SINGLE RETENTION/REFLECTIVE LAYER RECORDABLE/ERASABLE OPTICAL MEDIA

Recordable/erasable optical storage media are disclosed. More particularly, it provides a method and apparatus for recording and erasing information on an optical storage medium (2). The medium of the present invention generally includes a rigid substrate (4), and expansion layer (6) adjacent the substrate (4) and a single, dual-purpose, metal retention/reflective layer (8) adjacent the expansion layer (6). A protective layer (10) may or may not be present. Additionally, methods for writing and erasing on these media are described.

* See back of page
DESIGNATIONS OF "DE"

Until further notice, any designation of "DE" in any international application whose international filing date is prior to October 3, 1990, shall have effect in the territory of the Federal Republic of Germany with the exception of the territory of the former German Democratic Republic.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AT</td>
<td>Austria</td>
<td>ES</td>
<td>Spain</td>
<td>MC</td>
<td>Monaco</td>
</tr>
<tr>
<td>AU</td>
<td>Australia</td>
<td>FI</td>
<td>Finland</td>
<td>MG</td>
<td>Madagascar</td>
</tr>
<tr>
<td>BB</td>
<td>Barbados</td>
<td>FR</td>
<td>France</td>
<td>ML</td>
<td>Mali</td>
</tr>
<tr>
<td>BE</td>
<td>Belgium</td>
<td>GA</td>
<td>Gabon</td>
<td>MR</td>
<td>Mauritania</td>
</tr>
<tr>
<td>BF</td>
<td>Burkina Faso</td>
<td>GR</td>
<td>United Kingdom</td>
<td>MW</td>
<td>Malawi</td>
</tr>
<tr>
<td>BG</td>
<td>Bulgaria</td>
<td>HU</td>
<td>Hungary</td>
<td>NL</td>
<td>Netherlands</td>
</tr>
<tr>
<td>BJ</td>
<td>Benin</td>
<td>IT</td>
<td>Italy</td>
<td>NO</td>
<td>Norway</td>
</tr>
<tr>
<td>BR</td>
<td>Brazil</td>
<td>JP</td>
<td>Japan</td>
<td>PL</td>
<td>Poland</td>
</tr>
<tr>
<td>CA</td>
<td>Canada</td>
<td>KP</td>
<td>Democratic People's Republic of Korea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>Central African Republic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG</td>
<td>Congo</td>
<td>KR</td>
<td>Republic of Korea</td>
<td>RO</td>
<td>Romania</td>
</tr>
<tr>
<td>CH</td>
<td>Switzerland</td>
<td>LI</td>
<td>Liechtenstein</td>
<td>SD</td>
<td>Sudan</td>
</tr>
<tr>
<td>CM</td>
<td>Cameroon</td>
<td>LK</td>
<td>Sri Lanka</td>
<td>SE</td>
<td>Sweden</td>
</tr>
<tr>
<td>DE</td>
<td>Germany</td>
<td>LU</td>
<td>Luxembourg</td>
<td>SN</td>
<td>Senegal</td>
</tr>
<tr>
<td>DK</td>
<td>Denmark</td>
<td></td>
<td></td>
<td>SU</td>
<td>Soviet Union</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TD</td>
<td>Chad</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TG</td>
<td>Togo</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>US</td>
<td>United States of America</td>
</tr>
</tbody>
</table>
SINGLE RETENTION/REFLECTIVE LAYER
RECORDABLE/ERASABLE OPTICAL MEDIA

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates in general to the field of recording media. In particular, this invention provides a recordable/erasable optical storage medium with a single, dual-purpose, metal layer for retention and reflection and write/read/erase mechanism therefor in which data may be recorded and erased in response to thermal effects and, in particular, in response to light.

Description of the Related Art

Optical data storage media in the form of compact disks are well known as an alternative to long-playing records and magnetic tape cassettes. The disks with which consumers are familiar are optical read-only disks, and the common disk player is designed specifically for this type of disk. These disks have a reflective surface containing pits that represent data in binary form. A description of these pits and how they function is provided by Watkinson, "The Art of Digital Audio," Focal Press, Chapter 13.

Compact disks are currently produced by a pressing process similar to the process used to produce conventional long-playing records. The process, referred to herein as the mastering process, starts by first polishing a plain glass optical disk. This disk has an outside diameter from 200 to 240 mm, a thickness of 6 mm and undergoes various cleaning and washing steps. The disk is then coated with a thin chrome film or coupling agent, a step taken to produce adhesion between the glass disk and a layer of photo-resist, which is a photosensitive material. Data on a compact disk master tape are then transferred to the glass disk by a laser beam cutting method.
The glass disk is still completely flat after it is written on by the laser beam because pits are not formed until the glass is photographically developed. The disk surface is first made electrically conductive and then subjected to a nickel evaporation process. The disk, now known as the glass master, then undergoes nickel electrocasting, a process that is similar to that used in making analog phono records. A series of metal replications follow, resulting in a disk called a stamper. The stamper is equivalent to a photographic negative in the sense that it is a reverse of the final compact disk; that is, there are now bumps where there should be pits. This stamper is then used to make a pressing on a transparent polymer such as polyvinyl chloride, poly(ethyl-methacrylate), and polycarbonate. The stamped surface is then plated with a reflective film, such as aluminum or other metal, and finally a plastic coating is applied over the film to form a rigid structure.

The player operates by focusing a laser beam on the reflective metal through the substrate and then detecting reflected light. The optical properties of the substrate, such as its thickness and index of refraction, are thus critical to the player's detection systems and standard players are designed specifically with these parameters in mind.

The pits increase the optical path of the laser beam by an amount equivalent to a half wavelength, thereby producing destructive interference when combined with other (non-shifted) reflected beams. The presence of data takes the form of a drop in intensity of the reflected light. The detection system on a standard player is designed to require greater than 70% reflection when no destructive interference occurs and a modulation amplitude greater than 30% when data is present. These intensity limits, combined with the focusing parameters, set the criteria for the compact disks and other optical data storage media that can be read or played on such players.
Media on which data can be recorded directly on, and read directly from, have a different configuration and operate under a somewhat different principle. One example is described in U.S. Patent No. 4,719,615 (Feyrer, et al.).

The medium described in Feyrer, et al., includes a lower expansion layer of a rubbery material that expands when heated. The expansion layer is coupled to an upper retention layer that is glassy at ambient temperature and becomes rubbery when heated. Both layers are supported on a rigid substrate. The expansion and retention layers each contain dyes for absorption of light at different wavelengths. Data are recorded by heating the expansion layer by absorption of light from a laser beam at a "record" wavelength to cause the expansion layer to expand away from the substrate and form a protrusion or "bump" extending into the retention layer. While this is occurring, the retention layer rises in temperature above its glass transition temperature so that it can deform to accommodate the bump. The beam is then turned off and the retention layer cools quickly to its glassy state before the bump levels out, thereby fixing the bump.

Reading or playback of the data is then achieved by a low intensity "read" beam that is focused on the partially reflecting interface between the retention layer and air. When the read beam encounters the bump, some of the reflected light is scattered, while other portions of the reflected light destructively interfere with reflected light from non-bump areas. The resulting drop in intensity is registered by the detector. Removal of the bump to erase the data is achieved by a second laser beam at an "erase" wavelength that is absorbed by the retention layer and not by the expansion layer. This beam heats the retention layer alone to a rubbery state where its viscoelastic forces and those of the expansion layer return it to its original flat configuration. The write, read, and erase beams all enter the medium on the retention layer side, passing through retention layer before reaching the expansion layer.
The erasable optical storage medium system described in Feyrer, et al., has a number of disadvantages. For example, the writing and erasure of data must be performed at two different wavelengths of light. Furthermore, the device relies on reflection at the interface between the retention layer and air that results in an inherently low reflectivity (30% maximum). Thus, the system cannot be read by the detection mechanism of a standard compact disk player designed for focusing through a 1.2 mm polycarbonate substrate and requiring 70% reflectance. Additionally, there is either a predetermined level of thermal conductivity between the heated expansion layer, to sufficiently raise the temperature of the retention layer so that it can accommodate the bump formed by the expansion layer, or the retention layer must absorb a predetermined amount of light energy at the "record" wavelength, in order to produce the needed temperature rise in the retention layer during recording. In either case, this requirement must be met and accurately controlled if this media is to be produced with consistent recording characteristics.

In addition, in order for the most effective erasure to be achieved, the retention layer must be heated separately from the expansion layer. This follows from the fact that during erasure the retention layer must reach a rubery state in order for the viscoelastic forces of a cool expansion layer to pull the expansion layer back to its original flat configuration. If the expansion layer is heated during this time, it will not be in its relaxed state and it will therefore not return to its flat configuration. Because the expansion layer and the retention layers are in intimate physical contact, heat energy must be conducted between the two layers during both the recordation and erase processes, thus negating the possibility of only heating the retention layer. Any attempt to erase the medium during the act of recordation, i.e., direct overwrite data update, therefore would prove unsuccessful.
Copending application Serial No. 294,723 (assigned to the assignee of the present application) describes an improved optical recording method and apparatus. In one embodiment, the invention includes an expansion layer, a reflective layer, and a retention layer. As the expansion layer is heated it expands, pressing into the thin reflective layer, the retention layer, and a protective layer. In an alternative embodiment, the retention layer is provided between the reflective and expansion layers. The retention layer is pressed into, for example, the protective layer that is sufficiently compliant to allow deformations. The reflective layer is described as being, for example, gallium, aluminum, copper, silver, gold, or indium.

In one embodiment, copending application Serial No. 357,377 (assigned to the assignee of the present application) describes a liquid reflective layer that is provided adjacent the retention layer opposite the expansion layer. Additionally, improved expansion and retention layers are also described therein.

Optical media described above have one or more limitations. First, two lasers are normally necessary, one for the expansion layer and a second one for the retention layer. These lasers often require individual wavelengths: a "recording laser" emitting a beam with a wavelength corresponding to the absorption frequency of a dye in the expansion layer and an "erasing laser" emitting a beam with a wavelength corresponding to the absorption frequency of a dye in the retention layer. Second, manufacture of these media requires several separate coating operations, thereby increasing the risk of defects due to coating flaws, dust and handling, for example. Also, the manufacturing cost is increased with each additional coating operation.

A purpose of the present invention is to overcome these limitations and to provide recordable/erasable storage media requiring but a single laser for recordation and erasure and also one less coating operation.
SUMMARY OF THE INVENTION

The present invention provides recordable/erasable optical storage media. More particularly, it provides a method and apparatus for recording and erasing information on an optical storage medium. The medium of the present invention generally includes a rigid substrate and an expansion layer adjacent to the substrate. A single retention/reflective layer is adjacent to the expansion layer. Additionally, a protective layer is optionally present and is adjacent to the retention/reflective layer.

Functions of the retention and reflective layers of the prior art media are combined in this invention into a single, dual-purpose, metal layer, hereinafter referred to as the retention/reflective layer.

The media of the invention are susceptible to expansion and relaxation, to writing data thermally, to erasing data thermally, and to reading data optically.

Methods for writing and erasing on the media of the present invention are also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-section of a recording medium illustrating one embodiment of the present invention.

Fig. 2 illustrates a top view along line 2-2' of the medium shown in Fig. 1.

Fig. 3 illustrates an alternative embodiment of the recording medium of the invention, in cross-section and including data recorded thereon in the form of a recordation bump.

Fig. 4 illustrates a second alternative embodiment of the recording medium of the invention.

DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS

The present invention provides recordable/erasable optical storage media. Figs. 1 and 2 illustrate one embodiment of the invention as it applies to a disk 2. In Fig. 1, the disk includes a substrate 4 onto which an
expansion layer 6 is provided. A single, dual-purpose, metal retention/reflective layer 8 is adjacent to the expansion layer. A protective layer 10 may also be present, although it is not necessary. Fig. 4 illustrates an alternative embodiment where the protective layer 10 is absent.

If a protective layer is present, the protective layer will be adjacent the retention/reflective layer and will retain the material against the expansion layer. In one embodiment, as shown in Fig. 1, the protective layer will enclose and contain the retention/reflective layer, this being accomplished by the protective layer being provided with an inner ring 12 and an outer ring 14 that extend to and contact the expansion layer 6. Alternatively, as shown in Fig. 3, the retention/reflective layer 8 may extend to the edges of the disk so that the protective layer 10 does not contain it. Fig. 3 illustrates the invention in greater detail with a recorded "bump" 16. For purposes of illustration, the bump is not necessarily in proportion to the respective layers.

The substrate 4 is formed from a rigid transparent material that permits substantially full transmission of light for recording, reading, and erasure. The substrate is sufficiently thick and rigid to provide structural integrity to the optical medium, and it does not deform in response to pressure caused by expansive forces in the adjacent expansion layer. Recordation bumps in the expansion layer, caused by its thermal expansion upon absorption of the write beam's light energy, protrude away from the substrate because of the substrate's rigidity. With this layer arrangement, the bumps protrude into the retention/reflective layer, as described below.

The substrate may be constructed from a wide variety of readily available materials. Merely by way of example, the substrate can be fabricated from glass, polymers, and amorphous polymers. In a preferred embodiment, the substrate is made of polycarbonate. In many
embodiments, the substrate will be the thickest layer, with a thickness of about 1 mm or more.

Adjacent to the substrate is the expansion layer 6. The expansion layer is formed of a material that absorbs a percentage of light energy passing through it; displays a high coefficient of thermal expansion, particularly when compared to the other layers of the medium; and displays a high coefficient of elasticity to the extent that it will expand readily when heated at the temperatures encountered during a recordation process without exceeding its upper expansive limit. The expansion layer must also contract to its original relaxed condition upon cooling.

When at room temperature, the expansion layer material should be near or above its softening temperature, which is preferably below 30°C and more preferably at or below 20°C. By "softening temperature" is meant the temperature at which the modulus of elasticity of the material of the expansion layer has dropped to 25% to 50% of its maximum modulus. A coefficient of thermal expansion above about 1x10^-4/°C is preferred, with those greater than about 3x10^-4/°C more preferred, and those greater than about 5x10^-4/°C most preferred. The degree of single pass absorptivity of light energy should be between 20% and 40% in the wavelength range from 850 nm to 650 nm such that the expansion layer may be heated with a laser beam at a write wavelength. To maintain the ability to read data recorded on the optical media on standard detection mechanisms, such as those found on conventional compact disk players, a maximum double pass absorption at the standard compact disk read wavelength (780 nm) of 10% is most preferred.

Accordingly, the expansion layer material may comprise a base resin selected from the group consisting of rubbers, such as silicone rubbers, styrene-butadiene rubbers, and natural rubbers such as butyl rubbers; epoxys; polyurethane; polymers; amorphous polymers; cellulose acetate-butyrate; poly(vinyl butyryl); polyamides; acrylic polymers; polyvinyl acetate; silicone resins; styrene-butadiene copolymers; vinyl chloride-vinyl acetate

SUBSTITUTE SHEET
copolymers; and mixtures thereof. Materials with high elasticity such as elastomers and polymers with elongations greater than 15% are preferred for construction of the expansion layer.

In a preferred embodiment, the expansion layer is an epoxy resin with a softening temperature below 50°C and preferably at 30°C or below.

In another preferred embodiment, a base resin or mixture of resins is mixed with appropriate curing agents to form the expansion layer. For example, a bisphenol A/epichlorohydrin epoxy resin (Shell 828, manufactured by Shell Chemical) and an epichlorohydrin-dimer fatty acid-based epoxy resin (Shell 871, manufactured by Shell Chemical) may be mixed in approximately equal amounts with a nonstoichiometric (e.g., 2.6x) amount of a curing agent, such as Versamid V150 (a polyamide resin which is an adduct of a polyamine with a dibasic fatty acid, manufactured by Henkel). Additionally, Shell 828 may be mixed with a nonstoichiometric (e.g., 1.5x) amount of a curing agent such as Dow DEH52 (an aliphatic polyamine-epoxy adduct, manufactured by Dow Chemical).

The thickness of the expansion layer is approximately 0.5 to 3.0 microns. A preferred range is 1.0 to 2.0 microns. The expansion layer is bonded to the substrate and to the retention/reflective layer. This is achieved by methods known in the art. For example, coating of the expansion layer onto the substrate may be accomplished by a wet chemical process, such as spin coating or web coating. The retention/reflective layer is then deposited onto the expansion layer. The metal retention/reflective layer deposition process would utilize vacuum deposition, sputtering or chemical vapor deposition, for example.

A retention/reflective layer 8 is present adjacent to the expansion layer. An important feature of the present invention is the combination of the retention and reflective functions of the prior art into a single metal layer. This dual-purpose layer requires only one laser beam for both
recording and erasure. This retention/reflective layer serves to reflect light back through the expansion layer for purposes of recording and data detection. In one embodiment of the invention, this layer is highly reflective, preferably reflecting at least about 70% of the light striking it during both recording and reading. Additionally, the retention/reflective layer functions to hold the recording bumps formed as a result of expansion of the material in the expansion layer. Therefore, the retention/reflective layer is formed of a material that absorbs a percentage of light energy passing into it while reflecting sufficient light energy such that the total light energy loss sustained by light or other radiation is less than 30%; has a softening temperature above room temperature; is malleable and deformable, when above its softening temperature, with sufficient elasticity to permit it to conform to the contour of the recording bumps, formed by the expansion of the expansion layer, when the expansion layer is heated; and displays sufficient rigidity and strength below its softening temperature such that it will hold the expansion layer in the stretched, expanded condition which was effectuated while the expansion layer was heated, even though the expansion layer has cooled to ambient temperature.

The retention/reflective layer described above can comprise an elemental metal, a metal alloy or other reflective material that is soft but not liquid at room temperature, and softens or melts, or both, to be deformable near or below the temperature reached by the expansion layer during recording. Thus, the material will have a low melting point temperature, generally within the range of about 80°C to about 200°C. In a preferred embodiment, it is also highly reflective. Metals which may be useful in the layer include bismuth, lead, tin, cadmium, indium, gallium, and alloys thereof. Pure indium yields favorable results; however, in some cases, the large grain structure of indium produces less than optimal results such as noise during playback. When indium is combined with other materials, a
finer grain structure results and the noise is either reduced or eliminated. A preferred combination is indium plus bismuth, reducing the melting point from 156°C to approximately 80°C. Also useful are alloys, particularly eutectic alloys of bismuth or indium, and more particularly a eutectic alloy of bismuth with other metals such as, for example, tin, cadmium, lead, or indium. Such alloys will result in a melting point within the desired range of substantially below the softening temperature of the layer.

The thickness of the metal retention/reflective layer is from about 0.01 to about 0.15 microns, preferably about 0.02 to about 0.05 microns. This layer is bonded to the expansion layer and to the protective layer, i.e. the latter is present, by methods known in the art. The retention/reflective layer will be deformed out by a recordation bump extending from the expansion layer through the retention/reflective layer to its outer surface. This is illustrated in Fig. 3.

A protective layer 10 may be present which serves to protect the recordation bumps from damage due to contact with external objects. Characteristic of this layer is that it be sufficiently compliant to allow the deformations or bumps in the expansion layer to easily protrude into it and thereby offer little resistance to their formation. In addition, the protective layer preferably is relatively thick when compared to the expansion and retention/reflective layers so that the bumps are not transmitted into the protective layer and subsequently through the protective layer to its outer surface. This characteristic is illustrated in Fig. 3. It is also preferred, although not necessary, that the protective layer have a high thermal conductivity to enable it to function as a heat sink for purposes of rapid cooling of the retention/reflective layer immediately following formation of the bumps. A thermal conductivity of at least $5 \times 10^{-4}$ cal/((cm$^2$/°C)(sec/cm)) will provide adequate results. Suitable materials for use as a protective layer include silicone and acrylate.
The protective layer may or may not be required depending on the functionality, storage, and/or handling of the optical disk. Thus, in an application where the disk is stored and operated in a protective case or cartridge, a protective layer may not be required. A protective layer may also not be required where the retention/reflective layer is of sufficient thickness so that the recordation bumps are not transmitted through the retention/reflective layer to its outer surface.

In a preferred embodiment where rings 12 and 14 are present as a part of the protective layer, the width of the rings is between about 1 mm and 4 mm. The thickness of the inner and outer rings is selected in accordance with the desired thickness of the retention/reflective layer 8.

The thickness of the various layers comprising the media of the present invention will be selected in accordance with the optics of the system. For example, in order to maintain the minimum bump size during data recording with the greatest write sensitivity during recording, the laser beam should be maintained as small as possible as it passes through the expansion layer. Accordingly, most of the expansion layer 4 should be within the focal depth of the write beam. For recording systems having optical parameters similar to those found in standard compact disk players, the write beam is diffraction limited and has a focal depth of approximately 1.0-2.0 microns. In such cases, best results can be obtained with an expansion layer having a thickness of approximately 0.5 to 1.5 microns, preferably of 1.0 microns or less.

The substrate and the optional protective layers are considerably thicker than the expansion or the retention/reflective layer, the substrate layer being on the order of 1 mm or more and the optional protective layer being on the order of tens of microns, in view of their respective functions (i.e., the substrate must be thick enough to impart rigidity to the medium and the protective layer must be thick enough to protect the data protrusions or bumps from external abuse). The substrate is preferably...
about 1.2 mm thick. The protective layer is preferably about 2 microns thick.

Fig. 3 illustrates the invention during/after the writing (either during the initial recording or during subsequent recordings) of recordation bump 16. To write, a laser beam (indicated by "hv") enters the substrate 4 and passes into the expansion layer 6 where it is absorbed at a particular wavelength, known as the "write" wavelength. The absorptive characteristics of the layer may be imparted thereto using methods that will be apparent to those of skill in the art, such as by the addition of light-absorptive dyes or pigments. Since the medium of the present invention need not be wavelength-specific, a broad range of dyes or pigments is available for this purpose. In addition, except for the ability to pass a portion of the wavelength energy which is employed for the purpose of reading the recorded data, these dyes or pigments need not be wavelength-specific and may therefore absorb light energy over a broad spectrum of wavelengths. Thus, during recordation the laser beam is absorbed by a dye or a pigment contained within the expansion layer which will absorb light from the laser beam at the write wavelength to cause the expansion layer to expand away from the substrate and form recordation bump 16 extending into the retention/reflective layer. Dyes or pigments that can be used singly or in combination are nigrosin blue, aniline blue, Calco Oil Blue, ultramarine blue, methylene blue chloride, savinial blue, Monastral Blue, Malachite Green Ozalate, Sudan Black BM, Tricon blue, Macrolex green G, DDCI-4, and IR26. Preferred among these are savinial blue, Tricon blue, and Macrolex green G.

The dye(s) or pigment(s) in the expansion layer absorbs a high proportion of the energy at the wavelength of the writing laser to form a heated area in the layer. The heated spot of the polymer expansion layer is confined by a surrounding low temperature area, and expansion can take place only away from the substrate and into the retention/reflective layer 8.
Conduction of heat from the expansion layer raises the temperature of the single, dual-purpose, metal retention/reflective layer to the point where the metal softens or becomes a liquid. Because of the relationship between the thermo-mechanical properties of the expansion and retention/reflective layers, a critical feature for the present invention is the choice of materials for these two layers. The selection of metals and metal alloys with low melting points for the retention/reflective layer thus facilitates the expansion of the polymer expansion layer into the heated, softened area of the retention/reflective layer to form a recordation bump around which the retention/reflective layer conforms.

The shape of the recordation bump is retained in the metal retention/reflective layer because this layer has a comparatively high thermal conductivity that causes it to cool more rapidly than the polymer expansion layer. Thus, after the light beam is removed, the metal becomes rigid and locks the recordation bump into place while the polymer is still expanded. The use of a metal retention/reflective layer allows for a more highly defined or distinctive recordation bump.

After the optical medium has been recorded, as described above, erasure can be achieved by methods known in the art. For example, this may be accomplished by "spot" erasure, where either a different laser with a larger focused point, or the same laser used to record on the medium but defocused to a slightly larger spot, can be used to focus a light beam through the substrate 2 and the expansion layer 6. Erasure occurs when a recorded area of the expansion layer is heated relatively slowly to above the melting point temperature of the metal retention/reflective layer to a temperature at which the polymer expansion layer softens. The layers are then cooled slowly so that both the expansion layer and the retention/reflective layer return to their original spatial arrangements. By heating and then cooling the expansion layer slowly, the cooling rate of the layer is now slower than its viscoelastic restoring forces.
so that the polymeric material of the layer relaxes to its original unwritten state. The retention/reflective layer then resolidifies over the expansion after the relaxation of the expansion layer.

In contrast to much of the prior art, there is no reason which requires that the write or recordation wavelength be different from the erasure wavelength. The write wavelength chosen can, and is preferred to be the same wavelength as used for erasure. The previous need for two lasers, to record and to erase, often with different wavelengths corresponding to the absorption frequencies of different dyes in separate expansion and retention layers, is eliminated by the present invention.

Reading of the recorded data (bumps) from the optical disk is achieved by focusing a light beam, chosen from a wide spectrum of available light wavelengths, through the substrate 4 and through the expansion layer 6. Playback or reading can be accomplished, for example, on standard compact disk systems. The media of the present invention are compatible with such standard systems: the polymer expansion layer is transparent at the read wavelength of 780 nm; the reflectance of the retention/reflective layer is 70% or greater at the read wavelength; the recordation bumps generate interference with the reflected light beam; and the interference is then detected by the read or playback system.

It is to be understood that the above description is intended to be illustrative and not restrictive. Many embodiments will be apparent to those ordinary of skill in the art upon reviewing the above description. By way of example, although the invention has been illustrated with reference to the use of lasers as the radiant energy source, other sources can be used and will be readily apparent to one of ordinary skill. The feature of a single, dual-purpose, metal retention/reflective layer eliminating the need for separate polymer retention and metal reflective layers can be combined with other arrangements of the substrate, expansion, and protective layers. The scope of
the invention, therefore, should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled, and should not be limited to the above description.
WHAT'S CLAIMED IS:

1. A recording medium comprising:
   a) a substrate;
   b) an expansion region adjacent the substrate, the expansion region expanding in the presence of radiation at a write wavelength; and
   c) a retention/reflective region adjacent the expansion region, the retention/reflective region comprising a metal or an alloy of metals having a low melting point temperature.

2. An optical recording medium for writing and erasing data comprising:
   a) a substrate;
   b) an expansion region adjacent the substrate, the expansion region expanding in the presence of radiation at a write wavelength;
   c) a retention/reflective region adjacent the expansion region, the retention/reflective region comprising a metal or an alloy of metals having a low melting point temperature; and
   d) a protective layer adjacent the retention/reflective region, the protective layer retaining the retention/reflective region against the expansion region.

3. A recording medium, as recited in Claim 1 or 2, wherein the retention/reflective region comprises a metal or an alloy of metals having a melting point temperature in the range of about 80°C to about 200°C.

4. A recording medium, as recited in Claim 3, wherein the retention/reflective region is comprised of indium in substantially its purest state.
5. A recording medium, as recited in Claim 3, wherein the retention/reflective region is comprised of an alloy of indium and bismuth.

6. A recording medium, as recited in Claim 3, wherein the retention/reflective region is comprised of an eutectic alloy of bismuth or an eutectic alloy of indium.

7. A recording medium, as recited in Claim 6, wherein the eutectic alloy is comprised of bismuth and a metal selected from the group consisting of tin, cadmium, lead and indium.

8. A recording medium, as recited in Claim 3, wherein the expansion region has a softening temperature below 30°C and a coefficient of thermal expansion above about 1x10⁻⁴/°C.

9. A recording medium, as recited in Claim 8, wherein the expansion region comprises a base resin selected from the group consisting of epoxys, polyurethane, polymers, amorphous polymers, rubber, natural rubber, butyl rubber, silicone rubber, styrene-butadiene rubber, cellulose acetate-butyrate, poly(vinyl butyryl), acrylic polymers, polyvinyl acetate, silicone resins, styrene-butadiene copolymers, vinyl chloride-vinyl acetate copolymers, and mixtures thereof.

10. A recording medium, as recited in Claim 9, wherein the expansion region further comprises a curing agent.

11. A recording medium, as recited in Claim 10, wherein the expansion region comprises a mixture of an approximately equal amount of a bisphenol A/epichlorohydrin resin and an epichlorohydrin-dimer fatty acid-based epoxy resin together with a nonstoichiometric amount of the curing agent.
12. A recording medium, as recited in Claim 11, wherein the curing agent is an adduct of a polyamine with a dibasic fatty acid.

13. A recording medium, as recited in Claim 10, wherein the expansion region comprises a mixture of a bisphenol A/epichlorohydrin resin together with a nonstoichiometric amount of an adduct of an aliphatic polyamine.

14. A method of writing data on a medium, the method comprising the steps of:
   a) directing light at a medium, the medium comprising an expansion region and a retention/reflective region, the light heating a portion of the expansion region so as to cause expansion thereof;
   b) receiving an expanded portion from the expansion region in the metal retention/reflective region;
   c) removing the light from the medium so as to cause retention of the expanded portion of the retention/reflective region in an expanded state.

15. A method, as recited in Claim 14, wherein the retention/reflective region comprises a metal or an alloy of metals having a melting point temperature in the range of about 80°C to about 200°C.

16. A method, as recited in Claim 15, wherein the retention/reflective region is comprised of indium in substantially its purest state.

17. A method, as recited in Claim 15, wherein the retention/reflective region is comprised of an alloy of indium and bismuth.
18. A method, as recited in Claim 15, wherein the retention/reflective region is comprised of an eutectic alloy of bismuth or an eutectic alloy of indium.

19. A method, as recited in Claim 18, wherein the eutectic alloy is comprised of bismuth and a metal selected from the group consisting of tin, cadmium, lead and indium.

20. A method, as recited in Claim 14, wherein the expansion region has a softening temperature below 30°C and a coefficient of thermal expansion above about 1x10^-4/°C.

21. A method of erasing data on a medium, the medium comprising the steps of:
   a) slowly heating a recorded area of a medium comprising an expansion region and a retention/reflective region, so that the expansion region reaches its softening temperature and the retention/reflective region reaches its melting temperature in response to heating; and
   b) slowly cooling the medium, so that the expansion region and the retention/reflective region return to their original unwritten state.

22. A method, as recited in Claim 21, wherein the retention/reflective region comprises a metal or an alloy of metals having a melting point temperature in the range of about 80°C to about 200°C.

23. A method, as recited in Claim 22, wherein the retention/reflective region is comprised of indium in substantially its purest state.

24. A method, as recited in Claim 22, wherein the retention/reflective region is comprised of an alloy of indium and bismuth.
25. A method, as recited in Claim 22, wherein the retention/reflective region is comprised of an eutectic alloy of bismuth or an eutectic alloy of indium.

26. A method, as recited in Claim 25, wherein the eutectic alloy is comprised of bismuth and a metal selected from the group consisting of tin, cadmium, lead and indium.

27. A method, as recited in Claim 21, wherein the expansion region has a softening temperature below 30°C and a coefficient of thermal expansion above about 1x10^-4/°C.
FIG. 3.

FIG. 4.
**INTERNATIONAL SEARCH REPORT**

**International Application No.** PCT/US90/05475

---

### I. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both National Classification and IPC:
- GLIB 03/70, 05/84, 07/00
- G09D 09/00

---

### II. FIELDS SEARCHED

**Minimum Documentation Searched**

<table>
<thead>
<tr>
<th>Classification System</th>
<th>Classification Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>369/280, 282, 283, 284, 286, 275.2, 275.4, 100</td>
</tr>
<tr>
<td></td>
<td>346/135.1</td>
</tr>
</tbody>
</table>

**Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched**

---

### III. DOCUMENTS CONSIDERED TO BE RELEVANT

**Category** *1* | **Citation of Document, 1*2 with indication, where appropriate, of the relevant passages 1*3 | **Relevant to Claim No. 1*4** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>X, P</td>
<td>US, A, 4,896,314 (SKIENS ET AL) 23 January 1990</td>
<td>1, 2, 14, 21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-13, 15-20, 22-27</td>
</tr>
<tr>
<td>X</td>
<td>US, A, 4,852,077 (CLARK ET AL) 25 July 1989</td>
<td>1-10, 14-27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11-13</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 4,587,533 (NAKANE ET AL) 06 May 1986</td>
<td>ALL</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 4,852,075 (FEYRER ET AL) 25 July 1989</td>
<td>ALL</td>
</tr>
<tr>
<td>A</td>
<td>US, A, 4,855,992 (IKEGAWA ET AL) 08 August 1989</td>
<td>ALL</td>
</tr>
</tbody>
</table>

---

* 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 but 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
  - "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
  - "U" document member of the same patent family

---

### IV. CERTIFICATION

**Date of the Actual Completion of the International Search**

26 OCTOBER 1990

**Date of Mailing of this International Search Report**

31 JAN 1991

**International Searching Authority**

ISA/US

---

Form PCT/ISA/210 (second sheet) (May 1986)