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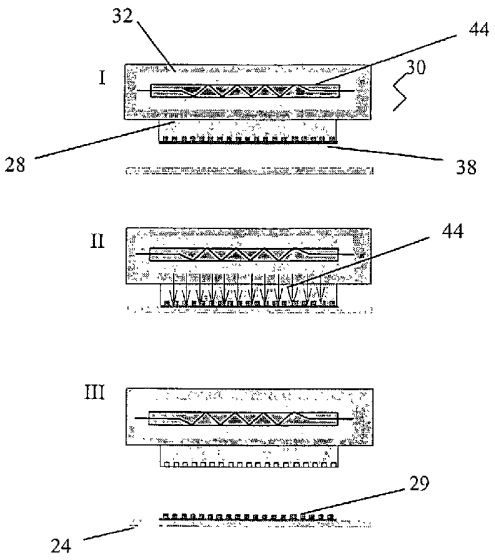
(54) Title: PORTABLE HOLOGRAPHIC MARKING UNIT



(57) Abstract: A portable holographic marking unit for providing holographic markings on a substrate is described. The unit includes a handle which forms an outer casing for the portable unit and inner casing to mount components of the unit. The components include an internally mounted light source which is partially encapsulated by the inner casing and provides illumination for the unit on the substrate. Another component is a transparent quartz window which, with the inner casing, passes the illumination of the internally mounted light source to the substrate. Additionally, a reflector is positioned between the internally mounted light source and the inner casing to redirect the illumination from the light source through the window and onto the substrate.

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PORTABLE HOLOGRAPHIC MARKING UNIT

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention pertains generally to a holographic marking unit and, more specifically, to a portable holographic marking unit for appending a holographic stamp or pattern onto any kind of transparent or non-transparent substrate.

The Prior Art

Holographic patterns are extensively used for numerous purposes, going from decoration and personalization to security certification and sealing attestation of items. On one hand, display holography consists in restituting a real appearance of a three dimensional object with a single photographic plate, giving an illusion that the real object is located in a box, just behind a plate.

With reference to Figures 1A-1D, fabrication of holograms consists, in general, of recording on a holographic plate 10 information given by two interfering laser beams 12, 14. One of them, called an object wave 12, is shaped dependent upon elements it encounters during its travel from a laser 16 to the plate 10. An infinity of shapes are possible for the object wave 12, depending on the optical function it has to play, and which optical system it passes through or what 3D object it reflects from. The second beam remains unaltered and is used as a reference beam 14.

During processing of the plate 10, interference

patterns are transformed into a diffractive structure. When the reference beam 14 illuminates the processed plate 10, it reconstructs the object beam 12 by diffraction 17, restituting the information this object beem was carrying at a recording stage. This way if, at the recording stage, the object wave 12 was the light reflected by a 3D object 20 placed behind the plate 10, the reconstruction will give to an observer 22 an illusion that this 3D object 20 stands behind the plate 10 when it is illuminated by the reference beam 14. Some adaptations of the technique allows the hologram to be read with a divergent white light source, giving some sort of rainbow aspect to the apparent object, as seen on credit card holograms.

The diffractive structures, based and fabricated on the same principle as holograms, are widely used in a vast range of applications. Scientific equipment or any kind of high-tech light-based applications, like spectrometers, optical multiplexing and interconnection devices, beam shaping systems, are taking benefits from the advantageous properties of these elements. Indeed, they are able to integrate several optical functions, such as dispersion, correction of aberration, polarization, and magnification, onto a single very compact arrangement, unachievable with conventional optics. In everyday life, such diffractive structures take an important place and can be found in equipment like CD players and scanners, or in some imaging, security or automation devices.

Figures 2A, 2B and 2C show, in general, replication of a master 23 and a forming of a replica by hot-embossing and UV-embossing. As shown in Figure 2A, the master 23 is, in this example, made of nickel and is formed on a substrate 56. The holographic plate 20 is made of photosensitive resin and, during recording, a photosensitive layer 25 is exposed to a contrasted interference pattern 26. Illuminated parts of this material are removed at the processing stage, giving rise to a relief diffractive structure, in accordance with the contrasted interference pattern 26, which was exposed during the recording

stage.

The master 23 is used for the replication steps, where a large number of copies will be replicated by transferring the relief structure of the master 23 into a low cost formable material on the substrate 24. Various replications techniques exist, depending upon the use of the hologram.

For holographic self-adhesive stickers, hot-embossing technique is used as shown in Figure 2B. The nickel master 23, grown from the photoresin layer 25, is a die for hot-pressing equipment or heater 36 which is used to transfer a relief structure into thin polymer or plastic films 57 to form a plastic replica 29. These plastic replicas are then metallized, protected, cut and converted into self-adhesive stickers or into hot-stamping foils for direct application on pre-existing substrates.

As shown in Figure 2C, replication can be carried out by applying the nickel master 23 on a surface of the substrate 24 where a hardening UV-curable material 38 has been coated. After hardening, the master 23 is separated from the resulting replication 29 which thus forms part of the substrate 24. Generally, a UV curable polymer is used as hardening material and the process is called UV-embossing.

This field is widely used for artistic effects and also for advertising or decorative purposes. A three dimensional effect emerges from a mode of fabrication which is able to store and to restitute information concerning a relief of a considered object.

The way holograms are fabricated gives another advantage. Holograms can be used for security purposes, as well. Holographic fabrication is based upon the recording of an image which is unique and original. Additionally, holographic fabrication currently requires high cost laboratory equipment. Because of the high cost of the equipment and the uniqueness of the original object, counterfeiting is drastically reduced. This means that there is an opportunity to use holograms for security

purposes and for good origin attestation.

In fact, well known 3D holograms can be found on credit cards, like the VISA dove or the EC Beethoven. Holograms can also be found on various original and registered product packages like inkjet printer cartridges or pre-recorded video tapes. When they are applied to a given product, holograms attest that its original state has not been altered (e.g. for credit cards or sealed cases of any kind). Unfortunately, such holograms are only produced in high volume series (several millions). Indeed, only large companies are equipped with the high priced equipment such as rotary presses, so that production becomes profitable when it reaches several hundreds of thousands items.

This way of production is not appropriate for marking limited series. A mark directly integrated onto a surface of a substrate, as is the case with the UV-embossing, would be much more suitable. Unfortunately, available industrial UV-embossing equipment are very cumbersome and the substrate to be marked has to be brought to the equipment instead of the contrary. Another problem is that the easily removable adhesive support of commercial holograms is inadequate to attest that a product has not been opened and altered. Moreover, the substrate to be marked has to be transparent for the UV radiation to reach the photopolymer coated on it.

SUMMARY OF THE INVENTION

In view of the problems and disadvantages of the prior art, the present invention seeks to provide a portable holographic marking unit which is particularly adapted for a performing holographic marking by transferring a replica of a diffractive structure, originally engraved on a master, into a hardening material which becomes part of the marked item. More specifically, compared to a classical UV-embossing process, the holographic unit of the present invention can place markings onto opaque substrates and, thanks to its portability, does not require the dismounting of the items to be marked. It is

particularly suitable for small series markings on an extremely large range of supports.

The device of the present invention can place the replication of an original diffractive structure on a pre-existing surface such as a window, a windshield, and also on a non-transparent substrate such as a document or a parcel. It can be used for security purposes and also for personalizing and decorative purposes.

The holographic stamp of the present invention is based upon the same principle as a conventional stamp where ink has been replaced with a hardening material and a rubber stamp with a flexible piece where a replica structure such as a 3-dimensional holographic structure has been engraved. The replica structure can be a rather simple diffraction grating or a much more personalized holographic logo. Marking is carried out by coating the surface of the flexible piece with a hardening material before it is applied to the surface to be marked. Once the material is hardened, the flexible piece is separated from the resulting replication which thus forms part of the transparent or non-transparent surface.

Various markings can be achieved since the flexible piece can be easily released from its mounting and replaced by another one. The portability of the device allows one to bring the equipment to the item to be marked without dismounting the item to be marked from its location. By using a light-curable material, hardening can also be carried out by exposing the whole system to a light beam. Since, the flexible piece is transparent, an illuminating device can be integrated into the handle of the portable device so that the light can pass through the flexible piece and harden the photosensitive material. This allows opaque surfaces to be marked. The light-curing option does not reduce the portability of the device but shortens the hardening time.

Accordingly, it is an object of the invention to provide a portable holographic marking unit for applying

holographic markings on a substrate. The unit has a handle forming an outer casing and inner casing to mount components of the unit. The components include an internally mounted light source which is partially encapsulated by the inner casing and provides illumination for the unit on the substrate.

Another object of the invention is to provide a transparent window which forms another part of the unit with the inner casing to pass the illumination of the internally mounted light source to the substrate.

A still further object is to provide a reflector positioned between the internally mounted light source and the inner casing to redirect the illumination from the light source through the window and onto the substrate.

It is an object of the invention to permit the portable holographic marking unit to mark substrates that are either non-transparent or transparent.

Another object of the invention is to provide that the window is of a quartz material, and that the light source is ultraviolet.

A still further object of the invention is to provide a soft mold wherein the soft mold is a flexible and transparent stamp, and has a diffractive structure engraved on an outer most exposed surface, and the diffractive structure shows detailed features smaller than 1 micrometer width and depth, wherein the soft mold is made of a silicone-elastomer, and is for use in electronics and micro-optics.

It is another object of the invention to provide the stamp from a replication of an original diffractive master which is created by following a classical hologram recording technique.

A still further object of the invention is to provide the window as a support and the stamp is mounted onto the window to enable its handling.

An object of the invention is to provide the unit as a kit with the light source being an ultraviolet illuminating lamp emitting at 365 nm, and the lamp having an intensity of

approximately 20-40 W/cm2.

Another object of the invention is to provide the kit with a ultraviolet curable polymer which is a clear, colorless, liquid that will cure when exposed to ultraviolet light, and has a maximum absorption range of 350-380 nanometers.

It is an object of the present invention to provide portable equipment which forms the marking on pre-existing surfaces by applying a diffractive or holographic pattern which becomes part of the surfaces.

It is also an object of the present invention to provide a process carried out with a stamping master, whereon a diffractive structure is engraved, to form a self-hardening material that becomes part of the surface.

Yet another object for the present invention is to provide a portable holographic marking unit in accordance with the preceding objects and which will conform to conventional forms of manufacture, be of simple construction and easy to use so as to provide a device that will be economically feasible, long lasting and relatively trouble free in operation.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred structural system embodiment and preferred subcomponents of this invention are disclosed in the accompanying drawings in which:

Figure 1A generally shows a recording of a diffractive grating on a holographic structure;

Figure 1B generally shows a reading of the diffractive grating of a holographic structure;

Figure 1C generally shows a recording of a display

hologram on a holographic structure;

Figure 1D generally shows a reading of the display hologram on a holographic structure;

Figure 2A generally shows a holographic recording of a nickel master;

Figure 2B generally shows three stages of replication by hot-embossing;

Figure 2C generally shows three stages of replication by UV-embossing;

Figure 3A is a schematic drawing of the operating components of a portable holographic marking unit of the present invention utilizing a self-hardening material;

Figure 3B is a schematic drawing of the operating components of the portable holographic marking unit of the present invention utilizing a light-hardening material and an external light source;

Figure 3C is a schematic drawing of the operating components of the portable holographic marking unit of the present invention utilizing a light-hardening material and a light source integrated in the handle;

Figure 4 illustrates the portable holographic marking unit of the present invention with a UV illuminating unit, UV lamp power supply, UV curable polymer and soft molds;

Figure 5 is an underside view of the UV illuminating unit illustrating a reflector, quartz window, UV lamp and casing of the present invention;

Figure 6 illustrates a soft imprint fabrication as formed by the portable holographic marking unit of the present invention;

Figure 7A illustrates a starting point for fabricating a holographic marking on a paper as the substrate with an aluminum foil strip as performed by the portable holographic marking unit of the present invention;

Figure 7B illustrates a self-adhesion property of the soft mold as it is fixed to the quartz window of the portable

holographic marking unit of the present invention;

Figure 7C illustrates a dispensing of the UV-curable polymer on the soft mold affixed to the quartz window of the portable holographic marking unit of the present invention;

Figure 7D illustrates an application of the portable marking unit to the paper and the aluminum foil strip with the UV lamp switched on as set forth in the present invention;

Figure 7E illustrates a hardened and molded layer of polymer attached to the paper and aluminum foil strip as applied by the portable holographic marking unit of the present invention;

Figures 8A and 8B show an example of of the holographic seal made by the portable holographic marking unit of the present invention being destroyed; and

Figures 9A-9C illustrate a marking through a transparent member using the portable holographic marking unit of the present invention.

DESCRIPTION OF THE INVENTION

Although only a couple of embodiments of the invention are explained in detail, it is to be understood that other embodiments are possible. Accordingly, it is not intended that the invention is to be limited in its scope to the details of construction and arrangement of components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or carried out in various ways. Also, in describing the embodiments, specific terminology will be resorted to for the sake of clarity. It is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

Figures 3A, 3B and 3C show various uses of the portable holographic marking unit which is generally indicated by reference numeral 30. The unit 30 includes a handle 32 and a holographic stamp 28 such as with a self-curing material 40, with

the UV-curing material 38 and an external UV illumination, as well as with the UV-curing material 38 and an internal UV illumination 44.

With reference to Figure 3A, the schematic drawing illustrates the operating components of the portable holographic marking unit 30 while utilizing the self-hardening material 40. In step 1, the handle 32 has the holographic stamp 28 previously formed and mounted to the unit 30. The self-hardening material 40 is applied to the stamp 28. The unit 30 is then, in step 2, placed on the substrate 24 and curing begins. When the self-hardening material has cured, the unit 30 is removed and the replica 29 is formed on the substrate 24, as illustrated in step 3.

Figure 3B is a schematic drawing of the operating components of the portable holographic marking unit 30 of the present invention utilizing the light-hardening material and the external light source 42. The process is shown in three steps. The handle 32 has the holographic stamp 28 previously formed and mounted to the unit 30. The light-curing material 38 is applied to the stamp 34. As shown in step 2, the unit 30 is then placed on the substrate 24. At this point, the light 42 from the external source is directed to the opposite side of the substrate 24 and the replication process begins. After a predetermined amount of time, the replica 29 is formed on the substrate 24 and the unit 30 is removed and the light 42 switched off.

The process of Figure 3C is similar to the process described in Figure 3B. As illustrated, the unit 30 has the internal light source 44 integrated or encapsulated by the handle 32 which allows, with the UV-curing material 38, opaque surfaces of substrate 24 to be marked, as illustrated in step 1. In step 2, the unit 30 and the holographic stamp 28 are placed on the opaque surface 24 to be marked. The light from the internal source 44 is switched on and the replication process begins. In step 3, after completion of the process, the light 44 is switched off and the replica 29 is formed on the substrate 24.

The portable holographic marking unit 30 is shown in Figure 4. This embodiment illustrates a typical marking kit with an ultraviolet ("UV") illuminating unit which is based on a commercial Pen Ray Lamp emitting at 365 nm. This lamp has an intensity of approximately 20-40 W/cm2. High compactness can be achieved by integrating the UV lamp 44, a reflector 47 and an electrical circuit inside the handle 32.

Power can be supplied either from electrical mains or from a battery unit 46. An electric wire or cord 48 is used to connect the system to the portable power supply 46 which can be a 230V power supply. Also, an extension cord can be added to the electric wire 48 between the handle 32 and the power supply 46 in order to increase the portability and to favor handiness.

The soft mold or plastic film 28 is also shown in Figure 4 and is made of a special silicone-elastomer. These types of molds are used in electronics and micro-optics.

The UV curable polymer 38 is the commercially available Norland Optical Adhesive 61 ("NOA 61") which is a clear, colorless, liquid photopolymer that will cure when exposed to ultraviolet light. The use of NOA 61 eliminates premixing, drying or heat curing operations common to other adhesive systems.

Curing time is fast, and is dependent upon the thickness applied and the amount of ultraviolet light energy available. The adhesive is designed to give the best possible optical bond to glass surfaces, metals, fiberglass and glass filled plastics. NOA 61 also has excellent clarity, low shrinkage and has light flexibility that make it superior to other materials for optical bonding. NOA 61 is cured by ultraviolet light with maximum absorption within the range of 350-380 nanometers. The recommended energy required for full cure is 3 Joules/sq. cm in these wavelengths. The cure is not inhibited by oxygen, hence any areas in contact with air will cure to a non-tacky state when exposed to ultraviolet light. NOA 61 can withstand temperatures before aging from -15°C to 60° C

when used for glass bonding. After aging, it will withstand temperatures from -150° C to 125° C.

Figure 5 is a view of the underside of the portable holographic marking unit 30. The unit 30 includes the handle or casing 32 which encapsulates the internal UV illumination light or lamp 44 entirely inside the unit 30. Surrounding the UV lamp 44 is the reflector 47 to redirect the UV light back and out the transparent quartz window 50 and towards a substrate to form a replica thereon.

With reference to Figures 6 and 7A-7C, a description of the process is presented. The soft holographic stamp 28 is the imprint for the original master 23 which is recorded by a conventional holographic process, as discussed with reference to Figures 1A-1D. The technique results in creating a microstructure on a surface of the photoresist layer 25. The resulting master 23 exhibits some visual effects depending upon how sophisticated is the recording process (but the principle remains the same).

The holographic formed on the master 23 can go from a typical rainbow aspects of the surface (in the case of a simple diffraction grating, like on the compact disc surface) up to very realistic effects (object reconstruction) like the famous VISA card dove. This way of producing the master 23 ensures that it is coming from an original piece of work and makes it difficult for any counterfeiting die to perform a copy in exactly the same conditions as the original one.

After the master 23 has been formed, the replication of the original photoresist master 23 is performed by molding it with the commercially available Sylgard #184 manufactured by Dow Corning. The new soft holographic stamp 28 is demolded without damaging the original master 23. This allows multiple replication of one original master 23 into several soft imprints. N the present case, the original master 23 is a diffraction grating recorded through a mask with a CSL logo.

Figures 7A-7E illustrate the procedure for performing a

holographic marking with the portable holographic marking unit 30.

With specific reference to Figure 7, marking is performed by coating the diffractive surface of the holographic stamp 28 with a hardening material before the whole unit 30 is applied to the surface to be marked. With this technique, even the non-transparent substrate 24 can be marked, since the UV light passes through the soft mold 28. The following example consists in appending a holographic seal onto a non-transparent document.

Figure 7A shows a typical starting point wherein the substrate 24 is a sheet of paper with a thin aluminum foil stip 52 diagonally placed over the word "security".

As shown in Figure 7B, the soft mold 28 is fixed to the quartz window 50 of the portable holographic marking unit 30. Thanks to the self-adhesion property of the soft mold 28, it will affix to the quartz window 50 for a sufficient period of time.

Figure 7C illustrates the application of a small amount of UV-curable polymer 38 to the soft mold 28.

As illustrated in Figure 7D, the portable holographic marking unit 30 is then applied to the paper 24 and the aluminum foil strip 52 to be sealed. The internal UV lamp 44 is switched on.

After approximately 3-5 minutes of curing, the portable holographic marking unit 30 is removed, leaving a hardened and molded layer of polymer with a holographic mark 34 attached to the paper 24.

Figures 8A and 8B illustrate what happens if the aluminum foil strip 52 is removed. The holographic mark 34 is damaged and the security of the document 24 can be visible noted.

Very confined spaces can be marked, thanks to the compactness of the portable holographic marking unit 30. Moreover, when substrates 24 is transparent, these transparent substrates can be marked by placing the soft mold 28 on one side and the portable holographic marking unit 30 with the UV light

source on the other side.

As an example of this type of transparent marking, reference is to Figures 9A, 9B and 9C. The portable holographic marking unit 30 is capable of marking very confined spaces or curved surfaces such as bottles, glasses thanks to the softness of the mold 28. Of course, the substrate 24 has to be longwave UV transparent. In the case of glass, which absorbs a part of UV light, curing time is increased as a function of a thickness of the glass. Of course, excess of hardened glue can be removed with a sharp cutter, leaving a clean and well delimited marked.

Marking is rather sensitive to any kind of pollution which could fill the 3D microstructure and then alter the diffractive effect. This fact can be used as an advantage for security reasons (such as fingerprint tracing) or artistic purposes (for example, a hologram in a bottle is only seen after water has been removed). Otherwise, marking has to be done in a way so that the marking will not be exposed to such altering factors or with a protective cap applied on it, as is the case for windshield marking. A metallized protective cap can be used in order to enhance the diffractive effect.

Thanks to the nature of the compound it is made of, the soft mold 28 can be assembled with other ones into a common silicone-based and transparent support. This way, a system can be imagined where multiple holographic patterns are put together into a common circular ribbon, rolling around the UV internal lamp 44. The symbol to be marked can be selected, just facing the quartz window 50 of the source of light from the UV lamp 44, like in classical ink stamps where any date can be chosen thanks to one ribbon for a day, a second one for a month and a third one for a year.

Among all the possible marking applications for fun, artistic, or personalization purposes, some examples where the portable holographic marking unit 30 could be particularly valuable are in windshield marking which can be done for personalization or security reasons. The holographic stamp 34

can be applied on an interior side of the windshield. This stamp 34 can be seen from an outside of the vehicle and it is protected from external environments. A protective and reflective cap can be applied in order to protect the hardened polymer and to enhance the diffractive effect. The mark can range from a simple logo or a serial number up to a more sophisticated 3D or computer generated hologram effect. This last one consists in illuminating the hologram with a specific light source, in order to project a special and unique figure on the dashboard. It is a very discrete but secure authentication system.

As set forth with reference to Figures 6 and 7A-7D, an official document sealing and authentication can be easily be provided by using the portable holographic marking unit 30.

Warranty seals can also be made out of holographic stickers. The stickers can be used to show that original parts have not been opened or separated. Presently, the non holographic stickers are often easily removed and then replaced, thus deceiving the warranty seal. With the portable marking unit 30, a small orifice between two pieces can be filled with the liquid polymer. Any attempt for opening and separating two holographic pieces results immediately in the destruction of the holographic seal, with no way to recover it.

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be recognized by one skilled in the art are intended to be included within the scope of the following claims.

What is claimed is:

1. A portable holographic marking unit for providing holographic markings on a substrate, said unit comprising a handle forming an outer casing for said portable holographic marking unit and inner casing to mount components of said unit, said components including an internally mounted light source being partially encapsulated by said inner casing and providing illumination for said unit on the substrate, a transparent window forming another part of said unit with said inner casing to pass the illumination of said internally mounted light source to the substrate, and a reflector positioned between said internally mounted light source and said inner casing to redirect the illumination from said light source through said window and onto said substrate.

2. The portable holographic marking unit as recited in claim 1, wherein said substrate is non-transparent.

3. The portable holographic marking unit as recited in claim 1, wherein said substrate is transparent.

4. The portable holographic marking unit as recited in claim 1, wherein said window is of a quartz material.

5. The portable holographic marking unit as recited in claim 1, wherein said light source is ultraviolet.

6. The portable holographic marking unit as recited in claim 1, further comprising a soft mold, said soft mold being a flexible and transparent stamp, and capable of having a diffractive structure engraved on an outer most exposed surface, said diffractive structure showing detailed features smaller than 1 micrometer width and depth.

7. The portable holographic marking unit as recited in claim 6, wherein said stamp results from a replication of an original diffractive master which is created by following a classical hologram recording technique.

8. The portable holographic marking unit as recited in claim 6, wherein said stamp is mounted onto said window to enable its handling.

9. The portable holographic marking unit as recited in claim 1, wherein said unit a kit with said light source being an ultraviolet illuminating lamp emitting at 365 nm, and said lamp having an intensity of approximately 20-40 W/cm2.

10. The portable holographic marking unit as recited in claim 1, wherein said unit comprises a power unit supplied either from electrical mains or from a battery.

11. The portable holographic marking unit as recited in claim 6, wherein said soft mold is made of a silicone-elastomer, and is for use in electronics and micro-optics.

12. The portable holographic marking unit as recited in claim 9, wherein said kit includes a ultraviolet curable polymer which is a clear, colorless, liquid that will cure when exposed to ultraviolet light, and has a maximum absorption range of 350-380 nanometers.

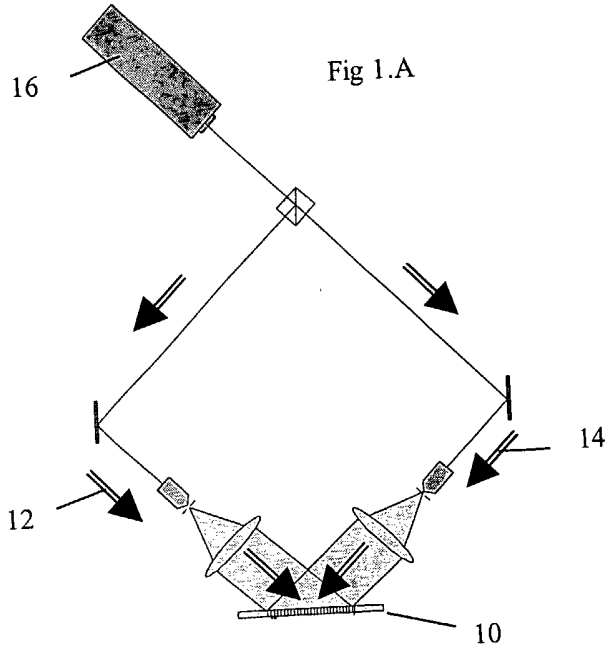


Fig 1.A

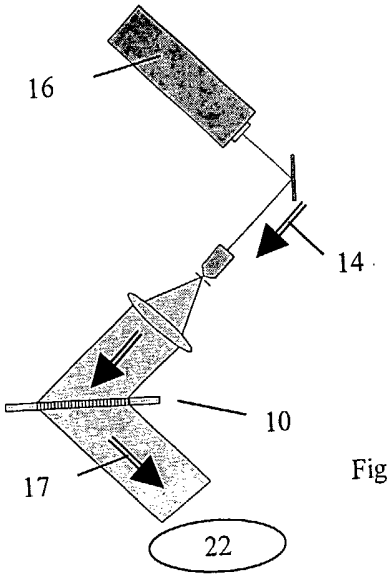


Fig 1.B

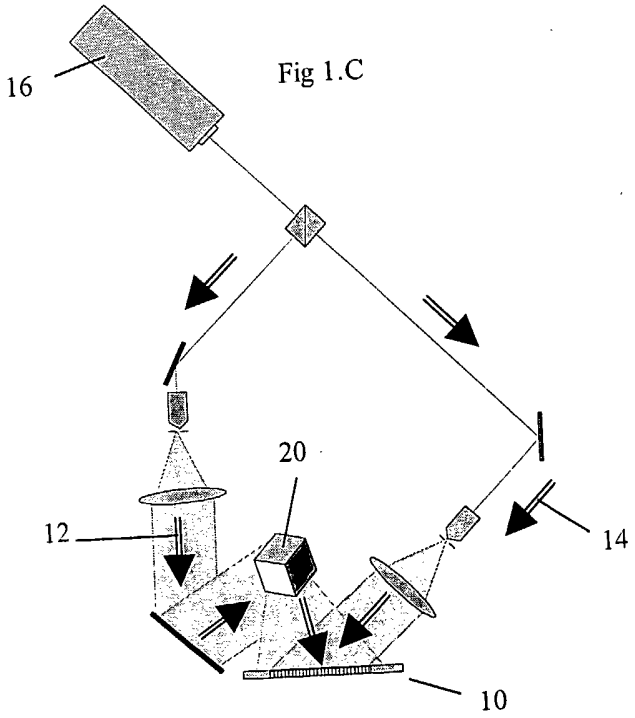


Fig 1.C

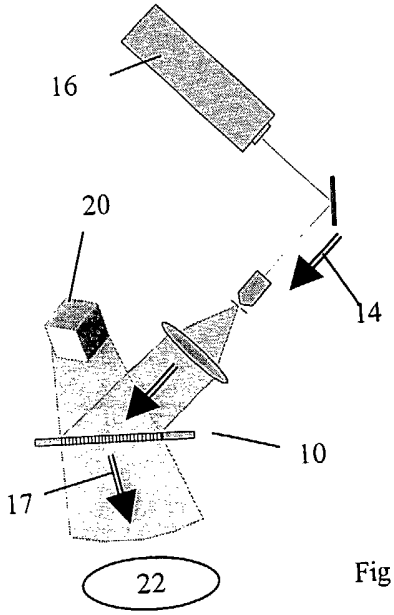


Fig 1.D

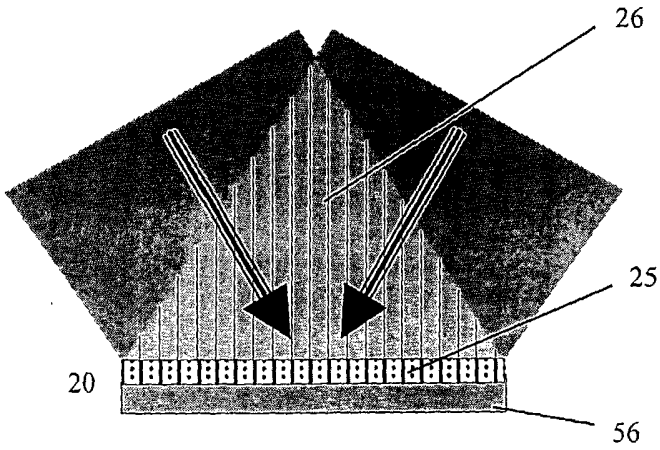


Fig. 2A

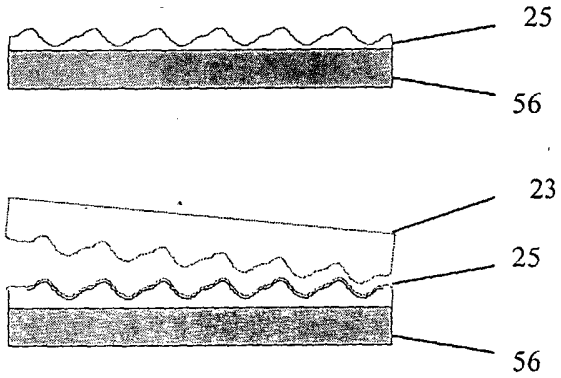


Fig. 2B

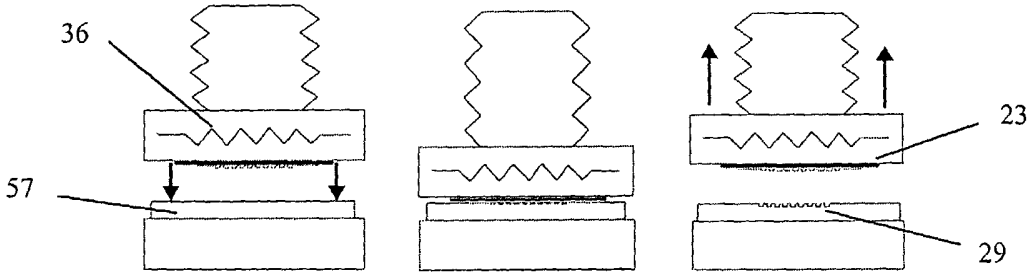


Fig. 2C

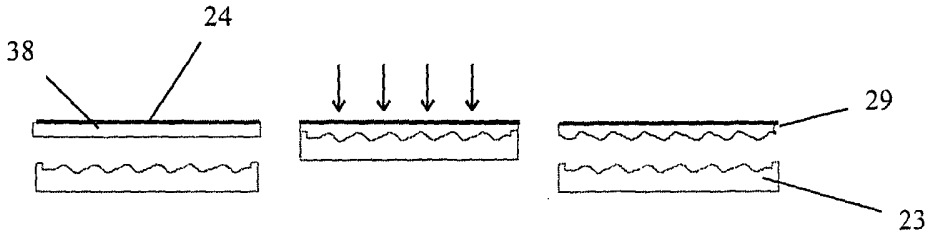
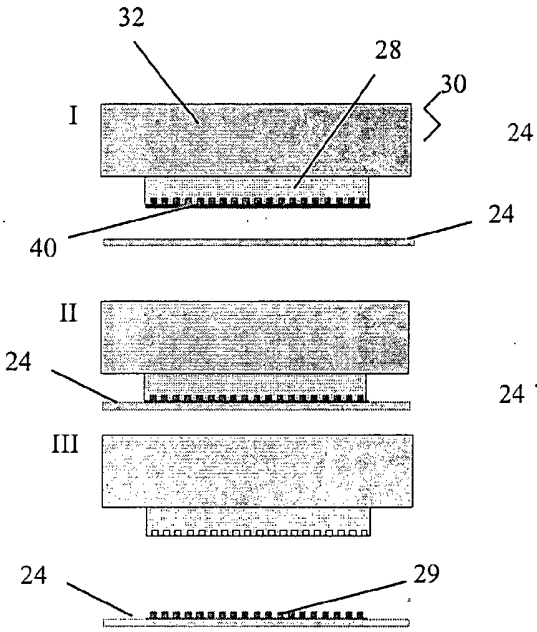


Fig. 3A



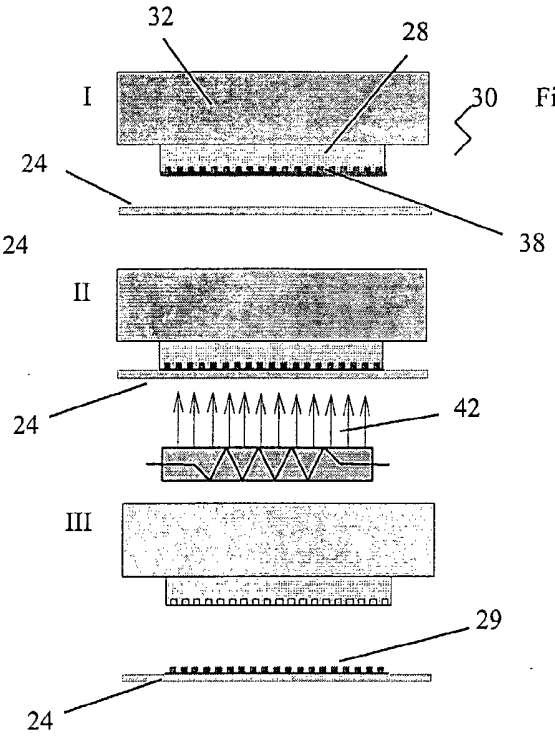


Fig. 3B

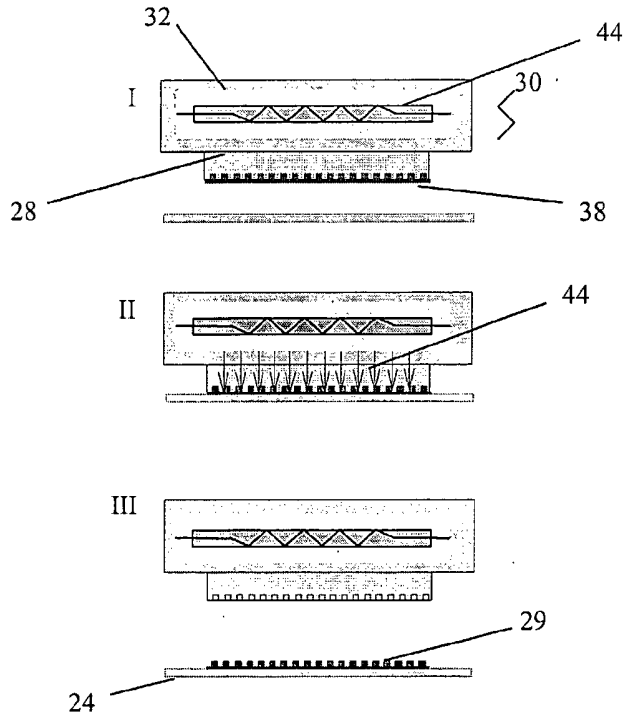


Fig. 3C

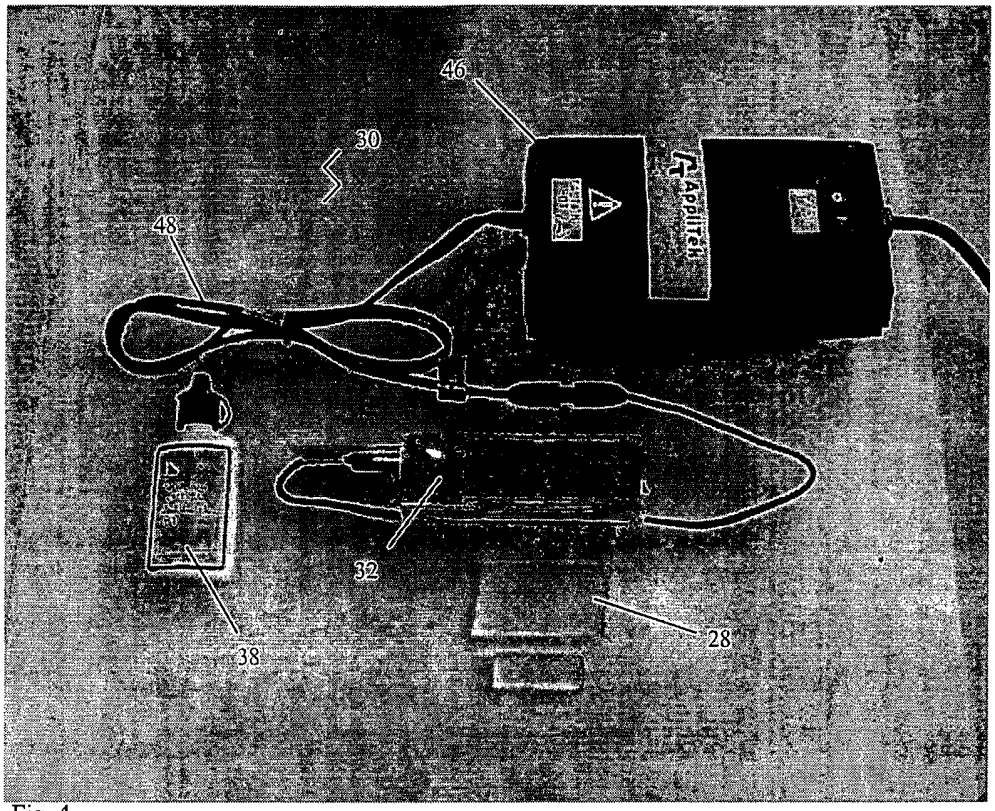


Fig. 4

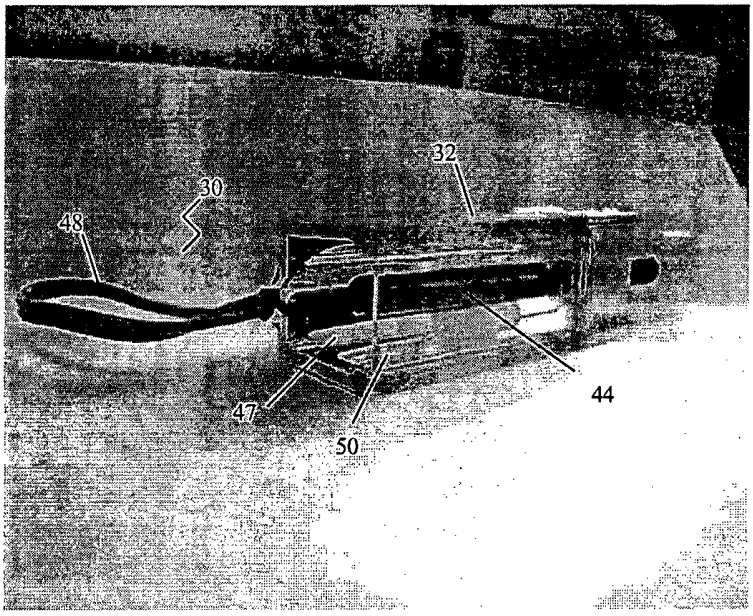


Fig. 5

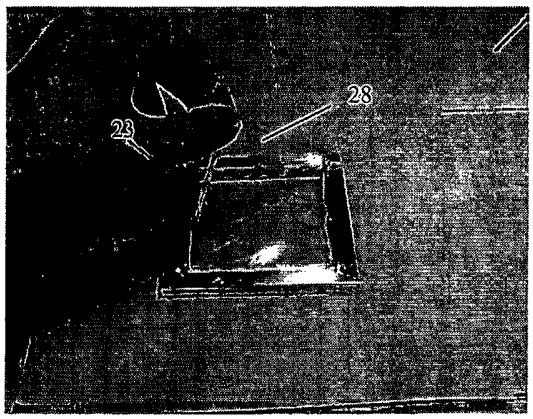


Fig. 6

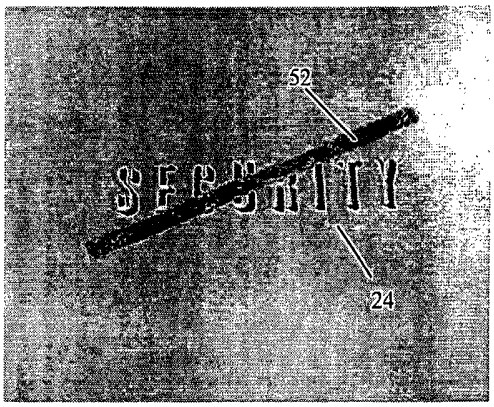


Fig. 7A

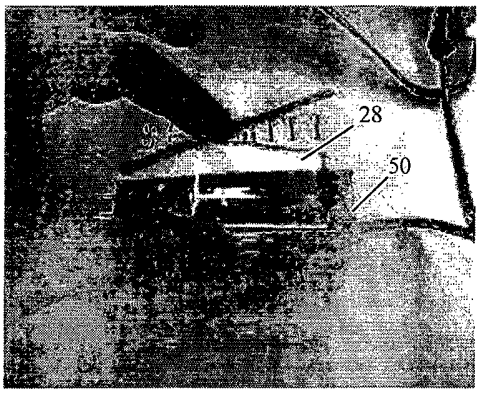


Fig. 7B

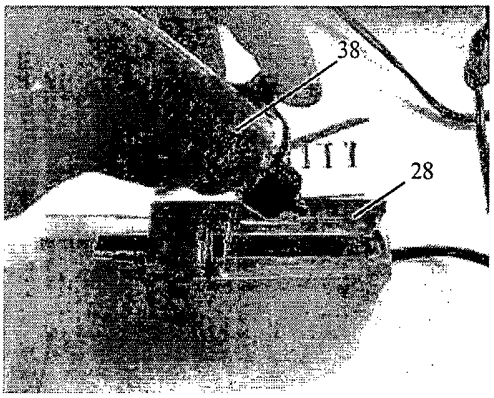


Fig. 7C

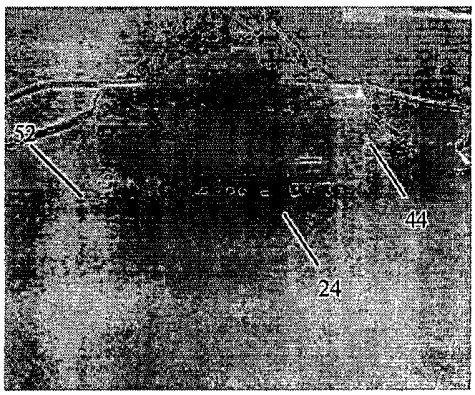


Fig. 7D

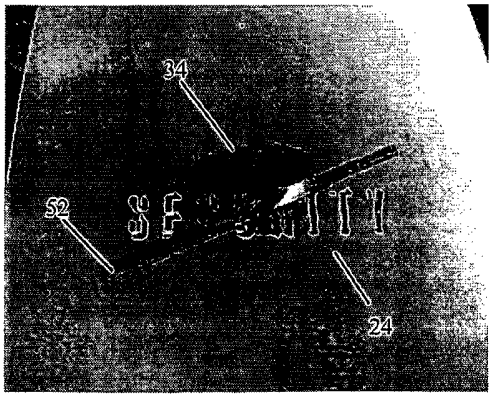


Fig. 7F

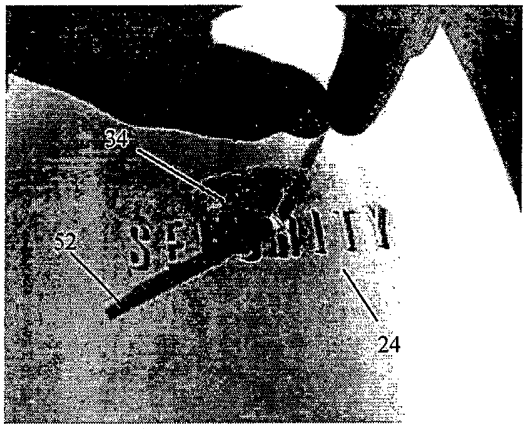


Fig. 8A

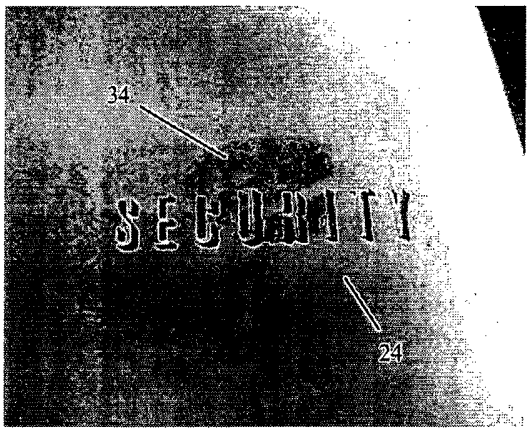


Fig. 8B

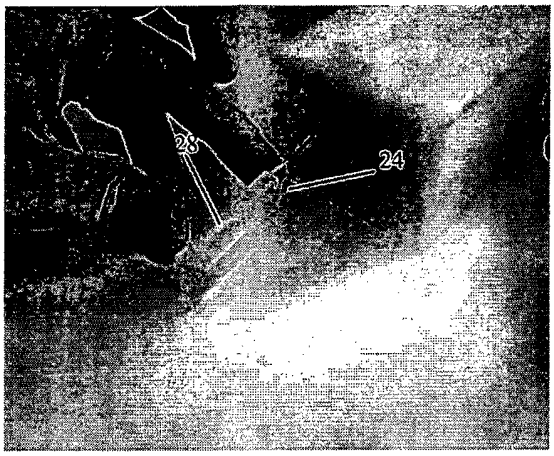


Fig. 9A

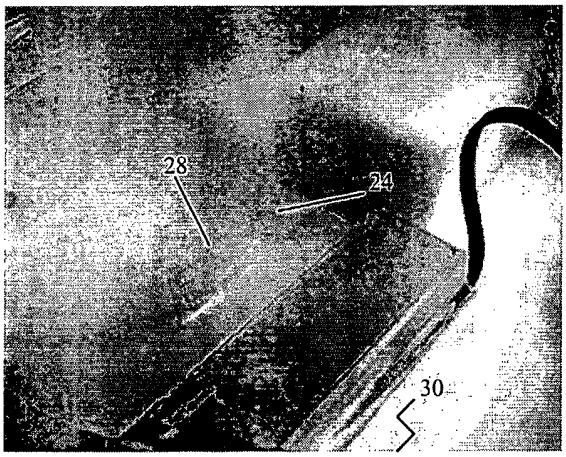


Fig. 9B

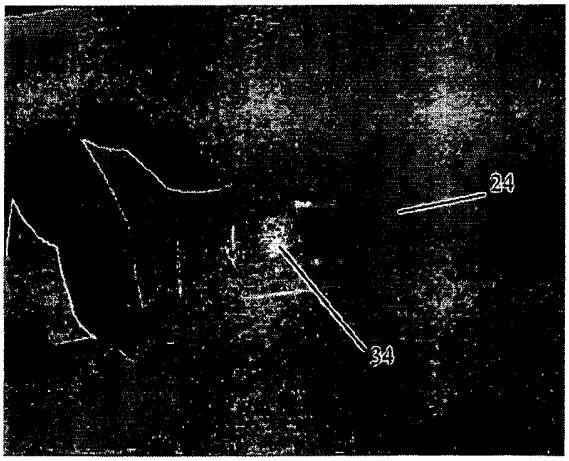


Fig. 9C