

Description

The invention relates to an optical recording medium with a transparent (light-permeable) substrate layer, a method for reading and a method for manufacturing such an optical recording medium.

A known such recording medium is, for example, the compact disk (CD) where a transparent layer is followed by a light reflecting layer aluminium layer having recesses, so-called pits, which represent the data stored on the compact disk. The data can be read from the compact disk by means of an optical scanning device because the reflection characteristics of the light reflecting aluminium layer depends on the pattern formed by the pits of the disk. Owing to desctructive interference, a recess, often also referred to as groove, reflects less light than a hump, which is often also referred to as land.

Therefore, from the intensity of the light reflected from the CD, the optical scanning device recognizes whether the bit scanned is, for example, a logical one or a logical zero.

A further such optical recording medium - known as magneto-optical disk - is described in the paper "Magneto-optische Versuche dauern an" (Magneto-optical Trials Continue) in *Funkschau* issue 13, 20 June 1986, on pages 37 through 41.

In contrast to a compact disk a magneto-optical disk has no pits. Behind the transparent layer there lies a magneto-optical layer on which data can be recorded and from which data can be read. Firstly, it will be explained how data are written onto a magneto-optical disk.

The magnetio-optical layer is heated up to a temperature in a region near the Curie temperature by means of a laser beam focused onto the disk. It is usually sufficient to heat up the magnetio-optical layer only to about the compensation temperature lying below the Curie temperature. An electromagnet is located behind the focal point on the disk and this magnetizes the area heated by the laser beam in the one or the other direction of magnetizing. As the heated point cools down again to below the compensation temperature after the laser beam has been switched off, the direction of magnetizing determined by the electromagnet remains fixed; it freezes so to speak. In this way the individual bits are stored in domains with differing directions of magnetizing. For example, in this case one direction of magnetizing corresponds to a domain for a logical one, while the opposing direction of magnetizing represents a logical zero.

In order to read the data, use is made of the Kerr effect. The plane of polarization of a linearly polarized light beam is turned by a measurable angle upon reflection in a magnetized mirror. The plane of polarization of the reflected light beam is turned to the right or the left according to in which direction the mirror is magnetized. However, as the individual domains on the disk act like magnetized mirrors, the plane of polarization of an scanning light beam turns through a measurable angle to the right or the left according to the direction of magnetizing of the domain just scanned.

The optical scanning device recognizes which bit is present, a logical one or a logical zero, from the turning of the plane of polarization of the light beam reflected from the disk. In contrast to a CD with pits, a magneto-optical disk can be erased and rewritten on almost indefinitely.

Although with optical recording media - compact disk and magneto-optical disk - storage capacity and recording density are agreeably high, an essential increase of storage capacity is desirable and of great advantage in particular in applications for computers and when used as a video disk.

A magneto-optical disk is known from the Japanese patent application JP-A 62 60147 in which short pit patterns containing address markings are provided on the data tracks with predetermined spacings. Said address markings serve for ordering the data stored on the disk in individual segments. Thus, data stored by means of magnetizing, on the one hand, and by means of the pits, on the other, lie in the same data track one above the other at the spots where said address markings are provided.

The Japanese patent application JP-A 58 114343 describes a magneto-optical disk which is subdivided into several circular sectors. The individual circular sectors are provided, alternately, with a magneto-optical layer for storing data magneto-optically and with pit patterns for storing data optically, so that a magneto-optical sector is followed by a sector with pit patterns.

On a magneto-optical disk, known from the Japanese patent application JP-A 58 211346, pit patterns are provided always between - as viewed in the direction of the tracks - two magneto-optical layers, so that when traveling along a data track each magneto-optical layer is followed by a pit pattern which in turn is followed by another magneto-optical layer, etc. Track addresses are stored in the pit patterns.

A further optical disk exhibiting the following construction is known from the JP-A 56 140 536. This optical disk is constructed from an optical layer 1, containing pits, and a magneto-optical layer 2 which is

followed by a protective layer 3. Two such disks are glued to each other at the protective layers. The data stored in the pits are read optically while, however, the data stored in the magnetic layer are read not optically but by means of a magnetic head.

Finally, the Japanese patent application JP-A 61 68742 describes a magneto-optical disk on which the data are stored alternately in helical or circular shaped magneto-optical data tracks and in data tracks with pit patterns. One winding of the helix or, respectively, a concentric circle is magneto-optical while the next winding or, respectively, the next circle is provided with pit patterns. Therefore, between every two magneto-optical helix windings or, respectively, circles there always lies a helix winding or, respectively, circle with pits.

However, in none of the above magneto-optical disks the storage capacity is increased in comparison to a conventional magneto-optical or an optical disk by the measures proposed in the named Japanese patent applications.

It is, therefore, the object of the invention to essentially increase the storage capacity with an optical recording medium.

A first solution of this task consists of the fact that the transparent substrate layer is followed by a magneto-optical layer which is partially reflective to light and partially transparent and in which data can be stored by means of magnetizing, that the magneto-optical layer is followed by a first transparent layer which is followed by a second transparent layer in which data can be stored by means of recesses, so-called pits, and that the data stored in the magneto-optical layer and the data stored by means of the pits lie one above the other in the same data track.

A second solution of this task provides that the transparent substrate layer is followed by a magneto-optical layer which is partially reflective to light and partially transparent and in which data can be stored by means of magnetizing, that the magneto-optical layer is followed by a transparent layer in which data can be stored by means of recesses, so-called pits, that the pits are provided on the outer side of the recording medium, and that the data stored in the magneto-optical layer and the data stored by means of the pits lie one above the other in the same data track.

A first method for reading an optical recording medium provides that one part of the light radiating onto the recording medium and scanning the data is reflected by the magneto-optical layer, while one part, however, radiates through the magneto-optical layer, that the reflected part of the light contains the magneto-optically stored data and that the part of the light radiating through the recording medium contains the data stored by means of the pits.

A second method for reading an optical recording medium provides that one part of the light radiating onto the recording medium and scanning the data is reflected by the magneto-optical layer, while one part, however, radiates through the magneto-optical layer, that the reflected part of the light contains the magneto-optically stored data, that the part of the light radiating through the recording medium contains the data stored by means of the pits (3) and that the pits (3) are provided on the outer side of the recording medium.

A third method for reading an optical recording medium provides that one part of the light radiating onto the recording medium and scanning the data is reflected by the magneto-optical layer, while one part, however, radiates through the magneto-optical layer, that the reflected part

of the light contains the data stored by means of the pits and that the part of the light radiating through the recording medium contains the magneto-optically stored data.

A method for manufacturing an optical recording medium provides that a magneto-optical layer is deposited onto a transparent substrate layer, said magneto-optical layer being followed by a transparent layer which is coated with a photosensitive resist onto which the pattern of pits is depicted by means of exposing, that the photosensitive resist is developed whereby the exposed or, respectively, the non-exposed areas of the photosensitive resist are stripped from the transparent layer, that the bare areas of the transparent layer (10) are etched away and that in a final procedure step the remaining photosensitive resist (14) is stripped from the transparent layer (10).

It is shown in

- Figure 1 an optical recording medium according to claim 6 with a circular photodetector;
- Figure 2 an optical recording medium according to claim 6 with a ring shaped photodetector;
- Figure 3 an optical recording medium according to claim 7;
- Figure 4 an optical recording medium according to claim 3;
- Figure 5 an optical recording medium according to claim 2.

The optical recording medium according to claim 1 represents, in the embodiment of a disk form plate, a

combination of a compact disk (CD) and a magneto-optical disk. As, on the one hand, data are stored in the pits and, on the other, data can be stored and erased almost indefinitely through magnetizing the magneto-optical layer, the storage capacity is doubled by the invention.

Furthermore, the invention provides the possibility of reading the data not only stored in the pits but also in the magnetic domains simultaneously using suitable optical scanning devices. This results in a doubling of the data rate. Likewise, it is possible to write new data into the domains while, at the same time, the data stored in the pits are read.

For the writing-in of data into the light reflecting magneto-optical layer the output of a laser provided, for example, as light source is increased to such an extent that the compensation temperature in the focal spot of the laser is exceeded; in contrast thereto, however, when reading data the output of the laser is reduced so far that the temperature in the light reflecting magneto-optical layer lies at a safe distance below the compensation temperature in order to exclude the unintentional destruction of data.

If the magneto-optical layer 2 is chosen to be of about the same thickness as or thinner than the wavelength of the scanning light a part of the light radiates through. Figure 1 shows that with a layer 2 having a thickness of $\lambda/2$ in the areas where there are no recesses about 9 per cent of the incident light radiates through while about 15 per cent is reflected; the remainder being absorbed. The magneto-optical layer 2 is protected from damage by a transparent layer 10 the refractive index of which is $n_1=1$.

Figure 2 shows the division of light at a pit 3, a recess, whose depth is half the wavelength of the scanning

light. Again, about 15 per cent of the incident light is reflected. Due to the pit depth of $\lambda/2$, however, diffractive patterns ensue behind the recording medium because, owing to the path difference of $\lambda/2$, those light components which radiate through a recess interfere with those light components which radiate through the thicker layer surrounding the recess. In order to protect the magneto-optical layer 2 from damage such as scratches, for example, a transparent layer 10 with a refractive index of $n_1=1$ is provided.

Because, owing to the pit depth of $\lambda/2$, the path difference between the light reflected at a hump and at a recess is $\lambda/2 + \lambda/2 = \lambda$, the light reflected at the magneto-optical layer 2 which scans the magneto-optically stored data is not adulterated by the pit pattern. Instead of $\lambda/2$ the pit depth may also be odd number multiples of $\lambda/2$. The only essential factor is that the path difference is λ or whole number multiples of λ .

The pits 3 can be detected in the following three ways.

Using a photodetector 5, preferably constructed circular in shape as indicated in Figure 1, pits can be recognized because without a pit about 9 per cent of the light hits the photodetector while where a pit is present, in the ideal case, owing to the interference no light at all hits the photodetector.

As the level one diffractive maximums can be detected by means of a ring shaped photodetector where a pit is present the data stored by means of the pits can be read. In the ideal case no light radiates onto the ring shaped photodetector where no pit is present while, however, the level one diffractive maximums are depicted on the photodetector behind a pit.

Finally, it is also possible to combine both photodetectors with each other in such a way that the circular photodetector 5 is surrounded by the ring shaped photodetector 6. Using the circular photodetector 5 the non-diffracted light beams are acquired while the level one diffractive beams are detected by means of the ring shaped photodetector 6. As the signals of the two photodetectors always have differing preceding signs the difference of the two signals supplies the data stored by means of the pits.

In the optical recording medium shown in Figure 3 the pit depth has been selected to be $\lambda/4$ so that the path difference is $\lambda/2$. Instead of $\lambda/4$ the pit depth may also be odd number multiples of $\lambda/4$. The only essential factor is that the path difference between the light reflected at a pit and that reflected in its surroundings is $\lambda/2 + n * \lambda$, where n is a whole number.

In contrast to the optical recording medium from Figure 1 and 2 the reflected light contains the data stored by means of the pits while the magnetically stored data are contained in the light radiating through. For reading the magnetically stored data, instead of the Kerr effect, use is made of the similar Faraday effect.

Now, the construction of layers of the optical recording medium shown in Figure 4 and specified in claim 3 is described and explained. This recording medium exhibits the following construction of layers.

A substrate layer 1 is followed by a first protective layer 8 which in turn is followed by a magneto-optical layer 2 which is followed by a second protective layer 9. The second protective layer 9 is followed by a first transparent layer 10 and a second transparent layer 11 which has pits. For reasons of clarity the thicknesses of the individual layers are not drawn to scale, however.

One part 12 of the light 4 radiating, in Figure 4, onto the substrate layer 1 from below is reflected at the magneto-optical layer 2, while one part 13, however, radiates through the magneto-optical layer 2 and through the remaining layers 9, 10 and 11.

The light 12 reflected from the magneto-optical layer 2 contains the data stored in the magneto-optical layer while the light 13 radiating through the recording medium contains the data stored by means of the pits 3, provided that the depth of the pits is chosen to be $\lambda/2$ or odd number multiples of $\lambda/2$. If the pit depth is $\lambda/4$, however, then the reflected light contains the data stored by means of the pits while the light radiating through contains the data stored in the magneto-optical layer. The refractive index of the substrate layer 1 and of the layer 11 is chosen to be, for example, $n_2 = 1.5$; however, the transparent layer 10 which could also be, for example, an empty space or an air cushion, a so-called air gap, has a refractive index of $n_1 = 1$.

Figure 5d shows the layer construction of the recording medium specified in claim 3.

A transparent substrate layer 1 is followed by a magneto-optical layer 2 which in turn is followed by a transparent layer 10. The pits 3 provided at the outer side of the transparent layer 10 have a depth of $\lambda/4$. As the magneto-optical layer 2 reflects a part - about 15 per cent - of the light radiating onto it while passing a part - about 9 per cent - the pits 3 can be detected in the same manner as with the recording media of the Figures 2, 3, 4 or 6 from the light radiating through by means of a circular or ring shaped photodetector or a combination of both. The magnetically stored data are contained in the reflected light.

This embodiment example can be manufactured in a particularly simple manner, as will now be described by means of the Figures 5a, 5b, 5c and 5d.

For the manufacturing one starts with a plate in which, as can be seen from Figure 5a, a transparent substrate layer 1 is followed by the magneto-optical layer 2 which in turn is followed by the transparent layer 10 which is covered by a photosensitive resist 14.

The pattern of pits is depicted onto the photosensitive resist 14 by means of exposing. On developing the photosensitive resist 14 the exposed or the non-exposed areas are stripped from the layer 10 so that in these areas the layer is bare such as shown in Figure 5b. Following this, the bare areas of the transparent layer 10 are etched away so that the photosensitive resist 14 and the transparent layer 10 remain present on the disk only in the exposed or, respectively, in the non-exposed areas. The recording medium processed thus far is shown in Figure 5c.

In a final procedure step the remaining photosensitive resist 14 is stripped from the transparent layer 10 so that only the humps, the so-called land components, remain; therefore, as can be seen in Figure 7d, the magneto-optical layer 2 is bare at the pits 3.

With the embodiment example of the invention described in claim 9 it is specified that the data stored in the magneto-optical layer are correlated with the data stored by means of the pits.

This way, for example, video signals in accordance with a known standard can be stored on a video disk by means of the pits. In addition to these video signals stored in the pit patterns, correlated data can be stored in the magneto-

optical layer which result, together with the data stored in the pit pattern, in a reproduced signal of high quality so that an improved picture and sound quality ensues. For example, one field may be stored in the pit pattern and the other in the magnetic layer. Such a video disk can be played back both in a conventional video disk player as well as in a device with high definition quality. This video disk bears the great advantage that it supplies a picture in known quality with a conventional video disk player while a video disk player evaluating both signals - the data stored by means of the pits as well as those stored in the magneto-optical layer - reproduces a picture of high quality.

With a compact disk, too, an essential increase of sound quality can be achieved if data correlated to the data stored by means of the pits are stored in the magneto-optical layer.

A further application is, for example, a video disk on which maps are stored. Fixed data such as, for example, mountains, contour lines or lakes are stored by means of the pits while variable data, for example, detours or constructions sites are stored in the magnetic layer.

The optical recording medium according to the invention, however, is in no way limited to the plate shape of a disk. It may also be constructed, for example, in the form of a cylinder. In the embodiment as a disk it is particularly well suitable as storage medium for computers, as video disk for video disk players and as compact disk for CD players.

A suitable material for the light reflecting magneto-optical layer 2 would be, for example, an alloy made of iron, terbium and gadolinium.

Because, as mentioned above, the invention in its embodiment as a disk represents a combination of a read-only

compact disk and a magneto-optical disk which can be read as well as written, it combines the characteristics of a ROM and a RAM disk and could therefore be designated ROMRAM disk.

Patent Claims

1. Optical recording medium with a transparent (light-permeable) substrate layer (1), characterized in that the transparent substrate layer (1) is followed by a magneto-optical layer (2) which is partially reflective to light and partially transparent and in which data can be stored by means of magnetizing, that the magneto-optical layer (2) is followed by a transparent layer (10) which is followed by a transparent layer (11) in which data can be stored by means of recesses, so-called pits (3), and that the data stored in the magneto-optical layer (2) and the data stored by means of the pits lie one above the other in the same data track.
2. Optical recording medium with a transparent substrate layer (1), characterized in that the transparent substrate layer (1) is followed by a magneto-optical layer (2) which is partially reflective to light and partially transparent and in which data can be stored by means of magnetizing, that the magneto-optical layer (2) is followed by a transparent layer (10) in which data can be stored by means of recesses, so-called pits (3), that the pits (3) are provided on the outer side of the recording medium, and that the data stored in the magneto-optical layer (2) and the data stored by means of the pits lie one above the other in the same data track.
3. Optical recording medium according to claim 1, characterized in by the following construction of layers in the specified sequence:



- a) a transparent substrate layer (1)
 - b) a first protective layer (8)
 - c) a magneto-optical layer (2)
 - d) a second protective layer (9)
 - e) a transparent layer (10) with a refractive index of n_1
 - f) a transparent layer (11) with a refractive index of $n_2 \neq n_1$ and with recesses (3), so-called pits.
4. Optical recording medium according to claim 1 or 3, characterized in that the depth of the recesses (3) is chosen to be smaller than the wavelength of the scanning light.
5. Optical recording medium according to claim 4, characterized in that the depth of the recesses (3) is about $1/10$ of the wavelength of the scanning light.
6. Optical recording medium according to claim 1 or 3, characterized in that the depth of the recesses (3) is about one-half or odd number multiples of one-half of the wavelength of the scanning light.
7. Optical recording medium according to claim 1 or 3, characterized in that the depth of the recesses (3) is about one-quarter or odd number multiples of one-quarter of the wavelength of the scanning light.



8. Optical recording medium according to claim 1, 3, 4, 5, 6 or 7, characterized in that the pits (3) lie at the border between two layers.
9. Optical recording medium according to claim 1, 2, 3, 4, 5, 6, 7 or 8, characterized in that the data stored in the magneto-optical layer (2) are auxiliary (additional) data correlated to the data stored by means of the pits (3).
10. Method for reading an optical recording medium according to claim 6, characterized in that one part of the light radiating onto the recording medium and scanning the data is reflected by the magneto-optical layer (2), while one part, however, radiates through the magneto-optical layer (2), that the reflected part of the light contains the magneto-optically stored data and that the part of the light radiating through the recording medium contains the data stored by means of the pits (3).
11. Method for reading an optical recording medium according to claim 7, characterized in that one part of the light radiating onto the recording medium and scanning the data is reflected by the magneto-optical layer (2), while one part, however, radiates through the magneto-optical layer (2), that the reflected part of the light contains the data stored by means of the pits (3) and that the part of the light radiating through the recording medium contains the magneto-optically stored data.
12. Method for manufacturing an optical recording medium, characterized in that a magneto-optical layer (2) is deposited onto a transparent substrate layer (1), said magneto-optical layer being



followed by a transparent layer (10) which is coated with a photosensitive resist (14) onto which the pattern of pits is depicted by means of exposing, that the photosensitive resist (14) is developed whereby the exposed or, respectively, the non-exposed areas of the photosensitive resist (14) are stripped from the transparent layer (10), that the bare areas of the transparent layer (10) are etched away and that in a final procedure step the remaining photosensitive resist (14) is stripped from the transparent layer (10).



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