This invention relates to disc recording apparatus and disc reproducing apparatus.

An optical disc has a recording capacity two to three orders of magnitude higher than that of a magnetic disc, while enabling higher-speed access than a tape-shaped recording medium. Moreover, an optical disc has excellent durability, due to non-contact data recording/reproduction. For these reasons, optical discs have come to be used extensively in recent years. The best known form of optical disc is the compact disc (CD).

To provide portable, especially pocket-size headphone stereo, devices, using optical discs, a CD with a disc diameter of 12 cm and a CD with a disc diameter of 8 cm (so-called CD single) have been proposed. To reduce the size of the recording/reproducing apparatus, a disc with a diameter of 8 cm or less would be preferred. However, in attempting to provide a portable or pocket-size recording/reproducing apparatus for an optical disc 8 cm or less in diameter, the following problem arises.

In the case of a standard CD format optical disc, on which are recorded stereophonic digital PCM audio signals sampled with a sampling frequency of 44.1 kHz and quantized with 16 bits, and where these signals are exclusively reproduced by the user (CD-DA format), the reproducing time of a disc 8 cm in diameter is 20 to 22 minutes at most, so that a symphony, for example, cannot be recorded on one disc side. A playback time of 74 minutes or longer, which is approximately equal to that of a 12 cm CD, is preferred. Moreover, it is not possible for the user to make recordings with this CD-DA format.

Likewise, with a CD-MO format (a format employing a recordable magneto-optical disc) as an extension of the above-mentioned standard CD-DA format, the recording/reproducing time of an 8 cm disc is only 20 to 22 minutes, as in the CD-DA format.

With the CD-I (CD-Interactive) format, levels A to C shown in Table 1 are prescribed as the modes for recording/reproducing bit-compressed digital audio signals.

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TABLE 1

Level	Sampling Frequency	Number of Quantization Bits	Band-Width	Playback Time Stereo/Mono
A	37.8kHz	8	17kHz	2/4
B	37.8kHz	4	17kHz	4/8
C	18.9kHz	4	8.5kHz	8/16

When reproducing a disc recorded using, for example, the level B mode, signals obtained by quadruple bit compression of standard CD-DA format digital signals are reproduced. Thus, if all of the recorded data are compressed stereophonic audio data, playback time is quadrupled, or reproduction of 4-channel data becomes feasible, so that reproduction for 70 minutes or longer becomes possible with an optical disc 8 cm in diameter or less.

Meanwhile, with the CD-I format, the disc is rotationally driven at the same linear velocity as that for the standard CD-DA format, so that continuous audio compressed data are reproduced at a rate of one unit to n recorded units on the disc, where n is a figure corresponding to the playback time or the bit compression rate of data, and is equal to four with the level B stereo mode. This unit is termed a block or sector, which is made up of 98 frames and has a period of 1/75 second. Therefore, with this level B stereo mode, a data string in which every fourth sector is an audio sector, such as:

S D D D S D D D ⋯ σ

where S is an audio sector and D is another sector(s), is recorded on the disc. However, for actual recording, since the above data string is processed with predetermined encoding similar to that for ordinary CD format audio data, such as error correction coding and interleaving, data of the audio sector S and data of the data sector D are arranged in a scrambled fashion in the recording sectors on the disc. The other data sectors may, for example, be video or computer data. When the bit-compressed audio signals are also used for the data sector D, a data string in which four-channel audio sectors S1 to S4 are cyclically arranged; that is a data string:

S1 S2 S3 S4 S1 S2 S3 S4 ⋯ ⋯

is encoded and recorded on the disc. When recording and reproducing

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continuous audio signals, the above-mentioned 4-channel audio signals are linked sequentially beginning at the first channel and terminating at the fourth channel. More specifically, channel 1 data corresponding to the audio sector S1 are reproduced from the innermost to the outermost areas of the disc. Channel 2 data corresponding to the audio sector S2 are reproduced from the innermost to the outermost areas of the disc. Channel 3 data corresponding to the audio sector S3 are reproduced from the innermost to the outermost areas of the disc. Finally, channel 4 data corresponding to the audio sector S4 are reproduced from the innermost to the outermost areas of the disc to enable data reproduction for a continuous quadrupled time duration.

However, for the above-mentioned continuous reproduction, several track jump operations between the inner and outer disc peripheries are required. Since a track jump cannot be performed instantaneously, playback data are interrupted for a short time period. This means that the reproduced sound is interrupted momentarily.

For overcoming the above-described problem, we have proposed the following technique.

More specifically, when data similar to those of the above-mentioned CD-DA format, that is audio PCM data having the sampling frequency of 44.1 kHz, sixteen quantization bits and a data transfer rate of 75 sectors/second, are recorded after bit compression in accordance with the B-level stereo mode, the sampling frequency of the audio PCM data with the data transfer rate of 75 sectors/second is converted to 37.8 kHz, while the number of quantization bits is reduced to four, to produce ADPCM audio data with the data transfer rate equal to one-fourth the original rate, or 18.75 sectors/second. The B-level stereo mode ADPCM audio data, continuously outputted at the 18.75 sectors/second, are written in a buffer memory. When the data volume of the ADPCM audio data stored in the buffer memory exceeds a predetermined volume K, the ADPCM data are read out from the buffer memory as recording data by the predetermined volume K in a burst fashion at the transfer rate of 75 sectors/second. These data are recorded in a continuous state on a recording track of the magneto-optical disc by address-controlling the recording positions on the recording track.

That is, in this recording system for the ADPCM audio data, the

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ADPCM audio data are continuously written in the buffer memory at the transfer rate of 18.75 sectors/second, by continuously incrementing the write pointer of the buffer memory at the transfer rate of 18.75 sectors/second. When the data volume of the ADPCM audio data stored in the buffer memory exceeds the predetermined volume K, the ADPCM audio data are read out from the buffer memory by the predetermined volume K as the recording data in a burst fashion at the above-mentioned transfer rate of 75 sectors/second by incrementing the read pointer of the buffer memory in a burst fashion at the transfer rate of 75 sectors/second.

On the other hand, in the reproducing system for the ADPCM data, playback data from the disc are written into the buffer memory at the transfer rate of 75 sectors/second by incrementing the write pointer of the buffer memory at the transfer rate of 75 sectors/second, while the playback data are continuously read from the buffer memory at the transfer rate of 18.75 sectors/second, by continuously incrementing the read pointer of the buffer memory at the transfer rate of 18.75 sectors/second. Writing is discontinued when the read pointer is overtaken by the write pointer. When the data volume of the playback data stored in the buffer memory is lower than a predetermined volume, the write pointer of the buffer memory is incremented in a burst fashion at the transfer rate of 75 sectors/second to write data in the buffer memory.

By controlling the buffer memory in this manner, the B-level stereo mode ADPCM audio data reproduced from the recording track of the magneto-optical disc are written in the buffer memory in a burst fashion at the transfer rate of 75 sectors/second, while the ADPCM audio data are continuously read from the buffer memory as playback data at the transfer rate of 18.75 sectors/second. In this manner, the playback data are continuously read from the buffer memory while the data volume exceeding the predetermined volume is maintained at all times in the buffer memory. By address-controlling the playback position on the recording track of the magneto-optical disc, the audio data may be continuously reproduced from the recording track of the magneto-optical disc.

If it is attempted to record continuous audio signals, it is not possible to record only the sector S2 signals, by reason of the

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interleaving operation performed at the time of recording, but it becomes necessary to perform interleaving involving neighbouring sectors S1 and S3, or even the sectors neighbouring thereto, such that it becomes necessary to rewrite signals of the pre-recorded signals. This indicates that it is extremely difficult to record the compressed continuous audio data.

If it were possible to switch between the above-mentioned compression modes, the usage of the recording/reproducing apparatus may be enhanced advantageously. However, if the rotational speed of the disc, recording pattern or signal processing operations should be switched for each of these selected compression modes, the construction of the circuit is complicated and the apparatus becomes expensive. It is therefore desirable that the controlling or signal processing operations or the recording patterns be changed as little as possible with changes in the compression modes.

For overcoming the above-mentioned problem, we have proposed a technique in which digital data are arranged into clusters at an interval of a predetermined number of, for example, 32 sectors, and for example five cluster-linking sectors, each longer than an interleaving length, are provided at each cluster-linking region so that data interleaving in each cluster does not affect the neighbouring clusters.

Long-duration recording or long-duration reproduction of the audio signals becomes possible by performing bit compression of the digital audio signals before recording these digital audio signals. However, the recordable data volume on one optical disc is limited, so that the maximum recording time is limited by the recording capacity of the optical disc. Although continuous recording or continuous reproduction for an extended period of time becomes possible by using a plurality of discs one after another, signal drop-out of the audio signals is produced at the time of exchange of the optical discs.

According to the present invention there is provided a disc recording apparatus for recording input data on disc-shaped recording media, the apparatus comprising:

memory means in which continuously inputted input data are sequentially written and from which the input data are read out as recording data at a transfer rate faster than the transfer rate at which the input data are written therein;

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recording means for recording the recording data read from said memory means on a first disc-shaped recording medium rotationally driven at a predetermined velocity;

recording controlling means for effecting read-out control of said memory means so that, when the data volume of said input data stored in said memory means exceeds a first predetermined volume, recording data of said first predetermined volume are read out continuously from said memory means so that a writing space in excess of a second predetermined volume is maintained at all times in said memory means, said recording controlling means also effecting recording position control so that the recording data of said first predetermined volume read out in a burst-like manner from said memory means by the read-out control of said memory means are continuously recorded on the recording track on said first recording medium; and

linking controlling means for capturing recording means of a second disc-shaped recording medium during the time interval when data next to the last of data recorded on said first recording medium are read from said memory means, for recording data continuously on said first recording medium and on said second recording medium.

According to the present invention there is also provided a disc reproducing apparatus for reproducing recorded data continuously recorded on disc-shaped recording media, the apparatus comprising:

reproducing means for sequentially reading the recorded data from a first disc-shaped recording medium, rotationally driven at a predetermined velocity, at a second transfer rate faster than a first transfer rate required of playback output data;

memory means in which playback data read by said reproducing means are sequentially written at said second transfer rate and from which the sequentially written playback data are continuously read as said playback output data at said first transfer rate;

playback controlling means for effecting writing controlling of said memory means for writing said playback data of a second predetermined volume when the volume of said playback data stored in said memory means becomes less than a first predetermined volume so that a volume of the playback data in excess of said first predetermined volume is always maintained in said memory means, said playback controlling means also effecting playback position controlling so that said playback data

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sequentially discontinuously written in said memory means by said writing controlling of said memory means are continuously read from the recording track of said disc-shaped recording medium; and

linking controlling means for capturing a recording system of a second disc-shaped recording medium during the time interval when the last of data recorded on said first recording medium are reproduced, to reproduce data continuously from said first recording medium and said second disc-shaped recording medium.

Thus the present invention provides an optical disc recording apparatus in which audio data obtained by digitizing analogue audio signals and time base compressing the resulting digital audio signals are read from a buffer memory on a cluster-by-cluster basis so as to be recorded on a recording track of an optical disc, and in which recording controlling means is provided whereby, during the time interval when a cluster audio data unit next to the last cluster audio data unit written on a first optical disc is read from a memory, a second optical disc driver is captured into synchronization for continuously recording audio signals on the first and the second optical discs under control by a system controller.

The present invention also provides an optical disc reproducing apparatus in which time base compressed audio data are reproduced on a cluster-by-cluster basis from a recording track on the optical disc so as to be read and outputted from a buffer memory after time base expansion, and in which playback controlling means is provided whereby, during the time the last cluster audio data unit reproduced from the first optical disc is read from the buffer memory, the playback system of the second optical disc is captured into synchronization for continuously reproducing the first optical disc and the second optical disc.

With optical disc recording apparatus according to the present invention, a second optical disc driver is captured into synchronization during the time interval when a cluster audio data unit next to the last cluster audio data unit written on a first optical disc is read from a memory, for continuously recording audio signals on the first and the second optical discs under control by a system controller.

With the optical disc reproducing apparatus according to the

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present invention, the playback system of the second optical disc is captured into synchronization during the time the last cluster audio data unit reproduced from the first optical disc is read from the buffer memory, for continuously reproducing the first optical disc and the second optical disc.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Figure 1 is a block diagram showing an embodiment of a disc recording/reproducing apparatus according to the present invention;

Figure 2 shows a signal format of a cluster as a recording unit in the apparatus of Figure 1;

Figure 3 shows the relation between the cluster, cluster address and the sector address in the apparatus of Figure 1;

Figure 4 shows a data format employed in the recording/reproducing apparatus;

Figure 5 shows the state of memory control in the recording system of the apparatus of Figure 1;

Figure 6 shows the recording state of continuous recording on two magneto-optical discs by the recording system of the apparatus of Figure 1; and

Figure 7 shows the state of memory control in the reproducing system of the apparatus of Figure 1.

Figure 1 shows an optical disc recording/reproducing apparatus according to the present invention in which audio signals are recorded on or reproduced from the recording track of a magneto-optical disc as digitized and time base compressed audio data. To this end, a first optical disc driver 1 and a second optical disc driver 2, each arranged for recording/reproducing audio data on a cluster-by-cluster basis, are operatively associated with each other by a system controller 3, so that the audio signals may be continuously recorded and reproduced by the disc drivers 1 and 2.

With this apparatus, the first and second disc drivers 1 and 2 are each operated so that data may be recorded along a recording track of the magneto-optical disc rotationally driven by a spindle motor by magnetic field modulation recording, by applying a magnetic field modulated in accordance with recording data by a magnetic head while

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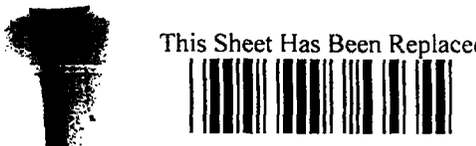
radiating a laser beam by an optical head on the magneto-optical disc. The recorded data may also be reproduced magneto-optically by tracing the recording track of the magneto-optical disc with the laser beam by the optical head. The data recording or reproduction is performed on the basis of the cluster addresses or sector addresses pre-recorded or pre-formatted on the magneto-optical disc, as later described.

The optical head of each of the disc drivers 1 and 2 is made up of optical components, such as a laser source, for example a laser diode, a collimator lens, an objective lens, a polarization beam spitter or a cylindrical lens, and split photodetectors, and is mounted facing the magnetic head with the magneto-optical disc in-between. When recording data, the optical head radiates a laser light on the target track of the disc, on which the magnetic field modulated in accordance with the recording data is applied by the magnetic head by the magnetic head driving circuit, to record the data thermomagnetically. The optical head also detects the laser light reflected from the target track for detecting focusing errors by, for example, a so-called astigmatic method and tracking errors by, for example, a so-called push-pull method. When reproducing recorded data from the disc, the optical head detects the difference in the polarization angle of the reflected light from the target track (Kerr rotation angle) for producing playback signals. The optical head also reproduces cluster addresses and sector addresses pre-formatted as pits along with, for example synchronization signals at the leading end of each sector.

The playback output obtained from the optical head of the first optical disc driver 1 is transmitted to a first RF circuit 4. The first RF circuit 4 extracts the tracking signals and the focusing signals from the output of the optical head to transmit the extracted signals to a first servo control circuit 5, while converting the playback signals into corresponding binary signals and transmitting the converted binary signals to a decoder 21 of the reproducing system via a changeover switch 20. The first RF circuit 4 also transmits the cluster and sector addresses to the system controller 3.

The first servo control circuit 5 servo-controls the first optical driver 1 and comprises, for example, a focusing servo control circuit, a tracking servo control circuit, a spindle motor servo

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control circuit and a thread servo control circuit. The focusing servo control circuit effects focusing control of an optical system of the optical head so that the focusing error signal will be reduced to zero. The tracking servo control circuit executes tracking control of the optical system of the optical head so that the tracking error signal will be reduced to zero. The spindle motor servo control circuit controls the spindle motor so that the magneto-optical disc is rotationally driven at a predetermined rotational velocity, such as at a constant linear velocity. The thread servo control circuit shifts the optical head and the magnetic head to a target track position of the magneto-optical disc designated by the system controller 3. The first optical disc driver 5, performing these various control operations, transmits the information indicating the operating states of various components of the first optical disc driver 1 to the system controller 3.

The playback output obtained from the optical head of the second optical disc driver 2 is transmitted to a second RF circuit 6. The second RF circuit 6 extracts the tracking signals and the focusing signals from the output of the optical head to transmit the extracted signals to a second servo control circuit 7, while converting the playback signals into corresponding binary signals and transmitting the converted binary signals to the decoder 21 of the reproducing system via the changeover switch 20. The first RF circuit 4 also transmits the cluster and sector addresses to the system controller 3.

The second servo control circuit 7 servo-controls the second optical driver 2 and comprises, for example, a focus servo control circuit, a tracking servo control circuit, a spindle motor servo control circuit and a thread servo control circuit. The focusing servo control circuit effects focusing control of an optical system of the optical head so that the focusing error signal will be reduced to zero. The tracking servo control circuit executes tracking control of the optical system of the optical head so that the tracking error signal will be reduced to zero. The spindle motor servo control circuit controls the spindle motor so that the magneto-optical disc is rotationally driven at a predetermined rotational velocity, such as at a constant linear velocity. The thread servo control circuit shifts the optical head and the magnetic head to a target track position of

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the magneto-optical disc designated by the system controller 3. The second servo control circuit 7, performing these various control operations, transmits the information indicating the operating states of various components of the second optical disc driver 2 to the system controller 3.

A key input operating unit 8 and a display 9 are connected to the system controller 3, which controls the recording system and the reproducing system with an operating mode designated by the operating input information from the key unit 8. On the basis of the cluster and sector addresses reproduced from the magneto-optical disc by the disc drivers 1 and 2, system controller 3 controls the recording and reproducing positions on the recording track traced by the optical and magnetic heads of the disc drivers 1 and 2. On the basis of the bit compression mode information at an ADPCM encoder 13, selected by the key input operating section 8, and the bit compression mode information in the reproduced data obtained by the reproducing system by the RF circuits 4 and 6, the system controller 3 causes the bit compression mode to be displayed on the display 9. Also, on the basis of the cluster addresses and the bit compression rate in the bit compression mode, the system controller 3 causes the play time, that is the reproducing time, to be displayed on the display 9.

For displaying the reproducing time, the cluster address reproduced from the recording track of the magneto-optical disc by the optical disc drivers 1 and 2 is multiplied by the reciprocal of the data compression rate in the bit compression mode, that is, four in the case of 1/4 compression, to find the actual time information, which is displayed on the display 9. Meanwhile, during recording, the current recording position may also be displayed by the actual recording time obtained by multiplying the pre-formatted cluster address, read out from the recording track, by the reciprocal of the data compression rate.

The recording system of this disc recording/reproducing apparatus includes an A/D converter 12 supplied with analogue audio signals A_{IN} from an input terminal 10 via a low-pass filter 11.

The A/D converter 12 quantizes the audio signals A_{IN}. The digital audio data obtained from the A/D converter 12 are transmitted to the

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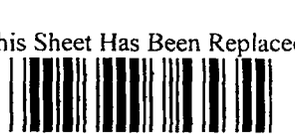


ADPCM encoder 13. In the ADPCM encoder 13, the operating mode of which is designated by the system controller 3, the digital audio data at the predetermined transfer rate, quantized from the audio signals A_{IN} by the A/D converter 12, are processed with a data compression operation in conformity with the various modes in the CD-I system shown in Table 1. For example, in the B-level mode of Table 1, the digital audio data are processed into compressed data (ADPCM audio data) having a sampling frequency of 37.8 kHz, with the number of bits per sample equal to four, before being supplied to a memory 14. The data transfer rate with the B-level stereo mode is reduced to one-fourth of the data transfer rate of 75 sectors/second of the standard CD-DA format, or to 18.75 sectors/second.

In the apparatus of Figure 1, it is assumed that the sampling frequency of the A/D converter 12 is fixed at the sampling frequency of the standard CD-DA format, or 44.1 kHz, and that, in the ADPCM encoder 13, bit compression from 16 to 4 bits is performed after converting the sampling rate in conformity with the compression mode, for example, from 44.1 kHz to 37.8 kHz for level B. Alternatively, the sampling frequency of the A/D converter 12 itself may be switchingly controlled as a function of the compression modes. In this case, the cut-off frequency of the low-pass filter 11 is also switchingly controlled as a function of the switchingly controlled sampling frequency of the A/D converter 12. That is, the sampling frequency of the A/D converter 12 and the cut-off frequency of the low-pass filter 11 may be simultaneously controlled depending on the compression modes.

The memory 14 is used as a buffer memory in which data writing and read-out are controlled by the system controller 3 and which temporarily stores ADPCM audio data supplied from the ADPCM encoder 13 for later recording on the disc whenever the necessity arises. Thus, in the B-level stereo mode, the compressed audio data supplied from the ADPCM encoder 13 has its transfer rate reduced to one-fourth of the standard CD-DA format data transfer rate of 75 sectors/second, or to 18.75 sectors/second, these compressed data being continuously written in the memory 14. Although it suffices to record the compressed data (ADPCM data) at a rate of every four sectors, as explained above, it is in practice impossible to record the data at this rate of every four sectors, so that the recording is made sector-continuously. This

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recording is made in a burst fashion at the same data transfer rate as that for the standard CD-DA format, or 75 sectors/second, with a predetermined number of sectors, for example, 32 plus several sectors, as a recording unit. That is, the B-level stereo mode ADPCM audio data, continuously written at the low transfer rate of 18.75 (=75/4) sectors/second in conformity with the bit compression rate is read from the memory 14 as recording data in a burst fashion at the transfer rate of 75 sectors/second. Although the overall data transfer rate of the data thus read out for recording, inclusive of the non-recording period, is the above-mentioned low transfer rate of 18.75 sectors/second, the instantaneous data transfer rate within the time interval of the burst-like recording operation is the above-mentioned standard rate of 75 sectors/second. Thus, when the rotational velocity of the disc is equal to that of the standard CD-DA format, or constant linear velocity, recording is made with the same storage pattern and at the same recording density as those of the CD-DA format.

The ADPCM audio data, that is recording data, read out from memory 14 in a burst fashion at the transfer rate of 75 sectors/second, are supplied to an encoder 15. In a data string supplied from the memory 14 to the encoder 15, a data unit continuously recorded with each recording is composed of a plurality of, for example, 32 sectors, and several cluster-linking sectors arrayed before and after each cluster. The cluster-linking sector has a length longer than the interleaving length at the encoder 15, so that interleaving of a given cluster does not affect data of neighbouring clusters. Details of recording on the cluster-by-cluster basis will be explained later referring to Figure 2.

In the encoder 15, the recording data supplied in a burst fashion from the memory 14 are processed with error-correction coding, such as by parity addition and interleaving, or 8-to-14 modulation (EFM). The recording data, thus processed with encoding by the encoder 15, are supplied via changeover switch 16 to magnetic head recording circuits 17 and 18 of the first and second optical disc drivers 1 and 2.

The magnetic head driving circuits 17 and 18 are connected to the magnetic heads of the first and second optical disc drivers 1 and 2 for driving these magnetic heads for applying magnetic fields conforming to the recording data to the magneto-optical disc.

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The system controller 3, controlling the memory 14 in the above-described manner, controls the recording position so that the recording data read out in the burst fashion from memory 14 may be continuously recorded on the recording track of each magneto-optical disc by the first and second optical disc drivers 1 and 2. During the time which elapses until reading from memory 14 of a cluster audio data unit following the last cluster audio data written on the recording track of the magneto-optical disc unit by the first optical disc driver 1, the system controller 3 captures the second optical disc driver 2 into synchronization to cause the first and second optical disc drivers 1 and 2 to perform continuous recording on the recording track of the magneto-optical discs.

Recording control by the system controller 3 is performed by controlling the recording position of the recording data read out in burst fashion from the memory 14 based on the cluster and sector addresses, and by supplying control signals designating the recording position on the magneto-optical disc to the first and second servo control circuits 5 and 7.

The reproducing system of the present disc recording/reproducing system will now be explained.

The reproducing system is designed to reproduce the recording data continuously recorded on the recording track of each magneto-optical disc by the first and second optical disc drivers 1 and 2, and includes the decoder 21 to which the playback output obtained on tracing the recording track of the magneto-optical disc by the optical head of the first and second optical heads 1 and 2 with a laser light is supplied via the changeover switch 20 after conversion into corresponding binary signals by the first and second RF circuits 4 and 6.

The decoder 21 is a counterpart of the encoder 15 of the above-described recording system and effects processing, such as decoding for error correction and 14-to-8 demodulation, on the binary playback output from the first and second RF circuits 4 and 6 for reproducing the above-mentioned B-level stereo mode ADPCM audio data at a transfer rate of 75 sectors/second which is faster than the normal transfer rate for the B-level stereo mode. The playback data produced by decoder 21 are supplied to a memory 22.

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The memory 22 has data writing and read-out controlled by the system controller 3 so that the playback data supplied from the decoder 21 at the transfer rate of 75 sectors/second are written therein in burst fashion at the transfer rate of 75 sectors/second. The playback data written in the memory 22 in burst fashion at the transfer rate of 75 sectors/second are also read out continuously from the memory 22 at the normal B-level stereo mode transfer rate of 18.75 sectors/second.

The system controller 3 controls the memory 22 so that the playback data are written in the memory 22 at the transfer rate of 75 sectors/second, while being continuously read from the memory 22 at the transfer rate of 18.75 sectors/second.

The system controller 3, controlling the memory 22 in the above-described manner, controls the playback position so that the playback data written in burst fashion in the memory 22 by the memory control may be continuously reproduced from the recording track of the magneto-optical disc. Also, during the time until the last cluster audio data unit read on the cluster-by cluster basis from the magneto-optical disc by the first optical disc driver 1 are read from the memory 22, the system controller 3 captures the second optical disc driver 2 into synchronization for continuously reproducing the audio data from the recording track of each magneto-optical disc by the first and second optical disc drivers 1 and 2.

The system controller 3 performs playback control by controlling the reproducing position of the reproduced data read out in a burst fashion from the memory 22 based on the cluster and sector addresses and supplying control signals designating the reproducing position on the recording track of the magneto-optical disc to the first and second servo control circuits 5 and 7.

The B-level stereo mode ADPCM audio data, produced as playback data continuously read from the memory 22 at the transfer rate of 18.75 sectors/second, are supplied to an ADPCM decoder 23.

The ADPCM decoder 23, which is a counterpart of the ADPCM encoder 13, has its operating mode specified by the system controller 3, and expands the B-level stereo mode ADPCM audio data by a factor of four to reproduce the CD-DA mode digital audio data. These digital audio data are transmitted by the ADPCM decoder 23 to a D/A converter 24.

The D/A converter 24 converts the digital audio data supplied

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from the ADPCM decoder 23 into corresponding analogue audio signals A_{OUT}. The analogue audio signals A_{OUT}, obtained from the D/A converter 24, are outputted via a low-pass filter 25 at an output terminal 26.

Recording/reproducing operation by the above-described disc recording/reproducing apparatus will now be explained in detail.

The recorded data, that is data read from the memory 14, are arranged into clusters at an interval of a predetermined number of sectors or blocks, with several cluster-linking sectors interposed between adjacent clusters. Specifically, as shown in Figure 2, each cluster C is made up of 32 sectors or blocks B0 to B31, and for example four linking sectors L0 to L3 are arrayed between the cluster C and the neighbouring cluster, as shown in Figure 2. For recording one such cluster, such as a K'th cluster C_k, not only the 32 sectors B0 to B31 of the cluster C_k, but also four linking clusters, that is two before the cluster C_k, namely sectors L2 and L3 (run-in blocks) and two after the cluster C_k, namely sectors L0, L1 (run-out blocks), totalling 36 sectors, are recorded as one recording unit. The 36-sector recorded data are transmitted from the memory 14 to the encoder 15 where the data are interleaved for an interval of 108 frames at the maximum, corresponding to about 1.1 sector. It is noted that data within the cluster C_k are within the extent of from the run-in blocks L2, L3 to the run-out blocks L0, L1 and thus do not affect the remaining clusters C_{k-1} or C_{k+1}. Meanwhile, the linking sectors L0 to L2 are composed of dummy data, such as "0", so that intrinsic data remain unaffected by interleaving. The linking sector L3 is composed of sub-data. The cluster may be composed of for example 36 sectors, inclusive of the linking sectors.

For cluster by cluster recording, a cluster address for identifying each cluster and a sector address for identifying each sector in the cluster are preformatted as pits at the leading end of each sector, so that recording may be made on the basis of the cluster and sector addresses obtained by reproducing these pits. Referring to Figure 3, a cluster is made up of 32 data-recording sectors and 4 linking sectors, and cells 0000 to 21XX are allocated to cluster addresses while cells 0 to 35 are allocated to sector addresses. These cluster and sector addresses are reproduced during recording and the

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recording position on the recording track is controlled based on the cluster and sector addresses reproduced during recording. Meanwhile, the cluster and sector addresses may also be preformatted with an offset of the recording track radially of the disc.

By performing the cluster by cluster recording in this manner, it becomes unnecessary to take account of interference with other clusters by interleaving, so that data processing may be simplified significantly. If data cannot be recorded accurately during recording due to malfunction such as defocusing or detracking, the data may be re-recorded on the cluster-by-cluster basis. On the other hand, if data cannot be read effectively during reproduction, the data may be re-read on the cluster-by-cluster basis.

In the recording system of the disc recording/reproducing apparatus, shown in Figure 1, digital data obtained from A/D converter 12 are the audio PCM data having the sampling frequency of 44.1 kHz, the number of quantization bits of 16 and the data transfer rate of 75 sectors/second, similar to the CD-DA format data, as shown in Figure 4. If these audio PCM data are supplied to the ADPCM encoder 13 for bit compression in accordance with the B-level stereo mode, the sampling frequency is converted to 37.8 kHz and the number of quantization bits is converted to four so that the audio PCM data are outputted as ADPCM audio data having the data transfer rate which is one-fourth the above-mentioned data transfer rate of 75 sectors/second, namely the data transfer rate of 18.75 sectors/second. The B-level stereo mode ADPCM audio data, continuously outputted from the ADPCM encoder 13 at the transfer rate of rate of 18.75 sectors/second, are transmitted to the memory 14.

Referring to Figure 5, the system controller 3 controls the memory 14 by continuously incrementing the write pointer W of the memory 14 at the transfer rate of 18.75 sectors/second for continuously writing the ADPCM audio data in the memory 14 at the transfer rate of 18.75 sectors/second. The system controller 3 also controls the memory 14 by incrementing the read pointer R of the memory 14 in a burst fashion at the transfer rate of 75 sectors/second, when the data volume of the ADPCM audio data stored in the memory 14 exceeds a volume K, for reading out the ADPCM audio data from the memory 14 as recording data by the predetermined data volume K.

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That is, in the recording system of the disc recording/reproducing apparatus, shown in Figure 1, the system controller 3 controls the memory 14 so that the ADPCM audio data, continuously outputted from the ADPCM encoder 13 at the transfer rate of, for example, 18.75 sectors/second, are written in the memory 14 at the above-mentioned transfer rate of 18.75 sectors/second. When the volume of the ADPCM audio data stored in the memory 14 exceeds the predetermined volume K, the ADPCM audio data stored in the memory 14 are read out as recording data in a burst fashion at the transfer rate of 75 sectors/second. In this manner, the input data may be written continuously in the memory 14 while a data write area in excess of the predetermined volume is always maintained in the memory 14.

Meanwhile, the recorded data read out in a burst fashion from the memory 14 may be continuously recorded on the recording track of each magneto-optical disc by controlling the recording position on the recording track of each magneto-optical disc by the first and second optical disc drivers 1 and 2 by the system controller 3 on the basis of the cluster and sector addresses. Moreover, since a data writing region in excess of a predetermined volume is always maintained in the memory 14, input data may be continuously recorded in this data writing region, even if the system controller 3 detects that track jumps have occurred by disturbances to interrupt the recording operation on the magneto-optical disc. During this time, a resetting operation of re-recording at the interrupted recording position may be performed based on the cluster address, so that the input data may be continuously recorded on the recording track of the magneto-optical disc. The current position may be displayed in terms of the actual recording time by multiplying the read-out cluster address by a reciprocal of the data compression rate and 32/75.

The recording position on the recording track of each magneto-optical disc by the first and second optical disc drivers 1 and 2 may be controlled on the basis of the cluster and sector addresses so that the second optical disc driver 2 is captured into synchronization to change over the switch 16 during the time until the cluster audio data unit next to the last cluster audio data unit written by the first optical disc driver on the first magneto-optical disc is read out from the memory 14, so that, as shown in Figure 6, cluster audio data are

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written by the second optical disc driver 2 on the second magneto-optical disc starting from the cluster audio data unit next to the last cluster audio data unit written by the first optical disc driver 1 on the first magneto-optical disc.

In the system controller 3, the time when the last cluster of the first magneto-optical disc is reached is calculated by the system controller 3 from the total number of clusters recorded in the TOC area of the first magneto-optical disc on which the recording is made by the first optical disc driver 1 for setting the timing of capturing the second optical disc driver 2 for starting the recording by the second optical disc driver 2. Index data or the like indicating that there are main data to be recorded on the second magneto-optical disc in continuation from the first magneto-optical disc are recorded in the TOC area of the first magneto-optical disc. Similarly, timing data or the like for specifying the leading cluster to be connected from the first magneto-optical disc are recorded in the TOC area of he second magneto-optical disc on which recording is made by the second optical disc driver 2.

In this manner, in this optical disc recording apparatus, the recording system of the second optical disc is captured into synchronization, during the time until the cluster audio data unit next to the last cluster audio data recorded on the first magneto-optical disc is read from the buffer memory, for continuously recording audio signals on the first and the second magneto-optical discs, so that the audio signals may be continuously recorded on a plurality of optical discs continuously for a prolonged time.

In the playback system of the disc recording/reproducing apparatus of Figure 1, the system controller 3 increments the write pointer W of the memory 22 at the transfer rate of 75 sectors/second to write the playback data in the memory 22 at the transfer rate of 75 sectors/second, while continuously incrementing the read pointer R of the memory 22 at the transfer rate of 18.75 sectors/second continuously to read the playback data from the memory 22 at the transfer rate of 18.75 sectors/second, as shown in Figure 7. When the write pointer W overtakes the read pointer R, the system controller 3 discontinues writing. When the data volume of the playback data stored in the memory 22 is lower than a predetermined volume L, the system controller

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3 increments the write pointer W of the memory 22 in a burst-like manner at a transfer rate of 75 sectors/second to write the playback data, by way of performing control of the memory 22.

Thus, in the above-described reproducing system of the disc recording/reproducing apparatus, the B-level stereo mode ADPCM audio data reproduced from the recording track of the magneto-optical disc are written in a burst-like manner in the memory 22, while the ADPCM audio data are continuously read from the memory 14 as playback data at the transfer rate of 18.75 sectors/second, by the above-described memory control by the system controller 3, so that the playback data may be continuously read from the memory 22 while data in excess of the predetermined volume L are always maintained in the memory 22. On the other hand, the playback data read out in a burst-like manner from the memory 22 may be continuously reproduced from the recording track of the magneto-optical disc by controlling the reproducing position on the recording track of the magneto-optical disc by the system controller 3 on the basis of the cluster addresses and the sector addresses. Besides, since the data in excess of the predetermined volume L are maintained in the memory 22, data stored in excess of the volume L may be read from the memory 22 to continue outputting analogue audio signals, even when the system controller 3 detects track jumps, etc. by disturbances, etc. to discontinue the reproducing operation from the magneto-optical disc. During this time, the resetting operation of again performing the reproduction at the interrupted reproducing position may be performed on the basis of the cluster addresses. In addition, during the time when the last of the cluster audio data reproduced from the magneto-optical disc by the first optical disc driver 1 are read from the memory 22, the second optical disc driver 2 is captured into synchronization, so that, after the above-mentioned last data are read out, the changeover switch 20 is changed over to link the reproducing operations. In this manner, audio signals may be continuously reproduced without signal drop-out from a plurality of optical discs to perform continuous reproduction for a prolonged time. Furthermore, by reading the last cluster address of a piece of music, and multiplying the cluster address by 32/75 and a reciprocal of the data compression factor, the play time may also be displayed.

It is to be noted that the present invention is not limited to

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the above-described embodiments. For example, although a disc recording/reproducing apparatus has been described above in connection with recording/reproduction of the B-level stereo mode ADPCM audio data, recording/reproduction may also be performed in a similar manner with other mode ADPCM audio data in other CD-I systems. Also, the data compression system is not limited to the ADPCM system. The number of sectors making up the cluster also is not limited to 32 but may for example be 64. Also, by using for example 4 Mbit buffer memories as the above-mentioned memories 14, 22, about 12 seconds of audio data may be stored therein, so that, by exchanging optical discs by a disc changer and capturing the recording system of the second optical disc into synchronization during this 12 second interval, recording or reproduction may be made continuously without signal drop-out by a single optical disc driver over a plurality of optical disc drivers.

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* C L M S *

CLAIMS

1. A disc recording apparatus for recording input data on disc-shaped recording media, the apparatus comprising:

memory means (14) in which continuously inputted input data are sequentially written and from which the input data are read out as recording data at a transfer rate faster than the transfer rate at which the input data are written therein;

recording means (1) for recording the recording data read from said memory means (14) on a first disc-shaped recording medium rotationally driven at a predetermined velocity;

recording controlling means (3) for effecting read-out control of said memory means (14) so that, when the data volume of said input data stored in said memory means (14) exceeds a first predetermined volume, recording data of said first predetermined volume are read out continuously from said memory means (14) so that a writing space in excess of a second predetermined volume is maintained at all times in said memory means (14), said recording controlling means (3) also effecting recording position control so that the recording data of said first predetermined volume read out in a burst-like manner from said memory means (14) by the read-out control of said memory means (14) are continuously recorded on the recording track on said first recording medium; and

linking controlling means (3) for capturing recording means (2) of a second disc-shaped recording medium during the time interval when data next to the last of data recorded on said first recording medium are read from said memory means (14), for recording data continuously on said first recording medium and on said second recording medium.

2. Apparatus according to claim 1 wherein said first predetermined volume is in excess of a minimum recording unit of said recording data.

3. Apparatus according to claim 2 wherein said recording controlling means (3) discontinues reading of the recording data from said memory means (14) when said recording means (1) is in an unrecordable state, said recording controlling means (3) reading the data which the recording means (1) has become unable to record from said memory means

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(14) after said recording means has reset to a recordable state, said recording controlling means (3) recording the read data in continuation of recording data preceding said data which the recording means (1) has become unable to record.

4. Apparatus according to claim 3 wherein said second predetermined volume is in excess of an input data volume inputted to said memory means (14) during the time of resetting from said unrecordable state to said recordable state.

5. Apparatus according to any one of the preceding claims wherein said input data are time base compressed data.

6. Apparatus according to any one of the preceding claims wherein the information indicating that data are continuous to said second recording medium is recorded in a predetermined area of said first recording medium.

7. Apparatus according to any one of the preceding claims wherein the information indicating that data are continuous from said first recording medium is recorded in a predetermined area of said second recording medium.

8. Apparatus according to any one of the preceding claims wherein said linking controlling means (3) starts capturing said second recording medium into synchronization responsive to the last address pre-recorded on said first recording medium and the current recording address.

9. Apparatus according to any one of the preceding claims wherein said first and second recording media are exchanged using a disc changer.

10. A disc reproducing apparatus for reproducing recorded data continuously recorded on disc-shaped recording media, the apparatus comprising:

reproducing means (1) for sequentially reading the recorded data from

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a first disc-shaped recording medium, rotationally driven at a predetermined velocity, at a second transfer rate faster than a first transfer rate required of playback output data;

memory means (14) in which playback data read by said reproducing means (1) are sequentially written at said second transfer rate and from which the sequentially written playback data are continuously read as said playback output data at said first transfer rate;

playback controlling means (3) for effecting writing controlling of said memory means (14) for writing said playback data of a second predetermined volume when the volume of said playback data stored in said memory means (14) becomes less than a first predetermined volume so that a volume of the playback data in excess of said first predetermined volume is always maintained in said memory means (14), said playback controlling means (3) also effecting playback position controlling so that said playback data sequentially discontinuously written in said memory means (14) by said writing controlling of said memory means (14) are continuously read from the recording track of said disc-shaped recording medium; and

linking controlling means (3) for capturing a recording system (2) of a second disc-shaped recording medium during the time interval when the last of data recorded on said first recording medium are reproduced, to reproduce data continuously from said first recording medium and said second disc-shaped recording medium.

11. Apparatus according to claim 10 wherein said second predetermined volume is in excess of a minimum recording unit of said recording data.

12. Apparatus according to claim 11 wherein said reproducing controlling means (3) discontinues writing of the playback data from said memory means (14) when said reproducing means (1) is in an unreproducible state, said reproducing controlling means (3) reading the data which the recording means (1) has become unable to reproduce from said first recording medium after said reproducing means (1) is reset to a reproducible state, said reproducing controlling means (3) recording the read data in continuation of playback data preceding said data which the recording means (1) has become unable to reproduce.

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13. Apparatus according to claim 12 wherein said first predetermined volume is in excess of playback output data volume outputted from said memory means (14) during the time of resetting from said unrecordable state to said recordable state.

14. Apparatus according to any one of claims 10 to 13 wherein said playback data read from said recording medium are time base compressed data.

15. Apparatus according to any one of claims 10 to 14 wherein linking controlling is performed responsive to the information recorded in a predetermined region of said first recording medium for indicating that data are continuous to said second recording medium.

16. Apparatus according to any one of claims 10 to 15 wherein said linking controlling means (3) starts capturing said second recording medium into synchronization responsive to the last address pre-recorded on said first recording medium and the current reproducing address.

17. Apparatus according to any one of claims 10 to 16 wherein said first and second recording media are exchanged using a disc changer.