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REPLACED SHEETS		SG 9804084-3
☒ Description	: paged 2 to paged 9	1105 copy
☒ Claim(s)	: paged 10 to paged 13	
☒ Drawing(s)	: paged 18 to paged 88	
☒ Abstract	: paged 14 to paged 14	

An Apparatus and Method to Transport, Inspect and Measure Objects and Surface Details at High Speeds

The invention relates to an apparatus with at least one inspection station for the inspection of objects or leaded objects travelling on a track and being singulated while being inspected, said apparatus using at least one vision inspection system with one or more imaging sensors for surface detail inspection as well as for object dimensioning and/or measuring protrusions from said objects to be inspected, said apparatus comprising at least one light source for front and/or back lighting.

It should be understood that vision inspection systems are well known, e.g. for inspection of semiconductor devices. Such a vision inspection system in use today utilizes three separate stations with three imaging sensors. One station and sensor for top surface detail inspection, one station and sensor for top view dimensional measurements and one station and sensor for side view dimensional measurements.

The first station for top surface inspection comprises a light source for front lighting that is lighting from the front of the object and an imaging sensor for inspection of the object from the same perspective as the viewing position. This inspection is used for surface detail inspection including feature extraction and pattern recognition of surface details. The second station for top view dimensional measurement including object length and width, or for a leaded object, the dimensions of these leads and their relationship with other features or objects as viewed from the top, comprises a light source for back lighting or silhouette lighting from below, that is lighting from the rear of the object relative to the viewing position so that the object is in shadow or silhouetted. Under these circumstances the outline of the object can be viewed with high accuracy. The same is true for side view dimensional measurement with back lighting from the side and viewing from the opposite side.

While utilizing the mentioned vision inspection system and in order to prevent inaccurate results, the inspected objects have to be individualized and not resting against each other. It is a common solution for gravity fed inclined machines to use a pair of stoppers. However, the singulation is limited by the speed the stoppers need to travel up and down. If stoppers are used at the inspection station, a settling time or dwell time is required so that the singulated unit can come to a complete stop prior to inspection. This dwell time is necessary, as the inertia of the object would otherwise cause the object to bounce off the stopper.

Efforts were made to reduce the number of inspection stations by incorporating the top surface inspection and the top view dimensional measurement into one station using front lighting. With this arrangement the top view will see both surface details and the object plan dimensions.

To view the two sides, two imaging sensors can be placed one at each side of the object to be inspected using front or back lighting. Alternatively, both side views for side dimensions can also be incorporated into one view using mirrors or prisms with an appropriate front or back lighting of a more complex nature.

It is also known to use three independent and non-interfering light sources at the same station to integrate the surface detail inspection with that of back-lighted top and side dimensioning. This can be done by the use of three strobes (flashlights) to be fired at different times, one to light up the surface and the second to provide a silhouetted top image and a third to provide a silhouetted side image at the same station.

From a photographic point of view, using strobes has the advantage of freezing the object in motion. This technique is also known as inspecting "on-the-fly". Although the act of freezing objects can also be done with electronic shuttered imaging sensors such as progressive scanning video cameras, strobe lights fired at different times do not interfere with one another, whereas continuous lighting setup using progressive scanning cameras can interfere with one another.

Although inspection can be carried out "on-the-fly", this kind of inspection is inherently unstable, if the object has to be presented in a known and consistent manner to the viewing device. For instance, cases where accurate measure-

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- 3 -

ments can only be achieved when the device is flat against a datum when inspected. If the object is floating during motion, inaccurate or invalid measurement results will occur.

In order to overcome the afore-mentioned drawbacks it is an object of the invention to reduce the number of stations and the number of imaging sensors by combining various views with a possibility that the objects can be viewed in motion with a considerably increased handling speed, so that there is no need to even momentarily stop the object during viewing. Thus, a moving object is stable while in motion so that inspection results are repeatable and accurate.

A further object of the invention is to provide means which prevent floating of the objects while being guided through the inspection station and being singulated, particularly, if the object is light and is travelling fast.

These objects are accomplished by an apparatus according to independent claim 1 and a method according to independent claim 16.

Further developments of the invention are subject to dependent claims.

The invention as disclosed provides the advantages that the number of imaging stations and imaging sensors can be reduced and that inspection can be carried out "on-the-fly". There is no need to even momentarily stop the object during viewing. Although known systems for "on-the-fly" inspections are inherently unstable, the invention has the advantage that the object is very stable while in high-speed motion and securely guided so that inspection results are repeatable and accurate.

The invention also provides the advantage that leaded objects can be inspected and dimensionally measured simultaneously from the top and from the side using front lighting for the top view inspection and back lighting for object dimensioning and/or measuring protrusions from the inspected objects.

The features and advantages of the present invention will be more readily understood from the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Fig. 1 is a diagrammatic cross-section view through an apparatus for
~~inspecting objects according to the invention.~~

- 4 -

Fig. 2 is a diagrammatic side view of the apparatus according to Fig. 1;

Fig. 3 is a perspective view of a triangle-shaped track and lipped guides according to the invention;

Fig. 4 is a diagrammatic side view of the apparatus according to the invention with a roller for singulation of the objects;

Fig. 5 is a diagrammatic side view of the apparatus according to the invention with a conveyor for singulation of the objects;

Figs. 6A and 6B are representations of a top imaging sensor view and a bottom imaging sensor view as shown on a display screen of a computer unit;

Figs. 7A bis 7D show modifications of the triangle track;

Fig. 8 diagrammatically shows a right angle triangle arrangement with an in and out as well as an up and down adjustment.

Referring now to the drawings, Fig. 1 shows a diagrammatic cross-section view of an apparatus for inspection of leaded objects 10 which, in the present embodiment, are semiconductor devices, whereas the same apparatus is shown in Fig. 2 in a diagrammatic side view.

The apparatus comprises an elongated track 11 which, as shown in Fig. 2, is inclined for gravity feed and movement of the objects. The track consists of a rail which is shaped into a right angle triangle with a basis between two 45° corners supporting the bottom of the objects 10 and the 90° apex of the triangle in an inverted pyramid position. The track is dimensionally smaller than the objects so that the sides of the objects and their leads or legs (20) protrude along both sides of the track.

The two adjacent faces of the triangle at the 90° corners are mirror finished so as to reflect the images of protruding leads of the leaded objects. Any material capable of a mirror-like finishing or coating or attachment can be used. Metal is a good example of a material for mirror finishing.

This Sheet Has Been Replaced



- 5 -

In order to guide the objects while being inspected, two lipped guides 12 are positioned on both sides of the track above the basis thereof. The bottom-inside surfaces of both guides are lipped at 45° from the horizontal and the top-outer surfaces of the guides are chamfered. The degree of chamfering is not crucial although the chamfer angle should prevent any shadows from being cast on the top surface. In the shown embodiment the chamfer angle is 60° from the horizontal.

The bottom-inside lip of each guide 12 is mirror finished. The length of the lip has to be long enough to reflect the leaded parts of the object. In order for the lipped guides to minimize any shadows cast on the top surface of the object due to one or more light sources 14 positioned for the surface detail inspection above the object, the guides 12 are as small as possible with respect to height.

For singulation of the objects 10 one or more stoppers, high-speed rollers or conveyors are used. The embodiment as shown in Fig. 2 uses three stoppers 40, 41 and 42 which are placed above the track 11 and operated in a sequenced up and down manner to allow the objects to be singulated one by one into the field of view of the imaging sensors 16 and 25.

In this embodiment, the invention requires only one station for both imaging sensors 16 and 25 to perform all the required measurements and inspections. As the top lighting 14 and side lighting 18 do not interfere with one another because of the shielding by the lipped track 12. The use of strobes is not essential and the invention can use continuous light sources for lighting. The stopper 40 momentarily stops the objects 10 so that each object is fully resting on the track 11 and is stable positioned for inspection and not floating. The two lipped guides 12 and the track 11 is novel in the invention as they act as both support for the objects 10 as well as back lighting reflectors for the imaging sensors.

The length of the lipped guides 12 and the right angle triangle track 11 can be of any length and size as appropriate to view the object to be measured and to support the object during travel.

With respect to different embodiments of the triangle track the below description of Fig. 7A through 7D gives further details.

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- 6 -

In another embodiment as shown in Fig. 4, the invention uses a single roller 43 instead of stoppers. The outer perimeter of the roller is made of a flexible rubber-like material so that the roller positively catches the object 10 as it enters. The flexible material will also cater to objects with small height variation. The roller is attached to a motor or any revolving mechanism.

The invention may also provide a feature whereby the roller 43 is spring-loaded so that both the pressure of the roller on the object is regulated and controlled. This feature is in addition to the rubber perimeter of the roller and reinforces the ability of the invention to cater for objects of slightly varying heights.

The roller 43 rolls the object forward until the roller is no longer in contact with the object. When this happens, the object will fall by gravity. As the velocity of the object falling by gravity is faster than the velocity of the subsequent objects transported by the roller, the falling object will separate from the rest of the objects. In this way, the objects will singulate and fall one at a time.

The gap between falling objects and the frequency of each falling object is controllable by the invention by adjusting the speed of the rotating roller. The faster the roller speeds, the smaller the gap and the faster the frequency of falling objects.

In this embodiment with the roller, the imaging sensor 25 positioned below the track is placed below that of the roller 43. This feature allows the imaging sensor 25 to inspect the object 10 when it is pressed against the track 11 and while the object is still in motion. Pressing the object against the track provides stability to the object which could otherwise float and provide erroneous measurement results when the object is viewed from the side. Whereas it is acceptable for the object to be slightly floating when viewed by the top imaging sensor 16, this is not acceptable for the bottom imaging sensor 25.

In yet another embodiment of the invention as shown in Fig. 5, a conveyor 44 is used for to transport the objects 10 instead of a roller. The lipped guide at the viewer's side is not shown in this drawing. The conveyor 44 will make contact across a larger surface area of the object and may even make contact with more than one object at a time. The entrance to the conveyor can also be made larger by leaving a small gap between the object and the conveyor so that the

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- 7 -

entrance is wider. This will allow to reduce the possibility of objects jamming at the entrance. The conveyor can be of any appropriate length and the conveyor can be of various design and size with two or more rollers.

For inspection or examination of the top surface of the object, as shown in Figs. 2, 4 or 5, the imaging sensor 16 is positioned above the track 11 at a distance high enough to detect full dimensional size of the top surface of the object. The representation 35 of an example of top surface details, which the top imaging sensor 16 can see, is shown in Fig. 6A. This drawing shows the top imaging sensor view on a display screen 32 of a computer unit 30 which according to Fig. 1 is supplied by the output signals of the top imaging sensor 16 via conductor 33. The displayed example indicates that not only printed data but also stains 36 and/or scratches 37 on the top surface can be recognized, as well as the dimensional length and width of an object.

With respect to the inspection of the object's dimensional size and the measuring of the protruding parts, particularly the leads or legs 20, diffused light sources 18 are placed on each side of the track 11 and the lipped guides 12 for lighting up the side view of the leaded object 10. Either continuous lighting or strobe (flash) lights can be used. These light sources are arranged to provide a back lighted or silhouetted image of the object and the leads. The same light is used to provide a silhouetted image of the bottom dimensions and that of the side dimensions of the leaded object.

The light of the light sources 18 is reflected at the 45° mirror finished surfaces at the bottom side of track 11 and the bottom-inside surfaces of the lipped guides 12. The shadows 21 of the back-lit horizontal part of the leads or legs 20 and the shadows 22 of the vertical part of the back-lit leads or legs 20 are shown in Fig. 1 on both sides of those portions 23 which are front lit by the light sources 18. These images will be detected by the imaging sensors 25.

The output signal of the imaging sensor 25 is applied through conductor 31 to the computer unit 30 which processes the signals for display on the screen 32. This bottom imaging sensor view is shown in Fig. 6B.

Since the images as seen by the imaging sensors are describable by a set of two coordinate axes, all object points are strictly linearly proportional. This

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- 8 -

simplifies the processing by the computer unit significantly, so that standard personal computers can be used without necessarily having high computational power.

Thus, the shadows 22 of the vertical part of the leads or legs 20 can be easily transformed in order to be shown on the screen as an extension of the shadows 21 of the horizontal part of the leads or legs together with the shadow 23 of the portion of object 10 protruding along both sides of the track 11.

Fig. 6B also shows that the horizontal part 27 and the vertical part 28 of the leads or legs are shorter than the nominal length which is indicated by dotted lines on the screen.

The invention provides also modifications for objects with long legs or long leads 45 as shown in Fig. 7B through 7D. The right angle triangle track as described according to Fig. 1 is shown in a simplified way for comparison purposes in Fig. 7A. In the further embodiment according to Fig. 7B the right angle triangle track is extended into an irregular pentagon 46 so that the right angle triangle sides of the pentagonal track can see the tip of the leads 45.

The invention also provides for the right angle triangle to be manually or automatically adjustable up and down to accommodate for the variations in lead length as shown in Fig. 7C by using a stationary platform 47 to support the object 10 in conjunction with a right angle triangle 48 adjustable up and down.

The apex angle of the triangle according to the invention does not strictly have to remain at 90° although the use of a right angle is of advantage for direct and linearly proportional reflection. A larger or smaller apex angle 50 for a triangle 49, as shown in Fig. 7D, can be used to provide an angled view of the features of the object. In this embodiment, the computer unit 30 that processes the signals will have to take this angled reflection into consideration.

The invention further includes features to allow objects of various sizes to be accommodated. For that purpose either lipped guides 52 are fixed onto moveable platforms 53 or they themselves can be moved inwards and outwards to accommodate for variation in object width. In this embodiment, as shown in Fig. 8, the lipped guides 52 are double chamfered on the outer surface to allow

- 9 -

more light to shine onto the top surface at an acute angle. A curved outer surface can also achieve the same effect of reducing shadows.

An elongated right angle track 55 is also placed on a moveable platform allowing upward and downward movements. In the shown embodiment, the right angle track 55 is divided into two halves that can be adjusted inward and outward to accommodate for variations in object width. The two halves of the track 55 can also be adjusted upward and downward to accommodate for variations in object thickness. With these possibilities for adjustment the side view light sources 18 have to be adjusted accordingly.

The platforms can be moved manually or automatically to accommodate for variations in size from batches of objects of the same size to individual variations in size.

The actual design of the platform or movement mechanism is immaterial provided that the lipped track guides and the right angle track can be moved to accommodate for the object and the features of the object to be inspected are not blocked from viewing by the imaging sensors.

Although a preferred embodiment of the invention has been described in detail, it is to be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

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- 10 -

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What is claimed is:

1. An apparatus with at least one inspection station for inspection of objects or leaded objects travelling on a track and being individually inspected, said apparatus using at least one vision inspection system with one or more imaging sensors for surface detail inspection as well as for object dimensioning and/or measuring protrusions from said objects to be inspected, said apparatus comprising at least one light source for front and/or back lighting, characterized by:

- said track (11; 46; 48; 49; 55) being shaped into a triangle with the basis between the two adjacent corners supporting said objects (10) and the apex being in an inverted pyramid position, with the two adjacent faces of said triangle at the apex being mirror polished, said basis between said two adjacent corners being dimensionally smaller than said objects (10) so that opposite sides of said objects and in case of a leaded object its leads or legs (20; 45) protrude along said adjacent corners of said track;
- two lipped guides (12; 52) which guide said objects (10) from opposite sides, the bottom-inside surfaces of both said guides being lipped at an acute angle from the horizontal and being mirror finished, said lips having a length long enough to reflect said leads or legs (20) of said leaded objects;
- said light source preferably consisting of a side view diffused light source (18) on each side of said track (11; 46; 48; 49; 55), said diffused light sources being used to provide a silhouetted image of said leads or legs (20; 45) and/or a front image of the bottom and side dimensions of said objects (10);
- and said imaging sensor (25) being positioned below said track.

2. An apparatus according to claim 1, wherein said track (11; 46; 48; 49; 55) is a right angle triangle with two adjacent 45° corners and a 90° apex,

- and wherein said bottom-inside surfaces of said lipped guides (12; 52) are lipped at 45° from the horizontal.

3. An apparatus according to claim 1 or 2, wherein at least one top view light source (14) and a top imaging sensor (16) are positioned above said objects (10) for top surface detail inspection.



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- 11 -

4. An apparatus according to anyone of claims 1 through 3, wherein a computer unit (30) receives output signals of said imaging sensor (25) and/or said top imaging sensor (16) for displaying said object dimensions as well as said leads or legs (20; 27, 28; 45) and/or said top surface details (35; 36, 37) on a display screen (32) after processing.
5. An apparatus according to claims 1, 3 and 4 or claims 2 through 4, wherein the top-outer surfaces of said lipped guides (12; 52) are chamfered or curved to prevent any shadows from being cast on the top surface of said object.
6. An apparatus according to anyone of claims 1 through 5, wherein said objects or leaded objects (10) are moved individually into said inspection station by use of a roller (43) or a conveyor-like device (44) which act as a transportation mechanism as well as a mechanism to stabilize the object to be inspected against the track.
7. An apparatus according to claim 6, wherein said roller (43) or said conveyor-like device (44) have a flexible rubber-like surface material in order to cater to variations of hight of the objects.
8. An apparatus according to anyone of claims 1 through 7, wherein said inspection is carried out as an "on-the-fly" inspection.
9. An apparatus according to anyone of claims 1 through 8, wherein said surface detail inspection on the one hand and said object dimensioning and/or said protrusion measuring inspection on the other hand are performed at two different stations.



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- 12 -

10. An apparatus according to claims 1 and 6, wherein the bottom inspection station is placed below the position of said roller (40) or said conveyor-like device (44), and wherein the top inspection station is placed closely in front of the bottom inspection station.

11. An apparatus according to anyone of claims 1 to 10, wherein the cross-section of the right angle triangle track is extended into an irregular pentagon (46).

12. An apparatus according to anyone of claims 1 to 10, wherein the track comprises a stationary platform (47) and a triangle (48) which is manually or automatically adjustable up and down to accommodate for variations in lead length of the objects.

13. An apparatus according to anyone of claims 1 to 12, wherein the two lipped guides (52) or said platform (53) to which they are fixed are movable inwards and outwards to accommodate for variations of the object width.

14. An apparatus according to claims 1 to 3, wherein said triangle track (55) consists of two halves which are movable for in and out and/or up and down adjustment.

15. An apparatus according to anyone of claims 1 to 14, wherein the elongated triangle (55) is positioned on a platform allowing upward and downward adjustment.



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- 13 -

16. A method for transporting, inspecting and measuring objects or leaded objects as well as surface details at high speeds said method comprising the steps of:

- providing a track (11; 46; 48; 49; 55) for feeding said objects or leaded objects (10) to an inspection station by means of "singulation" devices, said track being shaped into a triangle with the basis between two adjacent corners supporting said objects and the apex being in an inverted pyramid position, with the two adjacent faces of said triangle at the apex being mirror finished;
- guiding said objects (10) on said track (11; 46; 48; 49; 55) on both sides by means of lipped guides (12; 52), with said objects protruding along said adjacent corners, said lipped guides having a length long enough to reflect the leads (20; 45) of said objects on their mirror finished bottom-inside surfaces;
- providing side view light sources (18) on both sides of said track (11; 46; 48; 49; 55) to illuminate said leads (20; 52) from the rear and side portions of said objects at the front relative to the viewing position of an imaging sensor;
- providing said imaging sensor (25) below the track (11; 46; 48; 49; 55) imaging the back lighted leads (20; 27, 28; 45) of said objects and the front lighted portions of said objects protruding along the corner of said track;
- receiving output signals of said imaging sensor and applying them to a computer unit (30) which after processing displays the object dimensions as well as the leads on a display screen (32).

17. A method according to claim 16, further comprising for additional top surface detail inspection the steps of:

- positioning a top imaging sensor (16) as well as light sources (14) above said objects (10) to be inspected;
- and applying the output signals of said top imaging sensor (16) to said computer unit (30) for displaying after processing the top surface details of the inspected objects on said display screen (32).



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