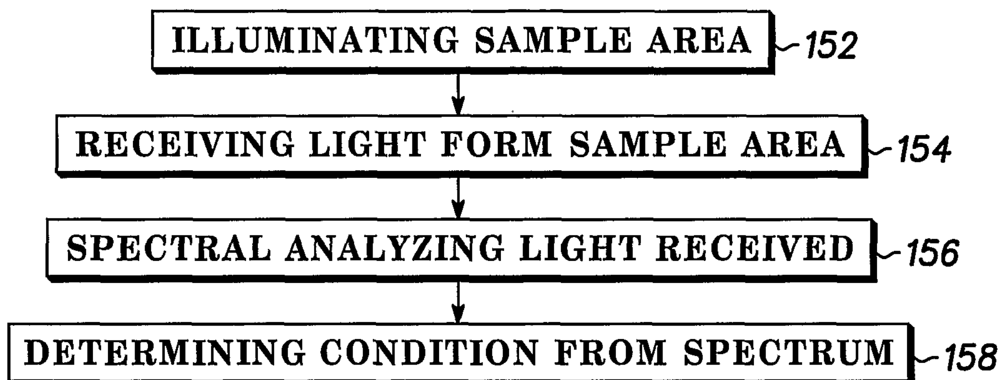

FIG. 2

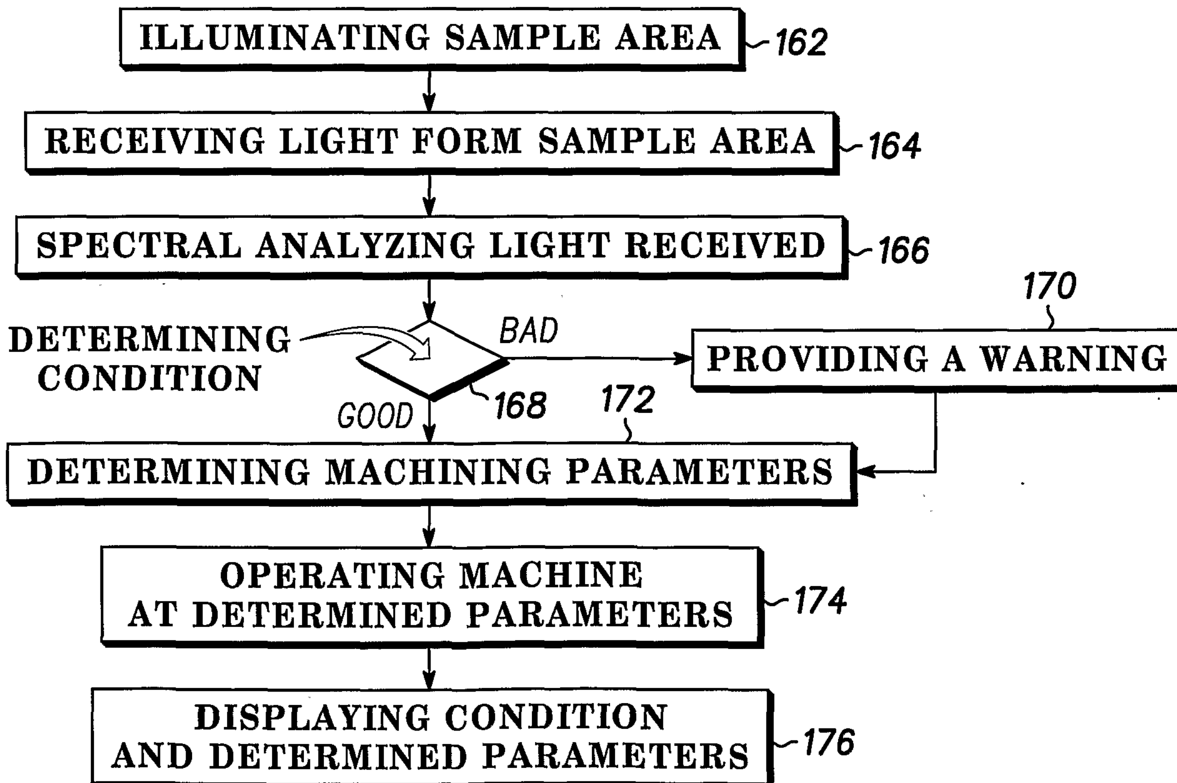

FIG. 3

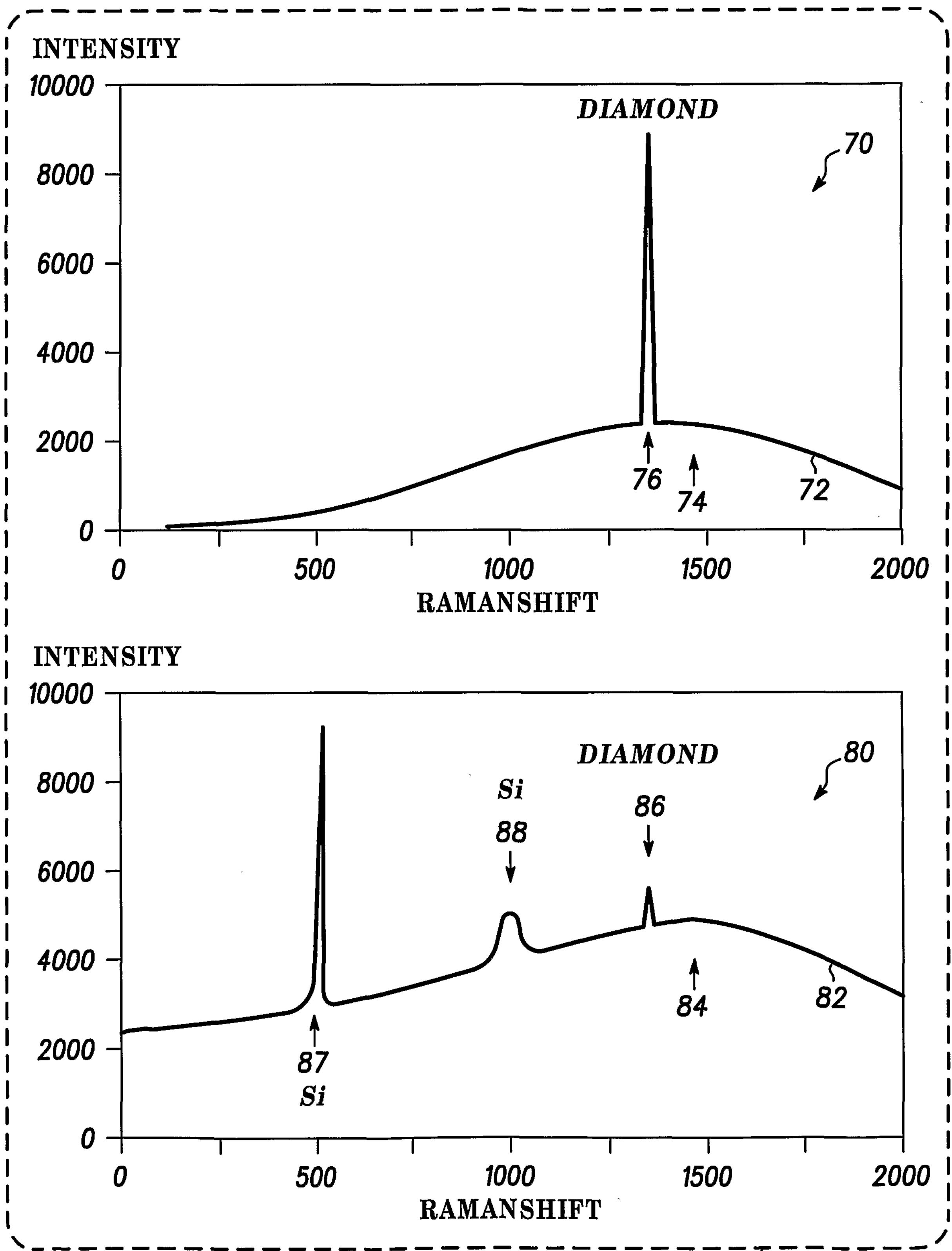

FIG. 4

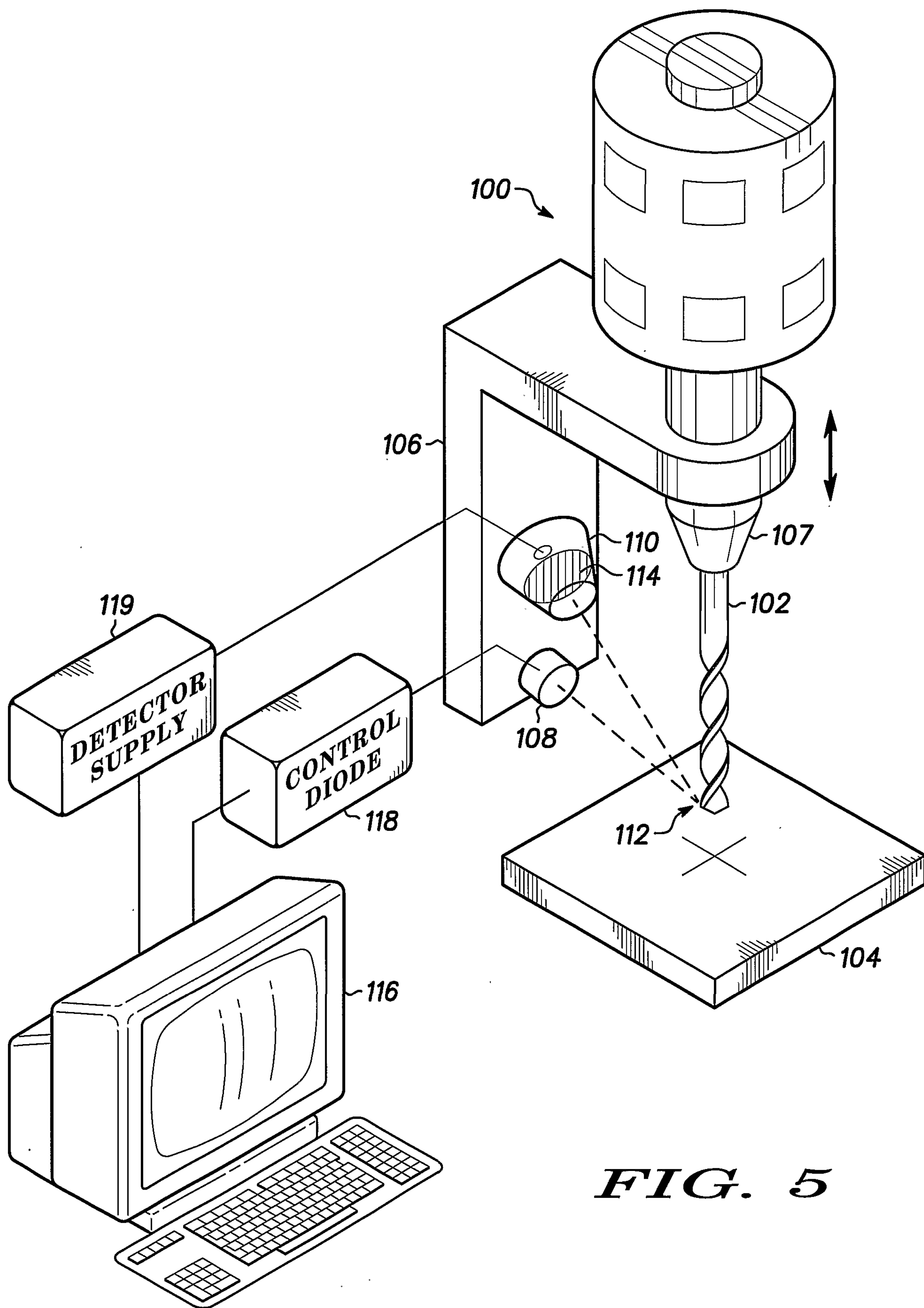

FIG. 5

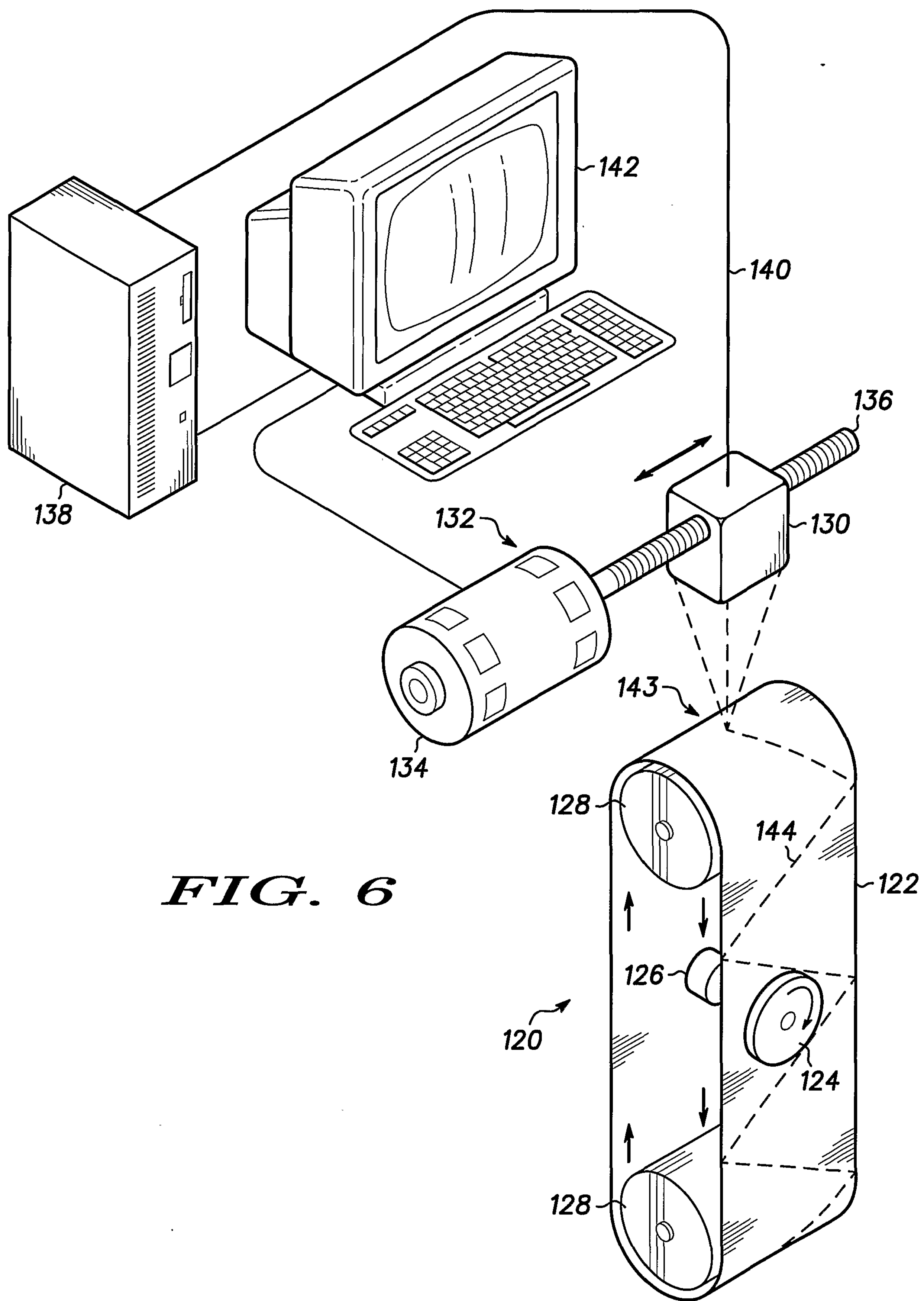

FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/13875

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B23Q17/09 B23Q17/24 G01N21/65 B24B49/12 B28D5/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B23Q G01N B24B B28D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00 16036 A (MUENZ WOLF DIETER ;RENISHAW PLC (GB); PITT GILLIES DAVID (GB)) 23 March 2000 (2000-03-23) the whole document particularly page 13, line 15 - line 21	1-8
X	US 5 144 773 A (FLORES GERHARD ET AL) 8 September 1992 (1992-09-08) column 3, line 34 -column 6, line 4 figures 1-3	1,4-8
A	DD 270 142 A (KOMB PUMPEN UND VERDICHTER VEB) 19 July 1989 (1989-07-19) the whole document	1,7

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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 August 2002	13/08/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Breare, D

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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