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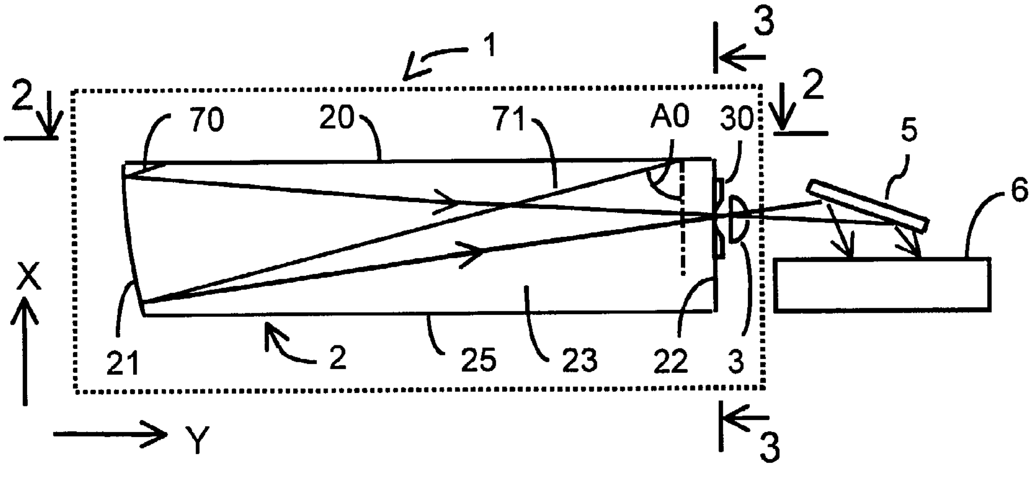
(54) Title: FINGERPRINT IMAGING DEVICE



(57) Abstract: A fingerprint imaging device (1) provides a wide range of fingerprint pattern observation angles to the normal to a surface of a finger field on an optical plate. The optical plate (2) includes a converging mirror (21) being formed at a lateral surface of the optical plate (2). The converging mirror (21) receives imaging light rays from the finger field (20) and then reflects them lengthwise through the optical plate (2) to an objective (3) external to the optical plate. The objective (3) is positioned such that its focal point is located in close proximity to substantially free of geometric distortions. To further reduce a thickness of the optical plate the optical plate finger field may be covered with micro-irregularities (400) that are accessible for contact with finger skin ridges (500). Reduction of the optical plate thickness is possible using this design because the fingerprint pattern observation angle with respect to slopes of the micro-irregularities is less than the observation angle with respect to the base finger field surface. Preferably, the micro-irregularities are made in the form of micro-prisms extended across the finger field in a direction transverse to the direction of imaging light rays.

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FINGERPRINT IMAGING DEVICE

TECHNICAL FIELD

This invention relates to fingerprint imaging devices for fingerprint matching systems.

BACKGROUND

Up-to-date fingerprint matching systems using fingerprint image transfer into electronic data usually apply the known contact method to create a fingerprint pattern. A surface topography of a finger is approximated by a series of ridges with intermediate valleys. When a finger is applied to a smooth surface of a transparent optical plate or prism, the ridges contact the optical plate while the valleys do not and instead serve to form the boundaries of regions of air and/or moisture.

The finger to be imaged is illuminated by a light source located below or near to the optical plate. Imaging light from the light source is incident on the smooth surface at an angle of incidence measured with respect to a normal to the smooth surface. Imaging light reflected from the smooth surface is detected by an imaging system that usually includes some form of a detector.

Components of a typical fingerprint imaging system are oriented so that an angle of observation (defined to be an angle between an optical axis of the imaging system and the normal to the smooth surface) is greater than a critical angle for the interface between the smooth surface and the air about the smooth surface. The critical angle at the surface/air interface is defined as the smallest angle of incidence for which imaging light striking the surface/air interface is totally internally reflected within the surface. Therefore, the critical angle at the surface/air interface depends on the index of refraction of the air and optical plate. Another constraint for the angle of observation arises because there is incentive to observe the image at the smallest practical angle of observation, as this reduces distortion due to object tilting. Therefore, the angle of observation is typically chosen to be close to, but greater than the critical angle at the surface/air interface.

At locations where the ridges of the finger contact the smooth surface, total internal reflection does not occur because the index of refraction of a finger is larger than that of air. In this case, imaging light incident on the surface of the optical plate at a location where the ridge of the finger contacts the surface is refracted through the surface/finger interface and then partially absorbed and partially diffused upon contact with the finger. In this case, only a small fraction of incident imaging light is reflected back to a detector of the imaging system.

The imaging system may be implemented to produce bright components at valley locations, thus producing a dark or positive fingerprint pattern. In this case, the imaging system detects the imaging light reflected from the surface/air interface. Alternatively, the imaging system may be implemented to produce bright components at ridge locations, thus producing a bright or positive fingerprint pattern. In this case, the imaging system detects a small percentage of the imaging light that is diffused upon contact with the finger.

Fingerprint imaging systems, in versions that produce positive and negative fingerprint patterns, are, for instance, described in U.S. Pat. No. 4,924,085 to Kato et al.; U.S. Pat. No. 5,416,573 to Sartor, Jr.; and U.S. Pat. No. 5,596,454 to Hebert.

A surface image transfer apparatus described in U.S. Pat. No. 5,596,454 has many complicated off-axis optical elements and, due to the multiple reflection of imaging light rays forming the image, total dimensions of the apparatus considerably exceed those of the finger receiving surface itself. Moreover, imaging light incident to the fingerprint surface must be inclined to create the fingerprint pattern image. Resulting geometric distortion of the image can make consequent fingerprint identification difficult. Geometric distortion includes trapezoidal distortion and scale distortion.

A simple fingerprint pattern imaging device is described in U.S. Pat. No. 4,924,085, the device being used as an add-in to a keyboard of a desktop personal computer to serve as an access key. To reduce geometric distortion, the angle of the axis of the imaging light ray from the light source with respect to the normal to the fingerprint pattern surface is chosen close to the lower limit of possible observation angle range. This critical total internal reflection angle at the boundary with air at valleys equals approximately 42 degrees, if the optical plate is made out of acrylic plastic. As a consequence, the section of the imaging light ray has considerable dimensions if the size of the fingerprint pattern fragment being imaged is fixed. In particular, the size of the imaging light ray determines thickness of the device.

U.S. Pat. No. 5,416,573 relates to a fingerprint pattern imaging device in which image deformation occurring when a finger is wet is reduced. The imaging system in this fingerprint pattern imaging device observes the fingerprint pattern at an angle exceeding the critical total internal reflection angle for the boundary with water and approaching the upper limit of the interval mentioned, that is, to the critical total internal reflection angle for the boundary with ridges. To decrease geometric distortion of the image, an optical plate material is selected with a high index of refraction, thus decreasing the observation angle. Because of these constraints, the fingerprint pattern imaging device has a large optical system.

SUMMARY

A simply-constructed compact-sized fingerprint imaging device is provided that is substantially free of geometric distortion. The size of the fingerprint imaging device does not substantially exceed the finger field in length and width. Accordingly, the fingerprint imaging device may be built into a compact apparatus.

A fingerprint imaging device is provided. The fingerprint imaging device includes an optical plate for creating a fingerprint pattern at a finger field. The finger field is positioned at a wider side of the optical plate where a finger is normally applied to produce a fingerprint pattern. Finger field regions that interface between the optical plate and finger skin ridges form the fingerprint pattern. This pattern is illuminated with light from illuminating tools and is observed in imaging light rays inclined to the normal to the finger field surface at the observation angle close to the value of a critical angle of total internal reflection (TIR) at the optical plate interface with finger skin ridges.

The imaging light rays are received by an objective that projects an image of the fingerprint pattern to an external image sensor.

The device provides the good quality image, due to the use of a converging mirror located on the lateral surface of the optical plate from the side opposite to the objective. The objective receives imaging light rays as reflected from the converging mirror through the optical plate. The objective is adjusted such that its focus point from the side of the converging mirror is located approximately at the converging mirror focal plane. This makes the converging mirror to receive a substantially parallel beam of the imaging light rays from the fingerprint pattern.

The high value of the observation angle of fingerprint pattern allows for using the optical plate of small thickness and, as the imaging light rays constitute a parallel beam, this provides all the regions of the fingerprint pattern to be imaged at the same scale. Thus, despite the high value of the observation angle, geometrical distortion is substantially reduced.

The illuminating tools are adjusted to illuminate the finger field from directions transverse to the imaging light rays by light penetrating into the optical plate through its lateral surfaces. The illuminating tools are mounted so that they do not protrude beyond the boundaries of the optical plate in height and the total thickness of the device is determined by a thickness of the optical plate.

A fingerprint imaging device is provided that includes an optical plate with its finger field surface being covered with gently sloping micro-irregularities. The finger being applied to the finger field surface produces regions of ridges in contact with micro-irregularities slopes.

The imaging light rays are inclined to the normal to the micro-irregularities slopes at the observation angle less than the angle to the normal to the finger field base surface. While the observation angle is set less than the critical TIR angle at the boundary with ridges, the angle to the normal to the finger field base surface may exceed this value. Since it is the value of the latter angle that determines required thickness of the optical plate, optical plate thickness may be further decreased.

The micro-irregularities may be shaped as microprisms that are triangular in cross-section and extended across the finger field transversely the imaging light rays.

The microprisms may have equally sized facets, with an angle between the facets being in the range from about 150 to about 160 degrees.

Aspects of the techniques and systems can include one or more of the following advantages. The optical plate and corresponding fingerprint imaging device may be reduced in size because a converging mirror is used in the device to capture the imaging light rays reflected from the finger field. For example, the fingerprint imaging device, because of its compact size, may be used in portable and/or compact electronic devices, such as, for example, computer notebooks, personal digital assistants, and cellular or land-based telephones. Moreover, because the components of the fingerprint imaging device are relatively cheap to produce and assemble, the fingerprint imaging device is cheaply made.

The details of one or more embodiments are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

Fig. 1 shows schematically a side view of a fingerprint imaging device that has a compact design.

Fig. 2 represents a top view of the fingerprint imaging device taken along the line 2-2 of Fig. 1.

Fig. 3 is a front view of the fingerprint imaging device taken along the line 3-3 of Fig. 1.

Fig. 4 is a perspective view of an optical plate illustrating a finger field surface structure that may be implemented in the fingerprint imaging device of Fig. 1.

Fig. 5 is a side view of a portion of the optical plate of Fig. 4.

Fig. 6a is a view of a fingerprint pattern fragment as seen along a normal to the finger field surface of Fig. 4.

Fig. 6b is a view of the image of the fingerprint pattern fragment of Fig. 6a.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

In the past, there has not been a need for compact fingerprint imaging devices because fingerprint imaging devices were traditionally used in the fingerprint matching systems used in the field of criminology. However, because there are advantages to using the fingerprint as an identifier, which cannot be forgotten or lost, the field of application for fingerprint imaging devices is constantly expanding. For example, a fingerprint may be used as an access key to resources of different portable personal electronic apparatus. Thus, it becomes beneficial to miniaturize the fingerprint imaging device for use with such portable apparatus.

A fingerprint imaging device with a compact configuration may be implemented in a mass-produced apparatus, such as the portable electronic apparatus. Examples of portable electronic apparatus include cellular telephones, personal computers such as notebooks, and personal digital assistants. For economic reasons, it is important that a fingerprint imaging device may be built into the portable electronic apparatus with substantially no changes in the design of those apparatus. This requirement may be met by a flat configuration of the fingerprint imaging device.

Referring to Fig. 1, a fingerprint imaging device 1 includes an optical plate 2, a flat mirror 5, an image sensor 6, and one or more illuminating tools (not shown in Fig. 1) that produce imaging light to illuminate the fingerprints. For further reference, directions

X and Y of the orthogonal coordinate system connected with the directions of propagation of imaging light rays in the fingerprint imaging device 1 are shown by arrows. A third direction Z of this orthogonal coordinate system is perpendicular to the drawing plane of Fig. 1.

The optical plate 2 is made of, for example, acrylic plastic. The flat mirror 5 may be any mirror coated to reflect light of a wavelength produced by the one or more illuminating tools. The image sensor 6 may be a single crystal CMOS image sensor, produced by Motorola Co., Inc. Or, the image sensor 6 may be a conventional array CCD.

An objective 3 such as, for example, a lens, is positioned external to the optical plate to focus the reflected and/or diffused imaging light rays onto the image sensor 6. In particular, the objective 3 may be a planoconvex lens. The planoconvex lens is a good choice because it provides reasonable image quality for a reasonable cost. Alternatively, to improve non-planarity of the image surface (which may be unacceptable with a planoconvex lens), a bi-concave or convexo-concave lens may be used instead.

The optical plate 2 also includes a finger field 20 located on its top. The fingerprint to be identified is applied to the finger field 20. The finger field 20 has an optically smooth surface to provide good contact with the finger skin ridges.

The finger field 20 has dimensions that are sufficient for reliable identification of the fingerprint pattern. In other words the finger field 20 has dimensions sufficient for a minimum required number of ridge comparisons, which may range anywhere from about 8 to about 16 comparisons. It is conventionally held that the fingerprint dimensions should not be less than about 16 millimeters (mm) in both dimensions. In particular, the surface of the finger field 20 is about 18 mm in length and about 18 mm in width.

A converging mirror 21 is positioned at a lateral surface of the optical plate 2. The converging mirror has a reflecting coating, which, for example, may be a deposited layer of aluminum. The converging mirror 21 for technological reasons is made spherical by way of practically acceptable approximation to theoretically required parabolic or hyperbolic form. The converging mirror 21 preferably has a radius of curvature of about 36 mm and a center of curvature being offset by about 5 mm up from the center of the optical plate along the direction X.

The objective 3 has its object side focal point located approximately at the focal plane of the mirror 21. In this way, the objective 3 together with the converging mirror 21 forms an afocal optical system that may be physically adjusted to receive a substantially parallel beam of the imaging light rays from the fingerprint pattern. Such an afocal optical system provides an image of the fingerprint pattern with minor geometric distortion notwithstanding high values of the observation angle.

The objective 3 and an associated aperture stop 30 are positioned near to a flat lateral surface 22 of the optical plate 2. The object side focal point of the objective 3 is located at a distance of about 1.5 mm from its plane surface facing the lateral surface 22.

The converging mirror 21 is adjusted to receive substantially parallel imaging light rays, which are traveling from the surface of the finger field 20 at the angle A0 with respect to the finger field surface normal. The outer imaging light rays are marked with arrowhead lines 70 and 71 pointing in their direction.

The mirror 21 reflects the imaging light rays through the optical plate 2 to the objective 3 as a converging beam. The objective 3 projects the fingerprint pattern image outside the optical plate 2. The flat mirror 5 directs the imaging light rays emerging from the objective 3 to the image sensor 6. The image sensor 6 detects imaging light rays that are incident on the mirror 21 and reflected from the mirror 21 along a plane parallel to the direction Y.

Thickness of the optical plate 2 along the direction X and the value of the angle A0 are related to each other by the condition that imaging light ray 71 coming from the border of the finger field 20 farthest from the mirror 21 must be captured by the mirror 21.

The angle range of the fingerprint pattern observability is limited by the values of the critical total internal reflection angle at the interface of the optical plate 2 with the ridges and valleys of the finger, correspondingly. Minimum thickness of the optical plate 2 is reached at the value of the angle A0 close to that of the critical total internal reflection angle at the optical plate interface with the finger skin. The material of the optical plate 2 is chosen such that its index of refraction only slightly exceeds the index of refraction for finger skin, which equals 1.44. An optical plate 2 made of acrylic plastic has an index of refraction of about 1.49. In this case, according to Snell's Law, the critical total internal reflection angle at the interface with ridges equals approximately 75 degrees, the angle A0 is therefore 74 degrees, and the thickness of the optical plate 2 corresponding to this value of the angle A0 is about 5 mm.

Traditionally, imaging systems have not been designed to observe fingerprint pattern images at such great angles. There existed an established notion that imaging systems should not or could not observe fingerprint patterns at such a wide angle range due to the impact of high geometric distortion of the fingerprint image, which occurs for converging image rays from the fingerprint pattern.

For the fingerprint imaging device 1, trapezoidal distortion is substantially eliminated because the converging mirror 21 and objective 3 are adjusted to receive a substantially parallel beam of imaging light rays from the fingerprint pattern.

The size of the device 1 along the direction X and also along the direction Y is further reduced because the afocal optical system uses a single reflecting surface (that is, the converging mirror 21) to capture imaging light rays reflected from the finger ridges.

Referring also to Figs. 2 and 3, the imaging device 1 includes illuminating tools 4 that are arranged and operated to illuminate the finger field 20. The illuminating tools 4 may be radiation sources that illuminate the finger field 20 from two opposite directions through lateral surfaces 23 and 24 of the optical plate 2. The illuminating tools 4 are represented by conventional light-emitting diodes irradiating in the red spectral region with the radiation spectrum width being approximately 50 nm.

The illuminating tools 4 emit evenly. However, inside the optical plate 2, a refracted light beam from each radiation source 4 propagates within the limits of an associated restricted solid angle of about 80 degrees in cross-section. The axes of the light rays that are travelling in the Z-X plane (that is, these imaging light rays have no Y direction component) are directed across the axes of the imaging light rays that are incident on the mirror 21 because the imaging light rays that are incident on the mirror 21 have a Y direction component. Moreover, light from the radiation sources 4 that is totally internally reflected by the surface/air interface of the finger field 20 (at the valleys of the finger skin) and surface 25 (Fig. 3) is not involved in the fingerprint pattern imaging.

Dimensions of the fingerprint imaging device 1 in the Z-Y plane are close to the limit imposed by the requirements of the minimum dimensions of the finger field 20.

When a finger is applied to the finger field 20, in the regions of its surface having the boundaries with ridges, the total internal reflection conditions are not met for light from the illuminating tools 4. Imaging light rays penetrate through the surface of the finger field 20 and illuminate the finger skin on its ridges in these regions. Imaging light rays reflected from ridges pass through the optical plate 2 in accordance with the refraction law at angles to the normal of the surface not exceeding the critical total internal reflection angle at the interface with the ridges. These imaging light rays create a negative fingerprint pattern formed by the bright regions corresponding to the ridges of the finger skin because the valleys of the finger skin produce a dark background.

The illuminating tools 4 are mounted along the lateral surfaces 23, 24 of the optical plate 2 as shown in Fig. 3 so that they do not protrude beyond a length of the optical plate along the X direction. Because the illuminating tools do not extend beyond the width of the optical plate 2 in the X direction, the width of the optical plate 2 in the X direction is substantially independent of the width of the illuminating tools. Therefore, a width of the fingerprint imaging device 1 in the X direction is determined by thickness of the optical plate 2 in the X direction.

Fig. 4 represents a perspective view of an alternate embodiment of an optical plate 400 that may be used in a fingerprint pattern imaging device that conforms to the fingerprint pattern imaging device 1 shown in Figs. 1-3 in all features, with the exception of those features discussed below in more detail.

The optical plate 400 includes a finger field 402 that is covered with micro-irregularities representing gently sloping inclines from the level of the finger field 402. Like the optical plate 2, the optical plate 400 also includes a converging mirror 404 made at a surface opposite to a surface 406 of the optical plate 400, adjacent to one or more surfaces 408 of the optical plate 400, and adjacent to a bottom surface 410 of the optical plate 400.

Micro-irregularities are used in the form of microprisms stretched along the direction Z, which are shown scaled-up in respect to the other elements of the device to illustrate their arrangement. These microprisms, triangular in section, are formed by facets 412 and 414 alternating along the direction Y with the period designated by digit 416.

Fig. 5 illustrates a side view of the optical plate 400 of Fig. 4 in which a finger 500 is placed on the finger field 402 and a fingerprint pattern image is formed at the microprism facets.

Facets 412 are inclined to a plane 502 of the finger field 402 shown with dotted line at a small angle B. When the finger 500 is applied to the finger field 402, its ridges, owing to elasticity of the finger skin, contact at least upper parts of facets 412, 414, producing interface regions between the optical plate 400 and the finger skin ridges.

Ray 504 forms the angle A1 to the normal to the plane 502 and the angle A2 to the normal to the facet 412. As it is seen from the drawing of Fig. 5, the value of the angle A1 is equal to the sum of the angles A2 and B.

The angle A2, like the angle A0 in Fig. 1, lies in the observability angle range of the contrast fingerprint pattern, close to the upper limit equal to the critical TIR angle on the boundary with ridges. As discussed above, A2 is approximately 74 degrees for an optical plate 400 made of acrylic plastic. The angle A1 exceeds the angle A2 by the value B and therefore A1 may exceed the critical TIR angle on the boundary with ridges.

A preferred value of the angle B is in a range of about 10 to about 15 degrees, which corresponds to a subtending angle of about 150 to about 160 degrees between the facet 412 and the facet 414. Using this value of angle B, A1 is between about 84 degrees and about 89 degrees for an optical plate made of acrylic plastic. For these values, the entire or almost entire surface of facets 412 is available for contact with the ridges.

Thus, the optical plate 400 provides a margin in the value of the angle A1, which is so large that the value of the critical total internal reflection angle on the boundary with ridges is not a factor in determining the thickness of the fingerprint pattern imaging device.

Converging mirror 404 receives the parallel beam of rays propagating at the angle A1 with respect to the normal to the plane of the finger field 402; therefore, it is the angle A1 that is responsible for the width of the optical plate 400. The thickness of the optical plate 400 may be reduced as compared with the minimum thickness available in the optical plate 2 where a smooth surface of the finger field is used.

The portions of the surface of facets 412 and 414 where the optical plate 400 has the boundaries with the ridges form the fingerprint pattern on the finger field 402. However, only light rays originating from facets 412 facing the mirror 404 take part in the imaging, as the angle formed by light rays received by the mirror 404 with respect to the normal to the surface of any facet 414 is, in contrast, greater than the angle A1 by the value of the angle B and is beyond the observability angle range of the fingerprint pattern.

Figs. 6a and 6b illustrate imaging when the angles A1 and B add up to 90 degrees.

Fig. 6a represents a fragment of the finger field 402 with the fingerprint pattern on it, as it could be seen along the direction X from inside the optical plate 400. Ridge contact regions are nominally shown bright and regions contacting with valleys are dark. Alternating strip portions 600, 602 of the fingerprint pattern correspond to facets 412, 414, respectively.

Fig. 6b shows the image of the fingerprint pattern fragment of Fig. 6a. Average anamorphosis of the entire image along the direction Y at the finger field 402, that is, the image scale in the direction Y relative to that in the direction Z, is determined by the value of the angle A1. The image scale in the Y direction is proportional to cos (A1). The image scale for the portions 600, observed at the angle A2, is two times greater than average anamorphosis, and, accordingly, portions 602 are not represented in the image. If facets 414 are observed at some small angle, each facet 414 only reflects light rays from the adjacent facet 412, which belongs to the same microprism. Accordingly, portions of the fingerprint pattern, following with the period 416 (Fig. 4), are not represented in the image.

Thus, the microprisms on the finger field surface provide the required observation angle of the fingerprint pattern owing to a nonlinear trasformation of the fingerprint pattern into a quantized fingerprint image.

The maximum value of the period of microprisms that could be set with no sacrifice in information about individual characteristics of ridge configuration should not exceed about half the minimum period of the low-frequency spectral region of spatial frequencies of the fingerprint pattern that contains this information. In the direction transverse to ridges (that is, in any direction along the plane Y-Z), a typical value of a period of the fingerprint pattern is in the range of about ½ mm to about ¼ mm. Therefore, the value of the period of microprisms is bounded above by the value of about 0.1 mm.

Choosing the magnitude of the period of microprisms close to this maximum value of 0.1 mm is preferable, since relative dimensions of the contact regions of ridges with surfaces 412 decrease as the period of microprisms decreases, owing to the limited elasticity of finger skin. The preferred value of the period of microprisms determined in the result of research is 0.05 mm. Assuming the facets 412, 414 are of approximately the same size, the size of a facet 412 or 414 is about 0.025 mm.

If the finger field is covered by gently sloping periodical micro-irregularities different from microprisms, the constraints imposed to the value of the period of microprisms refer to the distances between adjacent micro-irregularities of any periodical structure along two coordinates on the surface of the finger field.

The conclusions referring to the value of the maximum period of microprisms are also true for maximum distances along both coordinates of the finger field between adjacent micro-irregularities having random or similar to random distribution along the surface of the finger field.

A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. For example, advantageous results still could be achieved if steps of the disclosed techniques were performed in a different order and/or if components in the disclosed systems were combined in a different manner and/or replaced or supplemented by other components. Accordingly, other embodiments are within the scope of the following claims.

For example, the illuminating tools of the imaging device 1 may be light-emitting bars or compact filament lamps. The optical plate may be made of polystyrene that has an index of refraction of about 1.6. In this case, using Snell's Law, the critical total internal reflection angle at the interface between the ridges and the finger field surface equals approximately 64 degrees, and the angle A0 has a value of about 63 degrees. The optical plate may be made of any glass that has an index of refraction between about 1.5 and about 1.7. The range of indices of refraction of from about 1.5 to about 1.7 corresponds to angles A0 that range between about 73 degrees and about 57 degrees, respectively.

As is evident from the description of the optical plate 400, micro-irregularities of the finger field may have a shape different from that of microprisms, for example, micro-irregularities may be fabricated as smoothed riffles or "dot" projections, being near-conical or near-spherical shaped.

What is claimed is:

1. A device for projecting an image of a fingerprint pattern on a finger to an image sensor external to the device, the device comprising:

an optical plate to create the fingerprint pattern at a finger field, the optical plate including:

a converging mirror placed at an end of the finger field, the converging mirror having a focal plane,

a first surface placed at an end of the finger field that is substantially opposite to the converging mirror, and

a second surface that is placed at an end of the finger field,

an illuminating tool positioned to illuminate the finger field through the second surface to create imaging light rays relating to the fingerprint pattern; and

an objective positioned behind the first surface, the objective having an object side focal point located approximately at the focal plane of the converging mirror;

in which the converging mirror and the objective are physically adjusted to receive substantially parallel imaging light rays from the fingerprint pattern, and to project the imaging light rays of the fingerprint pattern to the image sensor.

2. The device of claim 1 in which the objective includes a planoconvex lens.

3. The device of claim 1 in which an axis of the illuminating tool lies in a direction that is transverse to imaging light rays.

4. The device of claim 1 in which the converging mirror is spherical.

5. The device of claim 1 in which the converging mirror reflects imaging light rays reflected from ridges on the finger lengthwise along the optical plate to the objective.

6. The device of claim 1 in which the image sensor includes a single crystal CMOS image sensor.

7. The devise of claim 1 in which the image sensor includes a CCD.

8. The device of claim 1 in which the first surface is lateral to the finger field.

9. The device of claim 1 in which the second surface is lateral to the finger field.

10. The device of claim 1 in which the finger field is approximately 18 mm in length and approximately 18 mm in width.

11. The device of claim 1 in which the converging mirror and objective receive substantially parallel imaging light rays that are reflected from ridges on the finger at an angle near to and less than a total internal reflection angle at an interface of the ridges and the finger field.

12. A device for projecting an image of a fingerprint pattern of a finger to an image sensor external to the device, the finger including ridges, the device comprising:

an optical plate including:

a finger field on which the finger to be imaged is placed, the finger field including irregularities positioned at a period that is less than a period of the ridges, and

one or more surfaces in which each surface is placed at an end of the finger field;

an illuminating tool positioned to illuminate the finger field to create imaging light rays relating to the fingerprint pattern when the finger to be imaged contacts the finger field; and

an objective that receives the imaging light rays to project the image of the fingerprint pattern to the image sensor.

13. The device according to claim 12 in which a first surface of the optical plate is a converging mirror, the converging mirror receiving the imaging light rays and reflecting the imaging light rays through a second surface to the objective.

14. The device according to claim 13 in which the objective is positioned behind he second surface, and the objective and the converging mirror are adjusted such that an object side focal point of the objective is located near to a focal plane of the converging mirror.

15. The device according to claim 12 in which the converging mirror is spherical.

16. The device according to claim 12 in which the illuminating tool is adjusted to illuminate the finger field through at least one of the optical plate surfaces.

17. The device according to claim 12 in which the illuminating tool is positioned to illuminate the finger field in a direction that is transverse to imaging light rays.

18. The device according to claim 12 in which the irregularities are prisms, and each prism includes a pair of facets extended transversely to the imaging light rays.

19. The device according to claim 18 in which the prisms have equal sized facets, with the angle subtended between them being in the range from about 150 to about 160 degrees.

20. The device according to claim 12 in which the irregularities are periodically arranged along the finger field with a period ranging from about 0.05 mm to about 0.1 mm.

21. The device according to claim 12 in which the irregularities are periodically arranged along the finger field with a period less than about 0.1 mm.

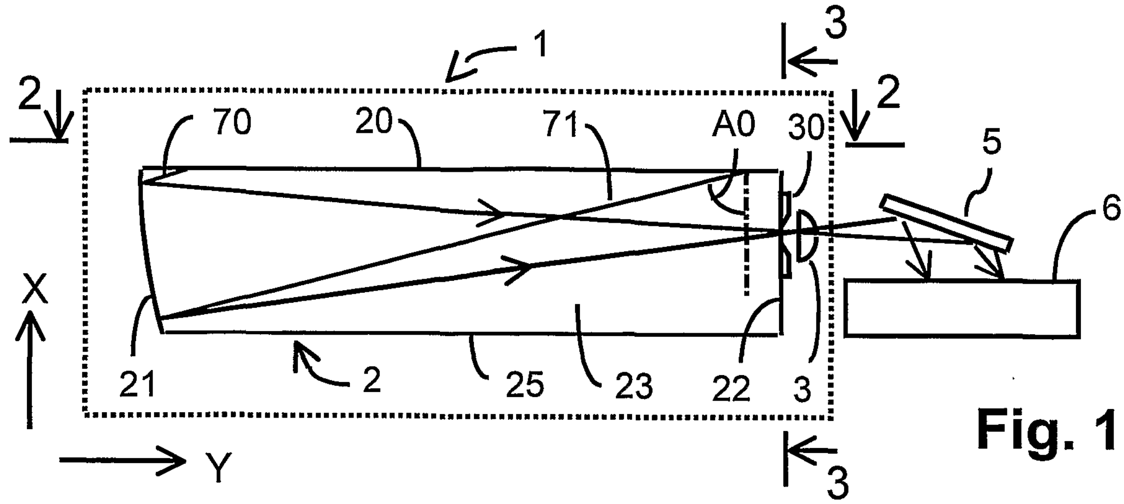

Fig. 1

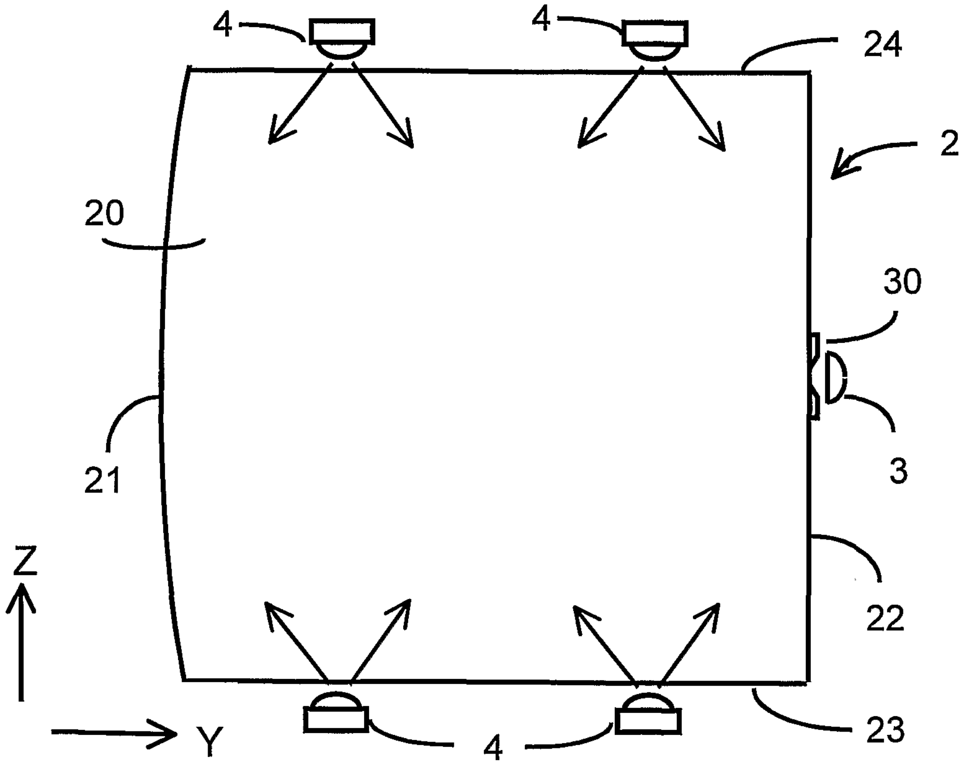

Fig. 2

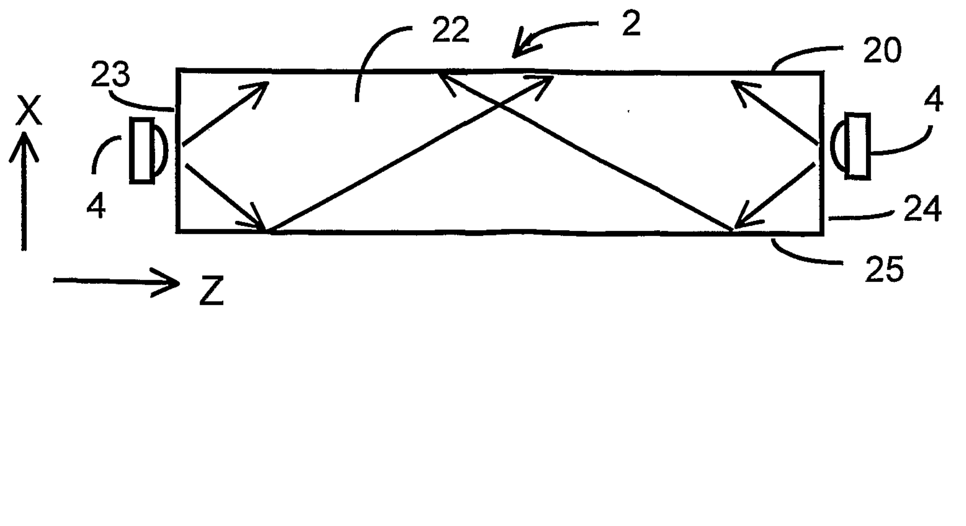

Fig. 3

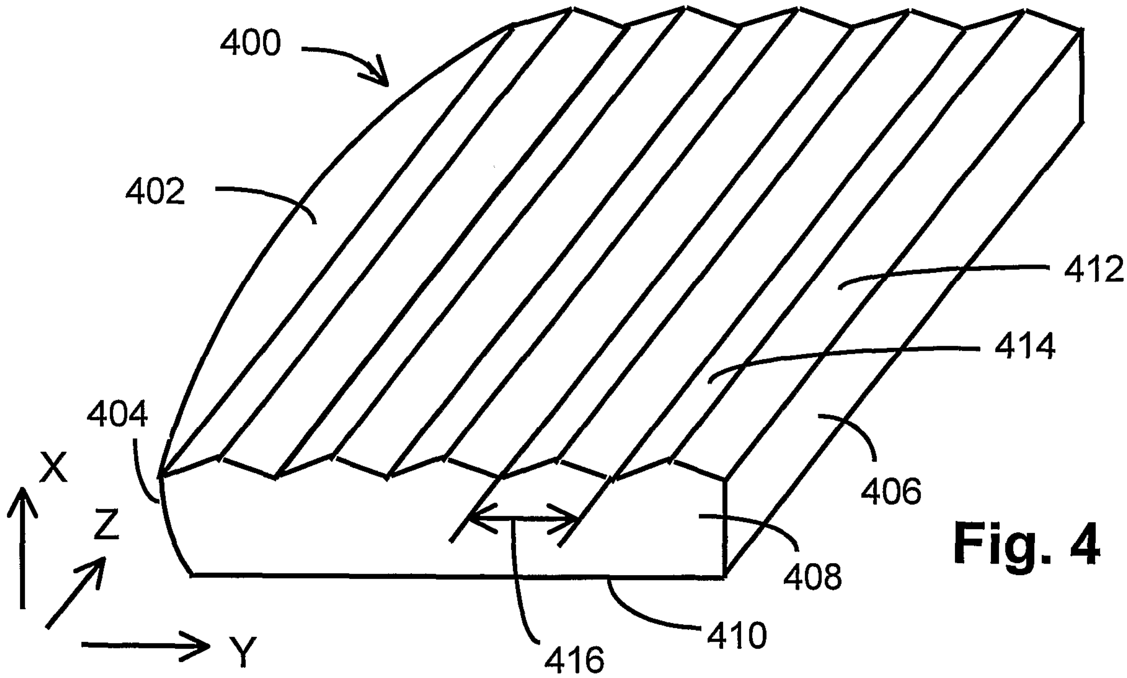

Fig. 4

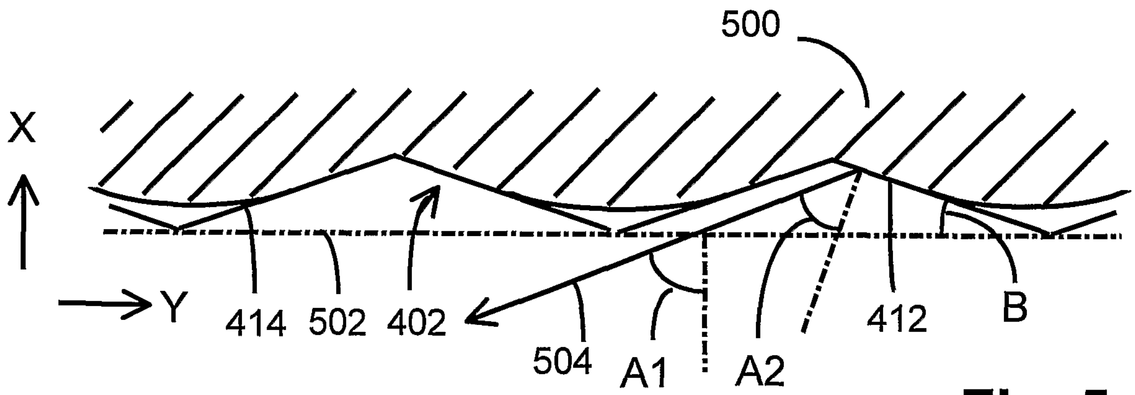

Fig. 5

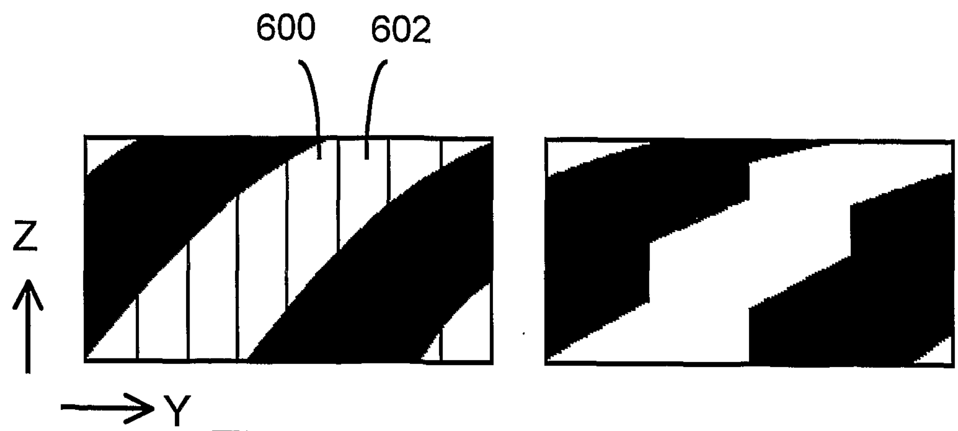

Fig. 6a

Fig. 6b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US01/15761

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :G06K 9/00
US CL :382/124
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)

U.S. : 382/124, 126, 127; 250/382, 345, 208.1, 216

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO APS EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,077,803 A (KATO et al) 31 December 1991 (31.12.1991), see entire document.	1-3, 5-9, 11
A,E	US 6,255,641 B1 (JOHNSON) 03 July 2001 (03.07.2001), see entire document.	1-21
A,P	US 6,069,969 A (KEAGY et al) 30 May 2000 (30.05.2000), see entire document.	1-21

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 JULY 2001	15 AUG 2001

Name and mailing address of the ISA/US	Authorized officer
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