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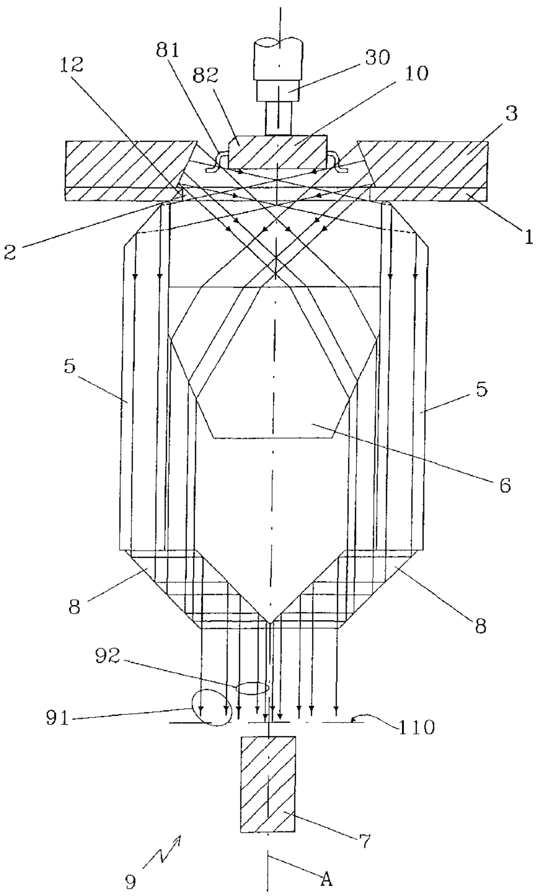

(57) Abstract: The invention refers to an optical inspection system for an inspection of an object in form of a leaded IC component, wherein the object is positioned in an overlapping relationship with an aperture of a datum and illuminated by a lateral diffuse light source, thereby projecting contour images of the object and of a reference contour of the reference edge through the aperture in several projection directions. An optical side prism and a center prism is provided to receive the projection light under two different incident angles thus defining two different projection paths so that a three dimensional image can be captured by analyzing the light of these two projection paths coming from one object point. The side prism and the center prism are designed and arranged such that the projection paths of the first and second projections have the same optical length between the lead-including contour of the object and an imaging plane of the system.

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THREE DIMENSIONAL INSPECTION OF LEADED ICs

The invention relates to an apparatus for a three dimensional inspection of a leaded integrated circuit (IC).

Background of the invention

In the manufacture of electronic components having a plurality of pins or leads, such as integrated circuits, inspection systems using an optical system have been proposed which provide three-dimensional inspection of electronic components.

In order to obtain a three-dimensional inspection of IC-components it was further proposed to provide at least two optical paths along which different images of the integrated circuit to be inspected are transmitted to an image sensor.

For example, in U.S. patent No. 5,909,285 a method for inspection of integrated circuits is disclosed which includes a camera to image a precision pattern mask deposited on a transparent reticle to be inspected. The integrated circuit to be inspected is illuminated using diffused light. A side view of the integrated circuit is reflected to the camera by using an overhead mirror or prism. However, this method uses front lighting and further requires the integrated circuit to be exactly positioned on the transparent reticle.

From U.S. patent No. 5,910,844 a vision inspection system is known in which eight optical images are instantaneously recorded on singular image frames which are output from two optical cameras. The inspection system according to U.S. patent 5,910,844 requires complex optical reflecting means using a plurality of optical directing members. However, according to U.S. patent 5,910,844, the optical directing members have to be selectively adjusted when objects of various sizes are inspected.

Moreover, from U.S. patent application No. 09/205,852 an optical inspection system for determining positional information of an object with respect to a reference is known. A datum, which is used as a reference of the system, is placed in proximity to the object to be inspected. Further, a diffuse light source is provided for illuminating the object. The light source is set up such that a point on the object and a point on the datum will lie in the same plane as their images along at least two optical paths that form an angle with one another. Further, an imaging subsystem is provided which captures images along the two optical paths. The captured images are correlated and analyzed by the imaging subsystem in order to provide positional information of the point on the object with respect to the point on the datum. According to U.S. patent application 09/205,852 it is possible to form the two optical paths which are relayed on the imaging subsystem by using a trapezoidal prism for one optical path and a mirror for the other optical path. Further, it is also possible to use one single trapezoidal prism for providing the two optical paths. In this way, one optical path is formed along an internal surface of the trapezoidal prism and the other optical path is formed along an external surface of the trapezoidal prism.

However, according to U.S. patent application 09/205,852, the two optical paths differ in optical length such that the image quality and thus the precision of the inspection system suffers. Further, in the case in which two sides of an object, e.g. of a dual sided IC, are inspected by using two of the optical arrangements for providing two optical paths each as disclosed in US 09/205,852, a large sensor area is required in the optical subsystem for capturing the images resulting from the two optical paths due to a large blank area existing in the central portion of the image produced by the inspection system.

Summary of the invention

The invention provides an inspection system in form of leaded integrated circuits (IC). A system according to the invention is capable of measuring the leads of a wide body IC package within a confined space. In other words, the object of the invention is to enable a three dimensional IC lead measurement in a very compact manner.

A system according to the invention comprises a datum with an aperture therein defined by a reference edge, the datum providing a reference plane which is at least substantially perpendicular to the optical axis of the system, wherein an object to be inspected is to be positioned in overlapping relationship with the aperture of the datum. The system further comprising a lateral diffuse light source for laterally irradiating diffuse light through the aperture thereby projecting contour images of a lead-including contour of the object and of a reference contour of the reference edge through the aperture in several projection directions, and an optical side prism for receiving a first projection of the contour images from a first projection direction. The side prism having an entrance surface, an exit surface and an internal reflection surface cooperating with the entrance surface and the exit surface for an internal reflection of the first projection through the exit surface of the side prism in an exit direction toward an imaging plane, and the system comprising an optical center prism arranged to receive a second projection of the contour images from a second projection direction, which center prism having an entrance refraction surface and an exit refraction surface cooperating with the entrance refraction surface in a predetermined position such that the second projection is refracted by the entrance refraction surface and by the entrance refraction surface toward the imaging plane. The side prism and the center prism are now designed and arranged such that the projection paths of the first and second projections have the same optical length between the lead-including contour of the object and the imaging plane.

For providing the same optical length of the two projection paths between the lead including contour of the object and the imaging plane definded by the side prism and the center prism, respectively, the side prism must be adapted in its shape corresponding to the shape of the center prism and the optical length of that light starting from the contour of the object and traveling through the center prism to the imaging plane, or vice versa. With other words, the dimensions of the side prism and the center prism and the arrangement must be coordinated, i.e. mated, with each other. Based on the principle that optical lengths of a light ray are different when traveling through different optical media, the optical length is thus a function of the geometrical length and the optical media. In the result, by providing two different optical media for the side prism and the center prism, respectively, and a third medium air, an adaption according to the same optical length can be achieved by adapting the respective prism dimension taking into consideration a special arrangement in the third medium air.

According to a preferred embodiment of the present invention it is possible to arrange two or more identical optical side prisms in order to measure or inspect for example two or more sides of a dual- or more-sided IC-component. That means that the system of a single side prism and center prism is mirrored at the center axis so that the side prisms are then arranged symmetrically around the optical axis of the system and they are also arranged symmetrically around the common center prism that is in turn arranged symmetrically around the center axis of the system. In the result a projection of the contour from the respective side of the IC runs through a respective side prism and the center prism, defining for each side of the object two projections. Thereby, the each side of the plural-sided IC-component is inspected simultaneously.

Further, in a preferred embodiment, in order to reduce the image area required for capturing an image of the projections provided by the one or two optical side prisms and the center prism, a rhomboid prism is provided which effects a displacement of the first projection and second projection parallel to and close to the optical axis of the system. The image area for the inspection is therefore reduced, leading to an improvement of the effective image resolution and thus to an improved measurement accuracy.

The images produced by the inspection system are preferably captured via a lens by a video camera and are then digitized and processed by a processor of a computer in order to determine the 3-D coordinates of the objects with respect to the datum.

Brief description of the drawings

To illustrate the invention a preferred embodiment will be described herein with reference to the accompanying drawings. In the drawings

Figure 1 shows a schematic view of the inspection system according to the preferred embodiment of the invention;

Figure 2 shows the two luminating beam paths of the side prism and the center prism, respectively.

Detailed description of the preferred embodiment

An inspection system for an inspection of an object in the form of a leaded IC-component according to one preferred embodiment of the invention is illustrated in Figure 1 and comprises: a datum 1 with an aperture 2 therein defined by a reference edge 12, the datum 1 providing a reference plane which is perpendicular to the optical axis A of the system, an object carrier 30 for positioning the object 10 in overlapping relationship with the aperture 2 of the datum 1 and thus in a plane being focused by the system, a diffuse light source 3 for radiating diffuse light through the aperture 2 thereby projecting a lead-including contour of the object 10 and a contour of the reference edge 12 through the aperture 2 in several projection directions, the system further comprises two optical side prisms 5 for receiving the projections of the contours and the leads, one center prism 6, and an image detecting system 9 including a lens and a camera with an image sensor.

As this can be seen in Fig. 1, the lighting 3 is preferably arranged laterally on top of the datum 1, but can also be arranged over the datum. Preferably the lighting 3 emits a light of a single wavelength or a narrow bandwidth of wavelengths in order to reduce the colour dispersion which might otherwise be caused by the long travel distances in the optical prisms. Such narrow bandwidth of the lighting 3 can for example be realized by a filter (not shown).

The object may be positioned in the neighbourhood of and overlapping the aperture 2, e.g. by an object carrier 30 which preferably has a vacuum tip in order to hold the object 10 from above. The object 10 is aligned with the optical axis A of the system and its position relative to the datum can be changed and adjusted by the object carrier to arrange the object in that effect that symmetrical object points lie in one plane parallel to the reference plane of the aperture, i.e. the datum. The lighting 3 provides a diffused back-lighting. Thus, the leads or pins 81 of the object 10 and the package body 82 of the object 10 are back-lighted by the lighting 3 by bringing the object with its leads to be inspected into said diffuse light.

As said above, the datum 1 provides a reference plane to the system. Preferably, the datum and accordingly the reference plane is at least substantially perpendicular to the optical axis of the system. The aperture 2 is formed in the datum 1 and defined by four reference edges 12 or two pairs of parallel reference edges 12, wherein the distance between two opposite reference edges is known. The distance between two opposite reference edges 12 of the datum 1 is slightly greater than the outer dimension of the largest IC-component 10 to be inspected. In order to provide a stable reference plane, the datum 1 is made of a mechanically strong and stable material such as carbide or Invar. The top surface of the datum 1 is ground and polished to a very high flatness. The reference edges 12 of the datum 1 are formed sharp, straight and accurately finished. The aperture wall of the datum 1 constituting the reference edges 12 can be blackened in order to avoid or reduce reflection from the opposite lighting.

After leaving the plane of the datum the projection light coming from the respective light source and having an incidence angle lying in a special angle range impinges onto a respective side prism 5. As this is to be seen in Fig. 1 the described preferred embodiment comprises two side prisms for inspecting two sides of the IC component which sides include the leads of the IC. Both the two optical side prisms 5 are arranged symmetrically with respect to the optical axis A of the system. Each optical side prism has six side surfaces and a four-sided cross-section including an entrance surface 61, an exit surface 62 and an internal reflection surface 52 cooperating with the entrance surface and the exit surface for an internal reflection of the projection of the contours of the object and the aperture through the exit surface of the respective side in an exit direction towards an imaging plane 110 in such a way that a first projection path between said contour and the imaging plane is defined.

It is possible that refraction occurs at the entrance surface and at the exit surface of the side prism depending on the angle at which the projection light impinges on the respective surface. While the reflection surface of the side prism is inclined with respect to the imaging plane to enable that the reflected light coming through the entrance surface by a special predetermined angle range is directed parallel to the central axis of the system, the exit surface is perpendicular to the central axis. In the result, the projection leaving the respective side prism is directed parallel to said center axis A, i.e. the optical axis of the system.

The system further comprises an optical center prism 6 with an entrance refractive surface 63 and an exit refractive surface 64, wherein the incoming projection light of the contour of the object and the aperture is refracted at both the entrance refraction surface 63 and the exit refraction surface 64, so as to define a second projection path 91 between the said contour and the imaging plane 110. The center prism 6 has a six-sided cross-section and has eighth side surfaces in case two side prisms are used and in case four side prisms are used the center prism is provided with ten side surfaces. The center prism has an axis around which the center prism is arranged symmetrically, wherein this center prism axis is coincident with the center axis A of the system when the center prism is positioned in the system.

While the exit refraction surface 64 of the center prism is slanted at an angle with respect to the center axis such that the ray exiting from the exit refraction surface is refracted to be parallel to the optical axis A, the entrance refraction surface is parallel to the imaging plane, i.e. perpendicular to the center axis of the system and thus perpendicular to the normal of the center prism.

According to a preferred embodiment, when using two opposite side prisms two rhomboid prisms 8 are arranged below the optical side prisms 5 and the center prism 6, i.e. between (i) the respective exit surface 62 of the side prisms and the exit refraction surface 64 of the center prism and (ii) the imaging plane 110, and the rhomboid prisms are directed towards the optical axis A of the inspection system. Further, the rhomboid prisms 8 are each arranged symmetrically with respect to the optical axis of the system. This arrangement of the rhomboid prisms enables to displace the projection light entering the respective rhomboid prism toward the optical center axis A of the system in order to reduce the image area required for capturing an image of the projections.

Each rhomboid prism 8 comprises an entrance surface and an exit surface each perpendicular to the optical axis and two internal reflection surfaces reflecting the projection light within its path through said prism. The entrance surface is provided with such dimensions to be capable of receiving the light of either the projection path 91 and projection path 92, i.e. the light which leaves the side prism 5 and the center prism 6, respectively. The respective projection light first impinges perpendicular onto the entrance surface and further at an angle of 45° onto the first reflection surface being reflected under 90°. The projection light then impinges onto the second reflection surface again at an angle of 45°, so that said light is parallel to the center axis A after last reflection. Since the projection light enters the respective rhomboid prism parallel to the optical axis of the system each reflective surface is thus inclined with an angle of 45° with respect to said axis A, so that in comparison of the incoming and outgoing projection light of the rhomboid prism the respective projection light direction is not changed by the rhomboid prism, but only displaced closer to the optical center axis of the system. The image area for the dual-sided inspection is therefore reduced, leading to an improvement of the effective image resolution and thus to improved measurement accuracy.

Preferably a lens is provided (not shown) which lens is attached to a video camera 7 and arranged in alignment with the optical axis of the system. A sensor plate is arranged in the imaging plane which sensor plate belongs to the video camera 7, so that a single image is captured comprising the projections of the contour of the reference edge 12 of the datum 1 and the contours of the leads 81 and the package body 82 of the object 10. This image is generated for one side of the object by projecting the contours of the reference edge 12 of the datum 1, the lead tips 81 and the package body 82 of the object 10 along two projection paths 91 and 92 having two different directions corresponding to two different viewing angles $\theta 1$ and $\theta 2$, respectively, and thus containing three-dimensional information. The image captured by the video camera 7 is digitized and analyzed using a digital image processing means, such as an edge detection means. With other words, the system derives the relative positions of the features such as lead tips and package outline of the object 10 and computes the mechanical parameters like lead pitch and terminal dimensions by correlating and analyzing the captured pictures.

With reference to Fig. 2 the two projection light paths of the left side prism and the center prism are shown, respectively, wherein only one side of the prism arrangement is disclosed, since the preferred arrangement is symmetrically provided with reference to the optical axis, and thus a corresponding projection light path is created by the opposite second side prism (not shown) according to Fig. 1.

Both projection paths shown in this Fig. 2 start from one point P of the object defining its contour point that is to be inspected, wherein this point can be viewed along the two projection paths 91 and 92 provided by the optical side prism 5 and the center prism 6. Thus the object point P must lie in a plane being capable of being focused by the system. This two different projection paths 91 and 92 provide two different views with two different viewing angles $\theta 1$ and $\theta 2$ of one object point.

The first projection path 91 is defined by a total internal reflection at the internal surface 52 of the optical side prism 5. This first projection path 91 is correlated with the first viewing angle $\theta 1$. As this is shown in Fig. 2 said first projection path is comprised of the ways a, b, and c, beginning at the object point P and ending at the image plane 110.

The second projection path 92 is defined by refraction at the entrance refraction surface 63 and the exit refraction surface 64 of the center prism 6. This second projection path 92 is correlated with a second viewing angle $\theta 2$. As this is shown in Fig. 2 said second projection path is comprised of the ways d, e, and f, beginning at the object point P and ending at the image plane 110.

The two different viewing angles $\theta 1$ and $\theta 2$ are provided by an predetermined angle between the plane of the reflection surface 52 of the side prism 5 and the plane of the entrance refraction surface 63 of the center prism 6.

While solely a reflection at the reflection surface 52 of the side prism 5 serves to deviate the projection light parallel to the optical center axis A, the projection light of the second projection path traveling through the center prism is deviated twice at the entrance refraction surface and the exit refraction surface to direct the light parallel to the optical axis A.

By deviating the projection light towards the optical center axis, i.e. the normal of the center prism, the center prism must have a refractive index that is higher than that of the other medium outside. According to the preferred embodiment of the invention, the other medium is air having an refractive index of approximately 1.

Between the plane 100 and the imaging plane 110, as indicated in Fig. 2, the projection light of the first projection path 91 and the projection light of the second projection path 92 are guided such that they are in parallel to the optical axis A of the system.

According to the invention, the optical length difference between two projection light rays is compensated at an exit plane 100 being arranged in parallel to the datum 1 and aligned with the bottom surface of the optical side prism 5, while the maximum allowable angular difference between the two viewing angles $\theta 1$ and $\theta 2$ is retained and a sufficient margin between the lead tip 81 and the reference edge 12 is maintained in the image.

The optical length difference δ between the first projection path 91 and the second projection path 92 at a surface 100 can be calculated from Formula 1:

$$\delta=[a/n1]+[(b+c)/n2]-[(d+f)/n1]-e/n3$$

wherein a, b, c, d, e, f are the partial lengths of the projection paths 91 and 92, n1 is the refractive index of the medium outside the optical prisms, n2 is the refractive index of the material of the optical prisms 5 and n3 is the refractive index of the material of the center prism 6. The optical length is referred to herein as $L_o=L_g*n$, wherein L_o is the optical length, L_g is the geometrical length and n is the refractive index of the material in which the geometrical length extends.

Since the medium outside the prisms 5 is preferably air, n1 is equal to 1, such that Formula 1 can be written as:

$$\delta = a+[(b+c)/n2]-(d+f)-[e/n3]$$

By choosing a material having a suitable refractive index n2 and n3, respectively, the optical length difference δ between the first projection path 91 (a+b+c) and the second projection path (d+e+f) can be compensated.

It is also possible to use another medium than air as the other medium, for example another gas or a fluid or glass.

As mentioned above, one aspect of influencing the optical length of the two projection paths 91 and 92 coming from the same object point such as the reference edge 12 or the lead tips 81 of the object at the viewing angles $\theta1$ and $\theta2$, respectively, is choosing a suitable optical material for the optical side prism 5 and the center prism 6.

A further aspect of minimizing the length difference between the two projection paths is providing appropriate viewing angles $\theta1$ and $\theta2$ as well as suitable dimensions of the optical side prisms 5 and/or the center prism 6.

According to the preferred embodiment of the invention a further aspect of influencing the equalization of the length of the two projection paths 91 and 92 is the dimension of the aperture 2 of the datum 1 and the arrangement of the optical side prisms 5 and/or the center prism 6 with respect to the datum 1 and the aperture 2 of the datum 1.

Although the invention has been described with respect to preferred embodiments in detail, it should 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.

Claims:

1. An optical inspection system for an inspection of an object in form of a leaded integrated circuit component, the system having an optical axis and comprising:

a datum (1) with an aperture (2) therein defined by a reference edge (12), the datum providing a reference plane which is at least substantially perpendicular to the optical axis (A) of the system, wherein the object (10) to be inspected is to be positioned in overlapping relationship with the aperture (2) of the datum (1) in a predetermined position,

a lateral diffuse light source (3) for laterally irradiating diffuse light onto the object and through the aperture (2) thereby projecting contour images of a lead-including contour of the positioned object (10) and of the reference edge (12) through the aperture (2) in several projection directions,

an optical side prism (5) for receiving a first projection light of the contour images from a first projection direction, which side prism having an entrance surface (51), an exit surface (62) and an internal reflection surface (52) cooperating with the entrance surface and the exit surface for an internal reflection of the first projection light through the exit surface of the side prism in an exit direction toward an imaging plane,

and an optical center prism (6) arranged to receive a second projection light of the contour images from a second projection direction, which center prism (6) having an entrance refraction surface (63) and an exit refraction surface (64) cooperating with the entrance refraction surface in a predetermined position such that the second projection light is refracted by the entrance refraction surface and by the exit refraction surface toward the imaging plane (110),

wherein the side prism (5) and the center prism (6) are designed and arranged such that the projection paths of the first and second projections have the same optical length between the lead-including contour of the object (10) and the imaging plane (110).

2. The system according to claim 1, further comprising:
an image detection system arranged at the imaging plane for detecting an image of the two projections of the contours.

3. The system according to claim 2, wherein the image detection system comprises a lens and a camera (7) with an image sensor.

4. The system according to one of claims 1 to 3, wherein the first projection direction and the second projection direction correspond to a first viewing angle ($\Theta 1$) and a second viewing angle ($\Theta 2$), respectively, which are different from each other.

5. The system according one of claims 1 to 4, further comprising a rhomboid prism (8) being arranged between the exit surfaces of the side prism and of the center prism and the imaging plane for displacing the projections entering the rhomboid prism parallel to and closer towards the optical axis of the system.

Fig. 1

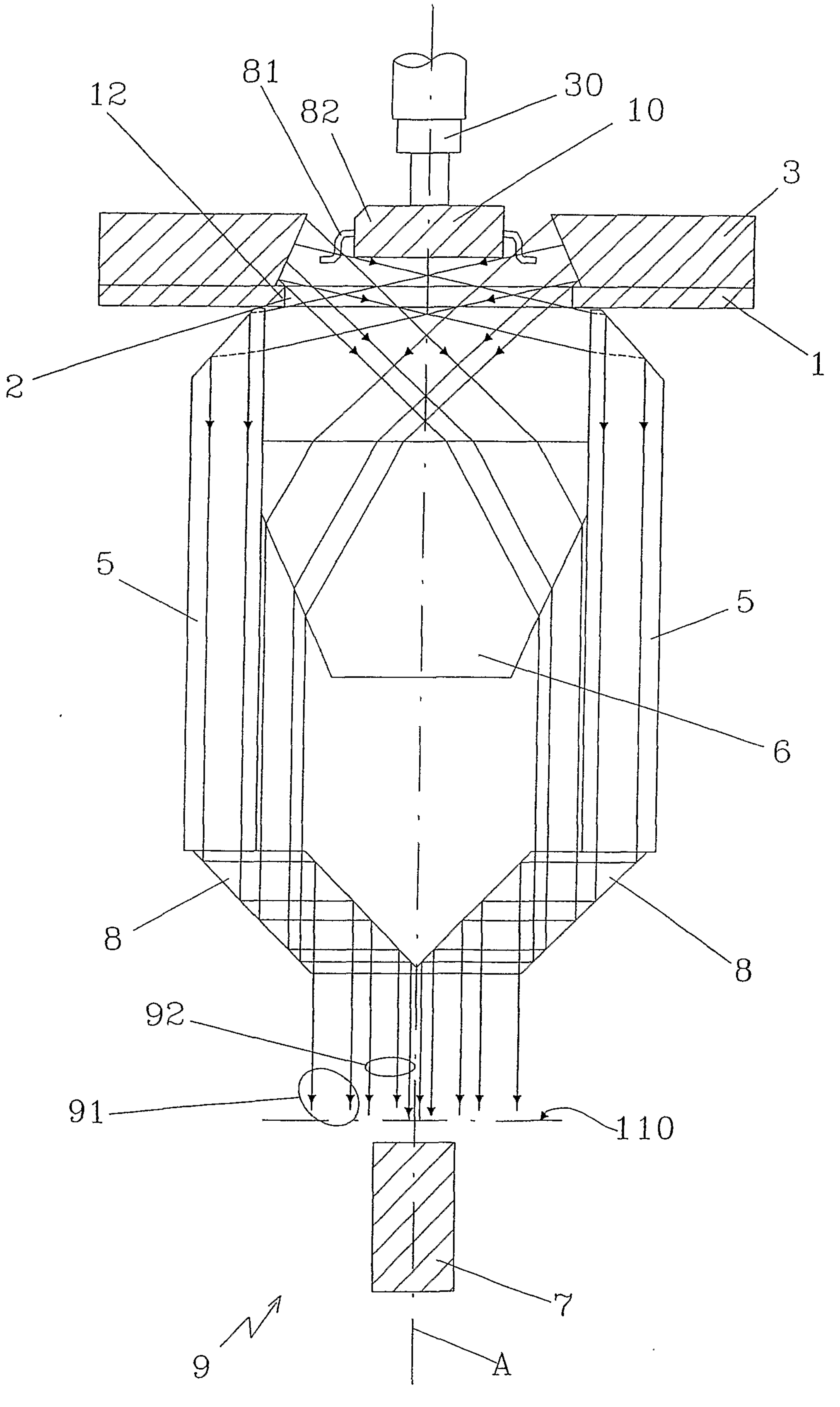

Fig. 2