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Method of Producing Optical Storage Media

On the one hand, this invention relates to a method of producing a substrate for fabricating optical storage media in which the information is stored serially in the form of pits and lands, and on the other hand to a method of fabricating such optical storage media.

The best-known optical storage media of the type in question here include the CD-Audio and the CD-ROM, whose mechanical and electrical parameters are largely standardized and put down in DIN EN 60908 as well as IEC 908 + A1 and in the Yellow Book. In an injection molding process, the storage media are molded out of polycarbonate from an embossing die, on which the molded surface structure in the form of the side bearing pits and lands is metallized, is provided with a protective lacquer and mostly printed with an indication of the contents etc. on the same side. The information is read out from the opposite, transparent side, i.e. through the polycarbonate.

Attempts have already been made at replacing the discontinuous manufacturing or replication process briefly outlined above by a continuous process, cf. WO 97/12279. The basic idea is to clamp the die bearing the negative of the surface structure to be generated onto the periphery of a roller, and to pass a plastic film tape drawn off from a roller between this roller and a counter-roller, so as to transfer the surface structure by embossing. As far as we know, however, this method has not been developed so far that it was ready to go into production.

For producing certain microoptical surface structures, in particular for producing embossed holograms, continuous methods are known, but so far no attempts have been made at transferring such methods to the production of optical storage media of the type mentioned above.

From DE 41 32 476 A1, for instance, there is known a method for the simultaneous replication and direct application of holograms and other diffraction gratings to a printing material, wherein at least one radiation-curable lacquer coating is applied to the latter, and by means of such lacquer coating the surface structure is molded from a die clamped onto a hollow roller. Along with the molding process, the lacquer coating should then be cured by means of ultraviolet light through the UV-transparent hollow roller and the likewise UV-transparent die. The practical realization of this method fails, however, because of the high costs of a UV-transparent hollow roller and a UV-transparent die.

Another method of producing microoptical surface structures, e.g. holograms, is known from DE 197 46 268 A1. As in the above-mentioned method, a radiation-curable lacquer coating is applied to a plastic film. During the application and subsequent molding, the viscosity of this lacquer coating is adjusted to a predetermined value by a controlled supply of heat and is kept constant. During molding, the lacquer coating is already cured by irradiation with ultraviolet light. Thus, the method can only be performed with special lacquers. Furthermore, adjusting and keeping constant a certain viscosity of the lacquer requires a very efficient and fast control.

From US 4,758,296 and US 4,906,315 further methods for the continuous production of surface relief holograms are known, which methods are based on molding a hologram master in the form of an endless loop by applying a radiation-curable syn-

thetic resin layer, curing the synthetic resin layer still in contact with the hologram master, and subsequently removing the same by means of a supplied transfer tape made of polyester.

Experts have so far assumed that these known methods are too expensive and/or too inaccurate for the production of optical storage media, because their pits, to be more precise the pit/land transitions, must be replicated very accurately, as every single pit/land transition embodies a binary information element, whereas in a hologram an inaccurate replication is known to lead not to a loss of information, but only to a loss of contrast, to put it simply.

It is the object underlying the invention to create a method which provides for an at least semi-continuous production of optical storage media.

A first solution of this object consists in a method which is characterized in that a plastic film tape is continuously coated with a liquid, UV-curable material in a predetermined layer thickness, that subsequently the coating of the tape is dried by supplying heat, possibly in a clocked passage, until a no longer flowable, but still embossable condition is reached, and that the coated tape is wound up for further use.

The proposed method differs from the above-described known methods for producing embossed holograms, diffraction gratings, microlenses etc. in that the coating of the tape is not cured, but merely dried, namely to such an extent that on the one hand the coated tape can be wound up without the individual layers or windings adhering to each other, but that on the other hand the coating still is embossable. By "embossable" it is meant that the surface relief in the form of pits and lands can be taken from a corresponding embossing die

with the required high accuracy. This embossing operation can be performed at a later date according to known techniques, for instance such that the coated tape, i.e. the substrate, is wound off and passed between two rollers, of which the roller facing the coating side carries the die. Subsequently, the coating is cured, the embossed surface is punched out of the substrate and processed to obtain a storage medium ready for use. Since coating and drying takes much more time than the embossing operation and all subsequent steps, the method in accordance with this embodiment has the advantage that the production of the embossable substrate and the production of the actual storage medium can take place separate from each other both in terms of time and in terms of place and hence optimized in terms of demand. For instance, two or more plants can fabricate the substrate on stock, which substrate will then be processed to obtain storage media in a single succeeding plant.

If this advantage is not important, the storage media can also be fabricated according to a continuous method instead of the above-described semi-continuous method, which continuous method in accordance with the invention is characterized in that a plastic film tape is continuously coated with a liquid, UV-curable material in a predetermined layer thickness, that subsequently the coating of the tape is dried by supplying heat, possibly in a clocked passage, until a no longer flowable, but still embossable condition is reached, that the coated tape is passed between two rollers, of which the roller facing the coating side bears a surface relief which is the negative of at least one blank of the surface relief of the storage medium to be fabricated and embosses the same into the coating, that for curing the coating the tape is subsequently passed below a UV radiation source, that the blanks are punched out of the tape, and that at the same time or in a separate step a central hole is punched into the blanks.

As end product, this method supplies storage media which may already be playback capable in this form.

As coating material, a solvent-based radiation-crosslinkable polymer may be used (claim 3). Suitable polymers are known in the prior art as so-called photopolymers.

Alternatively and preferably, a solvent-based radiation-crosslinkable sol-gel may be used as coating material (claim 4). Suitable sol-gel systems on the basis of SiO_2 are known for instance from the paper "Optical Disc Substrate Fabricated by the Sol-Gel-Method" by A. Matsuda et al., published in Key Engineering Materials, Vol. 150 (1998), pp. 111 to 120, but only for producing preformatted recordable optical storage media in the form of a correspondingly coated glass plate. Instead of SiO_2 other inert solids may also be used, whose grain size lies in the nanometer range. TiO_2 has been particularly useful.

In the liquid condition, the viscosity of the coating material preferably lies between 10 and 100 mPa/s, and in the largely solidified condition, i.e. after drying, between 20 and 100 Pa/s (claims 5 and 6).

The layer thickness of the coating material is not critical. For the liquid material, it may lie between 2 and 100 μm , and for the largely solidified material, i.e. after drying, it may lie between 1 and 50 μm (claims 7 and 8).

The same is true for the transport speed of the tape to be coated. It depends on the selected coating method and above all on the duration of the drying step in consideration of the layer thickness, the maximum applicable heating capacity to achieve a uniform drying over the entire layer thickness, and the path length available for drying. There can in par-

ticular be considered a transport speed between 20 and 50 m/min (claim 9).

Analogous considerations as regards optimization apply to the drying temperature, whose lower limit is about room temperature, at which a long drying time must be accepted, and whose upper limit is determined by the chemical stability of the coating material and the evaporation properties of the solvent. Preferably, the drying temperature lies between 50 and 90°C (claim 10).

In the case of a continuous method, the embossing speed necessarily equals the transport speed of the tape to be coated in the coating and drying region. However, if embossing is performed into the substrate produced according to the method of claim 1, the maximum embossing speed is only limited by the parameters of the plant used. The embossing speed may for instance lie between 10 and 50 m/min (claim 11).

For radiation crosslinkage, the coating material, preferably the solvent-based sol-gel, may be irradiated with 40 to 1000 mJ/cm² for e.g. one second (claim 12). A rather fast crosslinkage and thus a definitive fixation of the embossed surface structure is desirable. The maximum usable radiation capacity and the duration of the irradiation naturally depend on the kind of radiation-crosslinkable polymer used.

The same is true for the range of wavelengths of the radiation used. For commonly used radiation-crosslinkable polymers, these wavelengths may lie in the range between about 200 and about 500 nm (claim 13).

Expediently, the layer thickness of the coating is measured after drying and fed into a control circuit for keeping constant this layer thickness (claim 14).

Upon radiation curing, the depth of the surface relief may likewise be measured and fed into a control circuit controlling the pressure of the embossing roller (claim 15). Suitable interferometric measurement methods are known for instance for controlling the development process of the photoresist of a glass master described.

When dimensioning the geometry of the pits, above all the depth thereof, it is important to know whether the surface structure produced forms an interface with air or a transparent protective layer, whose index of refraction should then be considered.

The blanks produced by the method in accordance with the invention can be metallized at least on one side to increase the reflection (claim 16), e.g. by the known aluminum sputtering method. When the coating material has a sufficiently high index of refraction, i.e. for instance substantially consists of TiO_2 with an index of refraction of about 2 to 2.4, and no protective layers are applied, metallization can, however, be omitted, because the reflection obtained at the TiO_2 /air interface already leads to a large enough CA signal. This is completely sufficient for storage media which normally are read out only once, e.g. to load a certain software onto the fixed disk.

On the other hand, when it is desired to fabricate storage media which are read out repeatedly, it is recommended to provide the profiled side of the blanks with a protective lacquer (claim 17) and alternatively to laminate a protective film thereon.

The optical storage media produced by the method in accordance with the invention can have a considerably smaller thickness than the storage media used so far, e.g. of the CD and CD-ROM type. The autofocus servos of the usual reading

devices are, however adjusted to the standardized thickness of 1.2 mm of said storage media. It may therefore be necessary to provide each blank with an outer ring and an inner ring (claim 18), in order to bring the information-bearing layer into the autofocus plane of a commonly used reading device.

The plastics used for the plastic film tape include in particular those from the group of polyesters or polycarbonates (claim 19).

The invention will subsequently be explained with reference to the drawing, which shows greatly schematized embodiments and the details thereof, and in which:

Fig. 1 is a schematic diagram of a plant for the continuous production of a tape with a sequence of blanks each corresponding to one optical storage medium,

Fig. 2 shows a section through a first embodiment of the storage medium in the vicinity of a pit with simplified optical path of the reading beam,

Fig. 2a shows the detail "X" of Fig. 2 on an enlarged scale,

Fig. 3 shows a section as in Fig. 2 through a second embodiment,

Fig. 4 shows an adapter for reading out the storage medium in a CD or CD-ROM drive according to the prior art.

The plant represented in Fig. 1 comprises a take-off roller 1 from which a plastic film 2, e.g. a polyester film, is withdrawn with a width of about 1 m and a thickness of 50 μ m. Upon deflection about a deflection roller 3, the tape 2 is

passed between a coating roller 6 and a counter-roller 7. The coating roller 6 applies a sol-gel layer with a thickness of about 1 μm to the tape. The sol-gel is contained in a reservoir 4 in which a cup roller 5 is immersed, which transfers the adhering sol-gel to the coating roller 6. The application of a layer according to this principle is basically known from the printing industry and will therefore not be explained in detail. Other known coating methods are also applicable.

The coated tape subsequently passes through a drying station 8, in which the solvent is at least largely removed by supplying heat, e.g. by infrared irradiation. At the outlet of the drying station 8, the layer thickness of the dried, but still embossable coating is measured by means of the indicated interferometric film thickness gauge 12, whose output signal is fed into a controller 13, which in a manner known per se intervenes in the coating station at a suitable point, in order to keep the layer thickness at the desired value. Subsequently, the coated embossable tape can be wound up and be provided for further use (not represented). Instead, the coated tape can immediately be supplied to an embossing station, as represented. Said embossing station comprises an embossing roller 9, whose outer periphery is formed by a die which bears the negative of the surface structure to be generated in the coating of the tape. Opposite the embossing roller 9 a pressure roller 10 is disposed. The embossing station is followed by a curing station 11, which may in particular consist of one or more UV light sources, which initiate the radiation crosslinkage of the photopolymer contained in the coating. Behind the curing station 11, the depth of the pits is measured via the interferometric pit depth gauge 14, whose output signal is supplied to a controller 15, which in dependence on the result of the comparison of the actual value with a desired value changes the pressure of the embossing roller 9 towards maintaining the desired value. Be-

hind a deflection roller 16, the tape provided with the surface structure is either wound up on a wind-up roller 17 for further use or processed. The processing not represented here includes the punching of the blanks on the tape 2, the simultaneous or future punching of the central hole, if necessary a metallizing operation, applying a protective lacquer or laminating a protective film and mounting an adapter, which may for instance comprise an inner ring and an outer ring and which lifts the storage medium produced, which may be considerably thinner than a conventional CD or CD-ROM, into the reading or autofocus plane of a usual disk drive or reading device.

In a considerably magnified representation, Fig. 2 shows a section through a first embodiment of a storage medium corresponding to a blank punched out of the coated tape 2 of Fig. 1. The storage medium comprises a polyester film 20, which by means of the plant as shown in Fig. 1 has been provided with a sol-gel layer 21 (alternatively with a layer of a photopolymer), whose side facing away from the polyester film 20 has embossed pits such as 21a. The layer 21 can have a refractive index n of e.g. 1.5. By methods known per se, this information-bearing side has been provided with a metallization 22 (cf. Fig. 2a) and finally with a protective lacquer 23. The reading beam 24 reads out the sequence of embossed pits and lands as in a conventional CD or CD-ROM.

Fig. 3 shows a section through a second embodiment of the storage medium. On the polyester film 20 a layer 26 of a TiO_2 -based sol-gel is provided. The index of refraction of this layer may be in the range between 2 and 2.5. Therefore, the reflectivity of the layer 26 is so great that the additional metallization layer 21 of Fig. 2 can be omitted in this embodiment. In particular when this storage medium is read out only once, in order to copy its contents onto the fixed disk of a computer, the protective lacquer layer 23,

which is present in the embodiment as shown in Fig. 2, is superfluous. Instead, the surface to be read out by means of the reading beam 24 can merely be covered by an adhesion film (not represented), which is simply peeled off before inserting the storage medium into the reading device or disk drive.

Since the storage medium in accordance with the invention is considerably thinner than a conventional CD or CD-ROM, an adapter is recommendable for reading out, which adapter moves the surface of the storage medium to be read out to about the same plane in which the surface of a CD or CD-ROM to be read out would be disposed, once the storage medium has been inserted in the disk drive.

Fig. 4 shows a section of a suitable, schematically simplified adapter. It comprises a generally circular carrier plate 30 of plastics, which has a central hole 31 with the diameter of the central hole of a CD in an inner ring 32 protruding on the future read-out side. This inner ring serves to center the film-like storage medium 33, for instance of the structure explained with reference to Figs. 2 and 3. At its outer periphery, the storage medium is fixed by an outer ring 34. The thickness of the outer ring 34 and the thickness of the inner ring 32 are dimensioned such that upon inserting the adapter into the tray of a disk drive, the film-like storage medium 33, to be more precise its surface to be read out, is disposed at that level at which there would also be disposed the information-bearing surface of a CD or CD-ROM, which is covered by a polycarbonate layer.

C l a i m s

1. A method of producing a substrate for fabricating optical storage media in which the information is stored serially in the form of pits and lands, characterized in
 - that a plastic film tape is continuously coated with a liquid, UV-curable material in a predetermined layer thickness,
 - that subsequently the coating of the tape is dried by supplying heat, possibly in a clocked passage, until a no longer flowable, but still embossable condition is reached, and
 - that the coated tape is wound up for further use.

2. A method of fabricating optical storage media in which the information is stored serially in the form of pits and lands, characterized in
 - that a plastic film tape is continuously coated with a liquid, UV-curable material in a predetermined layer thickness,
 - that subsequently the coating of the tape is dried by supplying heat, possibly in a clocked passage, until a no longer flowable, but still embossable condition is reached,
 - that the coated tape is passed between two rollers, of which the roller facing the coating side bears a surface relief which is the negative of at least one blank of the surface relief of the storage medium to be fabricated and embosses the same into the coating,
 - that for curing the coating, the tape is subsequently passed below a UV radiation source,
 - that the blanks are punched out of the tape, and
 - that simultaneously or in a separate step a central hole is punched into the blanks.



3. The method as claimed in claim 1 or 2, characterized in that the coating material is a solvent-based photopolymer.
4. The method as claimed in claim 1 or 2, characterized in that the coating material is a solvent-based radiation-crosslinkable sol-gel.
5. The method as claimed in any of claims 1 to 4, characterized in that the viscosity of the liquid coating material lies between 10 and 100 mPa/s.
6. The method as claimed in any of claims 1 to 5, characterized in that upon drying the viscosity of the coating material lies between 20 and 100 Pa/s.
7. The method as claimed in any of claims 1 to 6, characterized in that the layer thickness of the liquid coating material lies between 2 and 100 μm .
8. The method as claimed in any of claims 1 to 7, characterized in that upon drying the layer thickness of the coating material lies between 1 and 50 μm .
9. The method as claimed in any of claims 1 to 8, characterized in that the transport speed of the tape to be coated lies between 20 and 50 m/min and preferably is about 25 m/min.
10. The method as claimed in any of claims 1 to 9, characterized in that the drying temperature of the coated tape is chosen between room temperature and about 150°C and preferably between 50 and 90°C.



11. The method as claimed in any of claims 2 to 10, characterized in that the embossing speed is adjusted to 10 to 50 m/min and preferably to about 25 m/min.
12. The method as claimed in claim 4, characterized in that for radiation crosslinkage the solvent-based coating material, in particular the sol-gel, is irradiated with 50 to 400 mJ/cm², until curing is sufficient for a permanent fixation of the embossing.
13. The method as claimed in claim 12, characterized in that for cross-linking radiation with a wavelength between about 200 and about 500 nm is used.
14. The method as claimed in any of claims 1 to 13, characterized in that the layer thickness of the coating is measured upon drying and fed into a control circuit for keeping constant the layer thickness.
15. The method as claimed in any of claims 1 to 14, characterized in that the depth of the surface relief is measured upon UV curing and fed into a control circuit controlling the pressure of the embossing roller.
16. The method as claimed in any of claims 1 to 15, characterized in that the blanks are metallized at least on one side.
17. The method as claimed in any of claims 1 to 15, characterized in that the profiled side of the blanks is provided with a protective lacquer.
18. The method as claimed in any of claims 1 to 17, characterized in that each blank is provided with an outer ring and an inner ring.



19. The method as claimed in any of claims 1 to 18, characterized in that the plastic material for the plastic film tape is selected from the group including polyesters or polycarbonates.

