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(54) CUTTERHEAD ASSEMBLY FOR SIGNAL RECORDING

(71) We, RCA CORPORATION, a corporation organized under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York 10020, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to cutterheads suitable for forming topographic signal-representative patterns on a recording medium such as a disc and more particularly to a cutterhead suitable for providing a substantially uniform, signal-responsive cutting stylus displacement over a relatively wide band of frequencies such as may be employed in a video disc system.

Cutterheads are known for topographically recording signal information, particularly in the field of recording audio photograph records. In the recording process of audio records, a topographic pattern, representative of audio signal information, is cut with a cutterhead in a laquer-coated disc. The laquer-coated disc, including the topographic information is then replicated, for example, in nickel. This nickel replica has topographic information formed in opposite contour from that on the laquer-coated disc and may be utilized to stamp audio records of, for example, vinyl or other thermoplastic material.

Cutterheads utilized for recording audio signals typically have a relatively flat frequency response to about 20 kilohertz and thereafter typically possess undesirable resonant modes. This frequency response is suitable for recording audio records in real time, i.e., the same time as utilized for playing back the record, but is unsuitable for real time recording of video signals having a much wider bandwidth, for example, of the order of 4 megahertz. If it is desired to record video signals with an audio cutterhead, the video information has to be arranged such that the highest frequency component, e.g., 4 megahertz, is translated to the

range of capability of the cutter, e.g., 20 kilohertz. This frequency translation, i.e., 4 megahertz to 20 kilohertz, may be accomplished by photographically recording the desired picture or video information on motion picture film and then operating the film at a greatly reduced speed, for example, 1/200 of the normal film speed, while electronically scanning and detecting the information on the film at a similar reduced speed. The signal information derived at the detector is then effectively translated in frequency such that the detected signal frequencies are 1/200 of the frequency values which would be detected at normal film and scan speeds.

If the video signal to be recorded is slowed down to 1/200 of real time, it would take approximately 100 hours of recording time to record 30 minutes of real time video signal information. This exceptionally long recording time is impractical and costly for producing discs recorded with video information. It is, therefore, desirable to decrease the recording time as much as possible. A decrease in recording time may be realized by increasing the bandwidth of the cutterhead. For example, if the bandwidth of the cutter head is increased from 20 kilohertz to 200 kilohertz, the recording time may be proportionally decreased from 1/200 of real time to 1/20 of real time. It is, therefore, desirable to provide a cutterhead having as wide a frequency response as possible in order to appropriately decrease recording time.

The resonant modes of known cutterheads, which serve to limit their frequency responses, are related at least in part to the physical dimensions of the devices and their mounting structures. That is, where dimensions of the structure correspond to 1/2 or 1/4 wavelengths of signal information passing through or coupled to such structure an undesired resonant condition may be produced, thereby preventing the desired uniform response of the cutterhead to signals at or near that wavelength or frequency. While reducing the dimensions of a cutterhead serves to increase such resonant fre-

quencies and thereby offers the prospect of higher frequency response, a limit is reached in that structural stability, heat dissipation, and motion of the cutting stylus with respect to its mount (and therefore depth of cut of a groove) are limited with small structures.

According to the present invention there is provided apparatus mounted to a bracket for providing displacement of a cutter in response to incident electrical signals comprising, a multi-surfaced pedestal including first and second opposite mounting surfaces, damping means between said first pedestal mounting surface and said bracket whereby said pedestal is supported on said bracket, a multi-surfaced piezoelectric element including first and second mounting surfaces, said first piezoelectric element mounting surface being adjacent to and rigidly coupled to said second pedestal mounting surface, a cutting stylus with a stylus mounting means coupling said stylus to said second piezoelectric element mounting surface, said pedestal, piezoelectric element and stylus mounting means forming elements of a composite structure having either a truncated conical surface, or having such exposed external surfaces that for each of said elements all the exposed surfaces thereof are disposed antiparallel to each other, and means for applying electrical signals to said piezoelectric element.

In the drawings:—

Figure 1 is a side elevation of the video disc cutterhead of this invention with electrical connections shown schematically; and

Figure 2 is a bottom plan view looking in the direction of line 2—2 of Figure 1 with the electrical connections removed.

With reference to the drawings, a cutterhead assembly 10 includes a cutting stylus 12 of a hard, rigid material (such as diamond) having a stylus point 14. The stylus 12 has a shank diameter proportioned with respect to its shank length to provide a desired structural strength.

Stylus 12 is mounted in a stylus mount 16 which, in the illustrated arrangement is of triangular truncated pyramidal shape. Stylus mount 16 includes a central mounting hole 18 for mounting the stylus rigidly therein and a base 20 for attachment, for example, by means of a combination of conductive and non-conductive epoxy cements, to one face of a piezoelectric element 22. Conductive epoxy cement is utilized to provide an electrical connection between stylus mount 16 and piezoelectric element 22, while the non-conductive epoxy is utilized to provide structural strength. The stylus mount 16 is constructed of material that is relatively inelastic and low in density as will be explained below.

Electrical signals representative of in-

formation to be recorded are applied to piezoelectric element 22 by means of electrical connections 38 and 40. Piezoelectric element 22 is responsive to the electrical signals and operates in the d_{33} mode, i.e., the displacement of the stylus 12 is in the same direction as the applied electric field. The electric field is therefore applied between the parallel faces 24, 25 of the element 22 in the direction of desired motion of the stylus 12. The piezoelectric element 22 has sides 26 and is triangular shaped in plan conforming with the shape of a supporting pedestal base 28 upon which it is mounted. Although the piezoelectric element 22 is illustrated with vertical sides 26 (see Figure 1), the sides of this element also may be sloped to form a truncated structure similar in shape to pedestal 28. Typical piezoelectric materials which are suitable for element 22 are of lead zirconate titanate type and are available from Clevite Corporation as PZT-8 or PZT-4 materials. Supporting pedestal surface 28 includes a surface 30 rigidly coupled to parallel surface 25 of element 22 by a combination of conductive and non-conductive epoxy cements as utilized for attaching element 22 to stylus mount 16. Pedestal 28 is formed in a truncated triangular pyramidal shape having a triangular cross-section similar in shape to the cross-sections of both piezoelectric element 22 and stylus mount 16. Apart from the horizontal surfaces, i.e. those not exposed, no one component has parallel surfaces, i.e. these are "anti-parallel".

The cutterhead assembly is supported from a mounting bracket 32 typically formed of aluminum or steel and is decoupled from this mounting bracket by means of damping material 34 positioned between base 35 of the supporting pedestal 28 and the mounting bracket 32. Damping material 34 may include relatively thin layers of pliable material separated by layers of rigid material such as that available from the Dupont Corporation under the Registered Trade Mark "Kapton". The thin layers of pliable material may be of silicon rubber or cellulose of the type manufactured by American Viscose Company, Markus Hook, Pennsylvania, under the name Viscoloid. Damping material at base 35 of support pedestal 28 inhibits reflection of waves generated by piezoelectric element 22 within pedestal 28.

A heating element 36 is wrapped about the tip of stylus 12 and aids in the cutting of a signal representative topography in a lacquer-coated disc (not shown) by heating cutting stylus 12. Electrical connection 40 is coupled to stylus mount 16 for providing, along with connection 38 to pedestal 28, the required electrical signals between surfaces 24, 25 of piezoelectric element 22. In constructing the illustrated apparatus, a stylus

mount 16 which is relatively inelastic i.e., having a high Young's modulus "E", and a low density ρ is desired in order to precisely transmit the displacement of the piezoelectric element 22 to stylus 12 over a wide frequency range. The displacement response of stylus 12 with respect to the base 20 is governed by the propagation velocity of a displacement applied at base 20 which travels through the material of mount 16 to stylus 12. A high propagation velocity C in the material of stylus mount 16 allows stylus 12 to follow relatively high frequency motion of base 20. The propagation velocity C is given by the equation $C = \sqrt{\frac{E}{\rho}}$.

Hence, materials having a high propagation velocity C have a large E to ρ ratio, e.g., a high Young's modulus and low density. Materials such as aluminum, magnesium, beryllium or sapphire are relatively inelastic, have low density and provide good performance when used for the stylus mount 16. A large E provides rigid stylus-PZT coupling.

In order to obtain maximum stylus displacement in response to electrical excitation of piezo-electric element 22, it is necessary to maintain surface 25 of piezoelectric element 22 as stationary as possible allowing parallel surface 24 to provide essentially all the displacement. In order to maintain surface 25 of piezoelectric element 22 as stationary as possible, surface 30 of pedestal 28 should present a relatively high mechanical impedance to the motion of element 22. This is accomplished by making the supporting pedestal 28 of a material having a relatively high density ρ and a relatively high velocity of propagation C. This provides a large specific mechanical impedance $\rho \times C$. Since the propagation velocity C is proportional to the square root of the Young's modulus E, a material having a high Young's modulus E is desirable as well as one having a relatively high density ρ . Steel or tungsten are suitable materials. Although tungsten gives a slightly greater bandwidth, it is much more difficult to fabricate. A steel pedestal has been found to give suitable performance, although other materials that are substantially inelastic and have a relatively high density can be used.

The relatively large size of pedestal 28 further provides a good heat sink for the relatively small piezoelectric element making it possible to operate the cutterhead assembly 10 to a relatively high signal level without encountering depolarization or thermal runaway of the piezoelectric element 22.

As can be seen with reference to Figures 1 and 2, the external surfaces of the assembled cutterhead are in the general form of a triangular pyramid and as such, allevi-

ate parallel transmission paths for propagating waves between points on different external surfaces. Hence, the chances for large resonances to occur within the cutterhead structure are minimized at frequencies where $1/2$ and $1/4$ wavelengths of the propagating waves are equal to or shorter than the various external dimensions of the cutterhead.

In one specific and non-limiting example, cutterhead 10 provided a uniform stylus displacement response to within ± 1 dB over a frequency range of 2 to 300 KHz. A constant level signal voltage was applied to connections 38 and 40 and provided a signal responsive stylus-displacement of up to 10μ inches peak-to-peak. The stylus mount and truncated triangular pyramidal supporting pedestal had side slopes of 45° and angles at the base of the pyramid as shown in Figure 2 of about 56° with an angle at the apex of the pyramid of 68° . The angles of the supporting pedestal, piezoelectric element and stylus mount were aligned as shown in Figure 2. The stylus mount was formed of aluminum and the supporting pedestal was formed of cold rolled steel. The supporting pedestal was about 0.8 inches across the longest leg of the base, while the piezoelectric element and stylus mount were about 0.22 inches along the longest edge of the base. The resilient damping material between the supporting pedestal and the mounting bracket was two layers of 0.005 inch thick "Kapton" bonded together by Viscoloid or similar damping material. The triangular piezoelectric element was lead zirconate titanate having a thickness of 0.05 inches between its parallel surfaces. The height of the stylus mount was 0.05 inches and the height of the supporting pedestal was 0.15 inches. With a 500 volt RMS signal applied through the electrical leads of the cutterhead, a frequency response of up to 380 KHz was produced before encountering resonant modes.

Although the cutterhead thus far has been described in terms of a substantially pyramidal shaped structure, other structures having antiparallel exposed surfaces may provide satisfactory performance. Alternatively the cutterhead illustrated in Figures 1 and 2 may be formed in a truncated conical shape, with each of the constituent elements having a circular, rather than triangular cross section. Cutterheads formed in a truncated conical configuration may offer certain constructional advantages providing cost savings in production, while similarly reducing the chances of large resonances occurring.

WHAT WE CLAIM IS:—

1. Apparatus mounted to a bracket for providing displacement of a cutter in response to incident electrical signals com-

mount 16 which is relatively inelastic i.e., having a high Young's modulus "E", and a low density ρ is desired in order to precisely transmit the displacement of the piezoelectric element 22 to stylus 12 over a wide frequency range. The displacement response of stylus 12 with respect to the base 20 is governed by the propagation velocity of a displacement applied at base 20 which travels through the material of mount 16 to stylus 12. A high propagation velocity C in the material of stylus mount 16 allows stylus 12 to follow relatively high frequency motion of base 20. The propagation velocity C is given by the equation $C = \sqrt{\frac{E}{\rho}}$.

Hence, materials having a high propagation velocity C have a large E to ρ ratio, e.g., a high Young's modulus and low density. Materials such as aluminum, magnesium, beryllium or sapphire are relatively inelastic, have low density and provide good performance when used for the stylus mount 16. A large E provides rigid stylus-PZT coupling.

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WHAT WE CLAIM IS:—

1. Apparatus mounted to a bracket for providing displacement of a cutter in response to incident electrical signals com-



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prising, a multi-surfaced pedestal including first and second opposite mounting surfaces, damping means between said first pedestal mounting surface and said bracket where-
5 by said pedestal is supported on said bracket, a multi-surfaced piezoelectric element including first and second mounting surfaces, said first piezoelectric element mounting surface being adjacent to and rigidly coupled to said second pedestal mounting surface, a
10 cutting stylus with a stylus mounting means coupling said stylus to said second piezoelectric element mounting surface, said pedestal, piezoelectric element and stylus mounting means forming elements of a composite structure having either a truncated conical surface, or having such exposed external surfaces that for each of said elements all the exposed surfaces thereof are
15 disposed anti-parallel to each other, and means for applying electrical signals to said piezoelectric element.
2. Apparatus as claimed in claim 1 in which said pedestal is made of material having a Young's modulus and a density each
25 substantially equal to or each greater than steel.

3. Apparatus as claimed in claim 1 or 2 in which said pedestal is made of material selected from the group of materials consisting of steel and tungsten.

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4. Apparatus as claimed in any one of the preceding claims in which said pedestal is a truncated triangular pyramid and said piezoelectric element is triangular in cross-section, the pyramidal shape of the pedestal tapering toward said cutting stylus.

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5. Apparatus as claimed in any one of the preceding claims in which said piezoelectric element is a truncated triangular pyramid tapering towards said cutting stylus.

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6. Apparatus as claimed in any one of the claims 1—3 in which said pedestal, said piezoelectric element and said stylus mount form a truncated conical shape tapering towards said cutting stylus.

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7. Cutter displacing apparatus substantially as hereinbefore described in conjunction with the drawings.

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