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**WO 03/103504 A2**

(54) Title: ULTRASONIC CUTTER

(57) Abstract: An ultrasonic cutter comprises a piezoelectric element having a driving portion and a cutting portion integral with the driving portion. The cutter may comprise a single piece PZT ceramic, and have a resonant frequency over 100 kHz, or over 250 kHz, or over 500 kHz.

Title: Ultrasonic Cutter

Description of Invention

This invention relates to ultrasonic cutters. In particular, but not exclusively, this invention relates to ultrasonic cutters used in safety critical applications such as surgery or personal care and CNC high speed, low inertia cutters.

Currently known ultrasonic cutters have application in many different fields, including in the medical field as surgical instruments. Conventional small medical ultrasonic cutters typically comprise a knife blade, made from a hardened material, for example special grades of steel, stainless steel or titanium, which is attached to an ultrasonic amplifier or booster horn through a Langevin transducer. The blade is vibrated along its length to cut through the material.

An alternative type of ultrasonic instrument, also extremely useful in surgery, has a bead of titanium, or an alloy known as titanium 6.4, formed at the end of an elongated wire or thin probe also conventionally of titanium driven by a transducer. This resonant device transmits a longitudinal mechanical compressive wave along the wire or probe from the transducer to the bead. The bead, vibrating typically at 20 kHz, as part of the resonant device, heats the tissue to produce a cutting or reforming effect.

These cutters fall short of acceptable performance in several respects. Firstly, since both devices require Langevin transducers operated in a longitudinal compression wave mode, their main dimension must be a multiple of half wavelengths, which restricts their shape and size. Secondly, both are difficult for the user to manoeuvre and to direct, albeit in different respects. The ultrasonic blades are extremely sharp and may easily cut more material than necessary, for example if the surgeon's hand slips or the patient moves. The ultrasonic bead, by contrast, simply heats all of the tissue around it, and

thus has low resolution. Thirdly, the cutters must be joined to the transducer by a clamping device or screw threads which is technically difficult and inconvenient.

There is, therefore, a need for an ultrasonic cutter which can be more easily controlled during cutting. This is particularly important when such cutters are used in safety critical applications, for example on people or animals. Conveniently such a device would be smaller and lighter than existing devices and, of particular importance in medical applications, be disposable in part at least.

According to this invention an ultrasonic cutter is provided comprising a piezoelectric element having a driving portion and a cutting portion integral with the driving portion.

This allows ultrasonic cutters to be made smaller and to be used in many applications for which they were previously unsuitable. For example extremely small cutters can be manufactured which may be inserted into tubes or through gaps in which conventional cutters cannot conveniently or safely be used, such as along the arteries or veins of the human body.

Preferably the cutter comprises a single piece ceramic, such as a PZT compound (lead zirconate titanate).

The cutter may have a resonant frequency of over 100 kHz, conveniently over 250 kHz and preferably over 500 kHz. This enhances cutting efficiency over lower frequency devices by virtue of the greater number of cutting cycles per second, which reduces the applied static force required. The high frequencies used allow the ultrasonic cutters to be made even smaller.

Many different shapes of ultrasonic cutter are enabled by this invention. The driving portion may be generally planar, for example a disc, or could comprise a curvi-planar structure such as a substantially hollow hemisphere or tube. Structures may be shaped to focus the ultrasonic vibrations and maximise the intensity of the ultrasound at the cutting portion.

The driving portion may be generally annular, but a substantially solid structure could also be used provided that vibrations may be generated in the driving portion and transmitted to the cutting portion.

The cutting portion may be formed on or provided by different parts of the cutter. Two embodiments are particularly preferred. In the first of these the cutting portion extends along the circumference of the driving portion. In this embodiment the cutter preferably vibrates in a radial (breathing) mode. Additional circumferential out-of-plane motion can enhance the cutting effect. This embodiment tends to be advantageous when a scraping action rather than a pure cutting action is required, for example when scraping sclerotic plaque from arteries or veins. In the second preferred embodiment the cutting portion projects from the driving portion in an axial direction. The cutting portion in this embodiment may be shaped for a specific application, for example it could resemble a conventional surgical scapel. This tends to be advantageous when a more conventional cutting action is required.

Preferably the driving portion is rotationally symmetrical and ultrasonic vibrations generated in the driving portion in an axial direction emanate as radial vibrations at the cutting portion. —

Preferably the cutter further comprises an amplifying portion integral with the driving portion and the cutting portion.

In such devices electrodes may be connected to the driving portion and stimulate movement in it. Many different combinations of electrode and piezoelectric element are possible. In a preferred embodiment electrodes are arranged on the surface of the driving portion and provide direct excitation of the cutting portion, typically utilising a silver-plated contact layer.

Such devices may be made having a largest dimension of less than 5mm, conveniently less than 2mm, and preferably less than 0.5mm.

Preferably the cutter further comprises at least one protective member, which may be arranged over the cutting portion, to protect the user and the material being cut.

An ultrasonic cutter as outlined above has applications in many different fields. For example, a surgical instrument or a razor comprising such an ultrasonic cutter may be provided according to this invention, or a low mass cutter head of a CNC cutting machine tool, or a domestic cutting tool.

Preferred embodiments of an ultrasonic cutter, selected by way of example, will now be described, with reference to the following drawings in which:

FIGURE 1a shows schematically a perspective view of a first embodiment of an ultrasonic cutter, which resembles a plate;

FIGURE 1b shows schematically a cross section through the first embodiment;

FIGURE 2a shows schematically a perspective view of a second embodiment of an ultrasonic cutter, which resembles a disc;

FIGURE 2b shows schematically a cross section through the second embodiment;

FIGURE 3a shows schematically a perspective view of a third embodiment of an ultrasonic cutter, which resembles an annular disc;

FIGURE 3b shows schematically a cross section through the third embodiment;

FIGURE 3c shows schematically a top view of the third embodiment;

FIGURE 4a shows schematically a perspective view of a fourth embodiment of an ultrasonic cutter, which resembles a hemisphere;

FIGURE 4b shows schematically a cross section through the fourth embodiment;

FIGURE 5a shows schematically a perspective view of a fifth embodiment of an ultrasonic cutter, which resembles a tube;

FIGURE 5b shows schematically a cross section through cutting portion of the fifth embodiment;

FIGURE 6a shows schematically a perspective view of a sixth embodiment of an ultrasonic cutter, which resembles a shear plate;

FIGURE 6b shows schematically a cross section through the sixth embodiment;

FIGURE 7a shows schematically an ultrasonic cutting system which uses a seventh embodiment of an ultrasonic cutter; and

FIGURE 7b shows schematically a top view of the ultrasonic cutter of the seventh embodiment.

Figure 1 shows one embodiment of the invention, which resembles a square planar plate. The cutter 10 comprises a ceramic element 12 sandwiched between two electrodes 14. The ceramic element 12, conveniently made of a single crystal of PZT, comprises a driving portion 16, which is stimulated directly by the electrodes, and a cutting portion 18. The cutting portion 18 is provided by a leading edge of the ceramic element 12, as best shown in Figure 1.

The driving portion 16 and the cutting portion 18 are integral, being different parts of the single ceramic element 12.

The integration of the driving portion 16 with the cutting portion 18 means that a powerful but very small cutter can be constructed. It also reduces the losses that would be generated through friction at a join between the driving portion and the cutting portion if formed separately and joined together.

Stimulation of the electrodes 14 causes the PZT crystal to resonate, conventionally at its resonant frequency, typically 1 MHZ. The shape of the ceramic element 12 and the positioning of the electrodes 14 causes the vibrations generated axially by the electrodes 14 and the driving portion 16 to emanate radially at the cutting portion 18. Thus the cutter 10 may easily be

used to clear material from the sides of tubes or cut into the tube wall whilst the main body of the cutter 10 is suspended in the tube lumen.

The electrodes 14 are arranged on either side of the ceramic element 12. The electrodes 14 are connected firmly to the element 12, conveniently being plated or sprayed on and cover much of the surface area of the driving portion 16. Thus the driving portion 16 of the cutter 10 is directly excited by the electrodes 14 and no conventional Langevin transducer is necessary. Since the cutting portion 18 and the driving portion 16 are integral, this construction results in a very compact and efficient ultrasonic cutter 10.

Figure 2 shows a second embodiment of an ultrasonic cutter 20. Similarly to the first embodiment, this embodiment has a ceramic element 22 sandwiched between two electrodes 24. In this embodiment, however, the element 22 is shaped in the form of a generally symmetrical disc, with one portion, the cutting portion 26 of the disc, being narrower than the main portion, the driving portion 28, this shape providing a mechanical gain at the cutting tip 29. This shape of cutter 20 is particularly convenient for medical work. The electrodes 24 cover only the driving portion 28.

Figure 3 shows a further embodiment of ultrasonic cutter 30, having a driving portion 32 which generally resembles an annular disc. The driving portion 32 is generally annular and cutting tips 34, 36, 38, 40 extend from the driving portion 32 around the circumference of the disc, the tips being shaped to suit the application required. The number of tips provided will also be selected to suit the application.

Figure 4 shows a further embodiment of an ultrasonic cutter 42, which resembles a hollow hemisphere. The cutter 42 comprises a driving portion 44, a cutting portion 46 which extends around the circumference of the hemisphere, and electrodes 48 covering the inner and outer surfaces of the hemisphere. The cutting portion 46 may be serrated and/or rotatable. This shape of cutter 42 is particularly suitable for medical applications since suction may be applied at

the tip of the hemisphere, in the direction of arrow B. This enables the removal of debris from the cutting site.

Figure 5 shows a further embodiment of a ultrasonic cutter 50, which resembles a tube, having a driving portion 54 and a cutting portion 56 around the circumference at an end of the tube. In this embodiment, electrodes 52 cover only a small part of the circumference of the driving portion 54. The excitement provided by the electrodes directs vibrations axially along the tube.

Figure 6 shows a further embodiment of an ultrasonic cutter, which resembles a sheer plate, having a shaped cutting edge 62.

Figure 7 shows how such ultrasonic cutters may be used. The cutter head 72 has a cutting tip 74 conveniently adapted for a radial scraping action in the direction of arrow C, and/or an axial drilling action.

The cutting portion with the cutting tip 74 at its tip is integral with a driving portion 76. Electrodes 78 generate radial or axial vibrations in the driving portion 76 which may be amplified by the shape of the driving portion 76 which incorporates an integral amplifying portion 75. The amplifying portion 75 enlarges the vibrations generated by the driving portion 76, and may change the direction of the vibrations from an axial direction to a radial direction. The driving portion 76 is attached to (or may be integral with) an at least partially curved, conveniently hemispherical, ball 80. This ball 80 is adapted to fit within a socket 82 which has a correspondingly curved hollow 84. Preferably the hollow 84 extends beyond the curved surface of the ball 80 so that the ball is retained within and can rotate with respect to the socket 84.

Movement of the ball 80 with respect to the socket 84 is accomplished by lever arms 86, 88 which extend through the socket 84, conveniently through channels worn therein, and are fixed to the ball 80 at or close to opposed diametrical positions. The lever arms 86, 88 conveniently comprise flexible cables. Axial tension may be applied along one lever arm 86 and/or axial compression along the other lever arm 88 to rotate the ball 80 within the socket

84. This causes the cutting tip 74 to sweep an arc indicated by the arrow C. An annular disc 90, conveniently stretchable and resilient, deforms to allow manipulation of the cutting head 72. The annular disc 90 is attached via appropriate sealing means to the driving portion 76 and to a flexible stainless steel sheath 94.

The socket 84 is preferably attached to the stainless steel sheath 94 along the portions of its outer radial circumference. Further lever arms (not shown) may be attached to the socket 84 to manipulate the instrument head as a whole.

Wires 96 extend through channels conveniently formed in the socket 84 and along the stainless steel sheath 94, to the proximal end of the instrument. Further elements of a system for remote surgery are also shown schematically (and not to scale): two manipulators 98, 100, a controller 102 and a display 104. Each manipulator 98, 100 is adapted to be easily used by a surgeon. Each manipulator 98, 100 may be connected to a respective lever arm 86, 88 and they enable independent operation of the lever arms 86, 88. Further manipulators (not shown) may be connected to any further lever arms (not shown) attached to the socket 84 or other elements of the distal end of the instrument.

The manipulators 98, 100 are also electrically connected to a controller 102. One or more of the manipulators may conveniently feature a trigger 106 which may activate the ultrasonic driver when manually operated. Controls 108 which may be attached to the controller and/or operated by a separate remote device (not shown) may also be used to activate the ultrasound, controller display, move the lever arms, or control other elements of the remote surgery system. The display 104 may portray schematically or otherwise movement of the distal end of the instrument. It is electrically connected to the controller 102 and may conveniently receive information therefrom relating to the movement of the manipulators 98, 100 to enable a schematic depiction of movement of the cutter head 72 to be portrayed.

Displays 104 may alternatively or additionally conveniently be electrically connected to an imaging system which may use x-ray, magnetic resonance, or any other imaging modality to display a desired portion of the patient's body. It may thus directly depict the situation at the distal end of the instrument. By use of this invention, ultrasonic energy can be applied to tissue more easily and more safely. It will increase the range of uses for ultrasonic cutters.

If desired, the cutting portion may be coated by a protective coating, such as zirconium.

In the present specification "comprise" means "includes or consists of" and "comprising" means "including or consisting of".

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

CLAIMS

1. An ultrasonic cutter comprising a piezoelectric element having a driving portion and a cutting portion integral with the driving portion.
2. An ultrasonic cutter according to claim 1 in which the cutter comprises a single piece PZT ceramic.
3. An ultrasonic cutter according to any preceding claim having a resonant frequency over 100 kHz.
4. An ultrasonic cutter according to claim 3 having a resonant frequency over 250 kHz.
5. An ultrasonic cutter according to claim 4 having a resonant frequency over 500 kHz.
6. An ultrasonic cutter according to any preceding claim in which the cutting portion extends circumferentially of the driving portion.
7. An ultrasonic cutter according to any preceding claim in which the driving portion is rotationally symmetrical and ultrasonic vibrations generated in the driving portion in an axial direction emanate as radial vibrations at the cutting portion.
8. An ultrasonic cutter according to any one of claims 1 to 5 in which the cutting portion projects from the driving portion in an axial direction.

9. An ultrasonic cutter according to any preceding claim further comprising an amplifying portion integral with the driving portion and the cutting portion.
10. An ultrasonic cutter according to any preceding claim in which the electrodes are arranged on the surface of the driving portion and provide direct excitation of the cutting portion.
11. An ultrasonic cutter according to any preceding claim having a largest dimension of less than 5 mm.
12. An ultrasonic cutter according to claim 11 having a largest dimension of less than 2 mm.
13. An ultrasonic cutter according to claim 12 having a largest dimension of less than 0.5 mm.
14. An ultrasonic cutter comprising a single piezoelectric crystal which provides integral driving and cutting portions, the maximum dimension of which is less than 5mm.
15. An ultrasonic cutter according to any preceding claim further comprising a protective member arranged over the cutting portion.
16. A surgical instrument comprising an ultrasonic cutter according to any preceding claim.
17. A razor comprising an ultrasonic cutter according to any of claims 1 to 15.

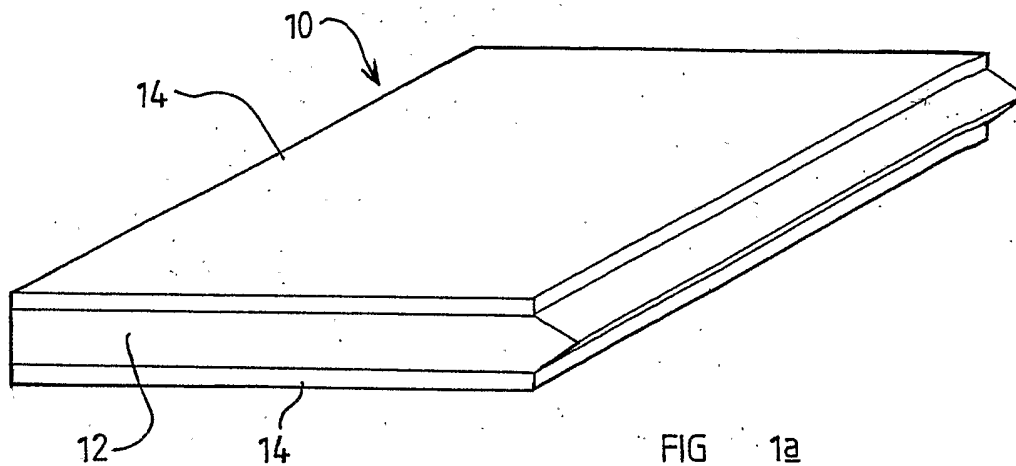


FIG 1a

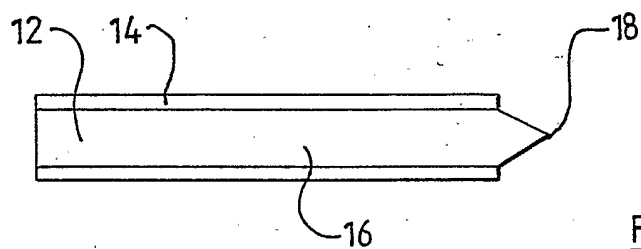


FIG 1b

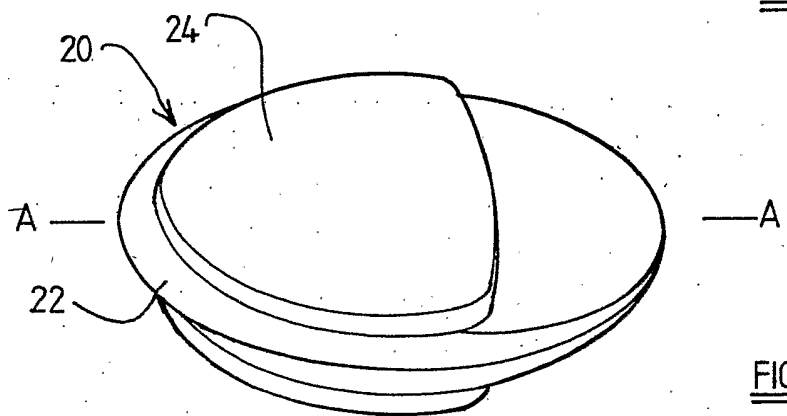


FIG 2a

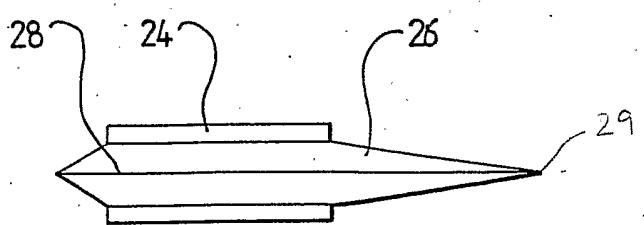


FIG 2b

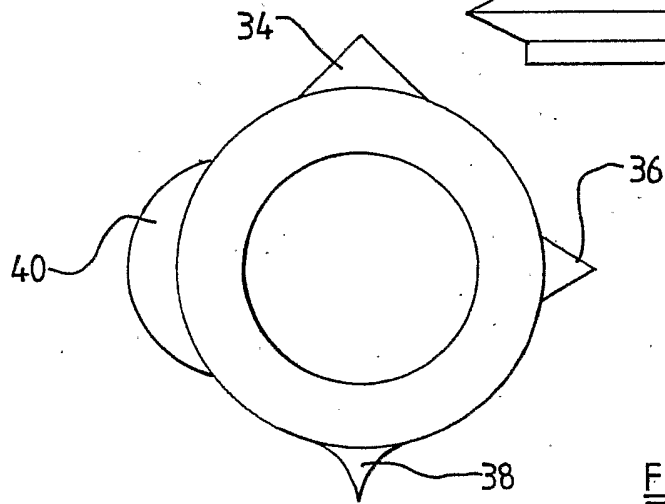
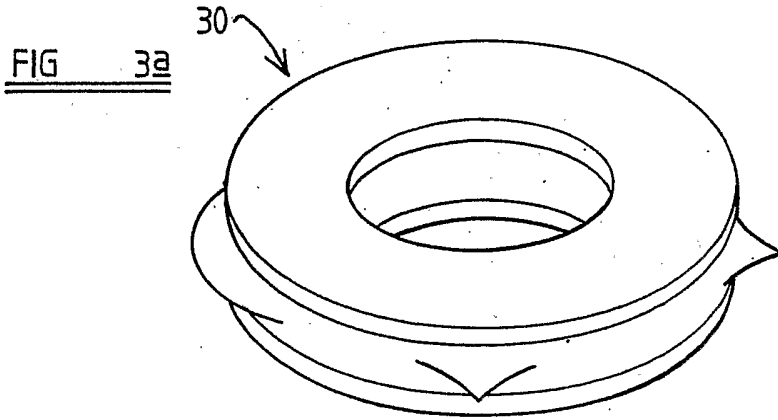


FIG 3b

FIG 3c

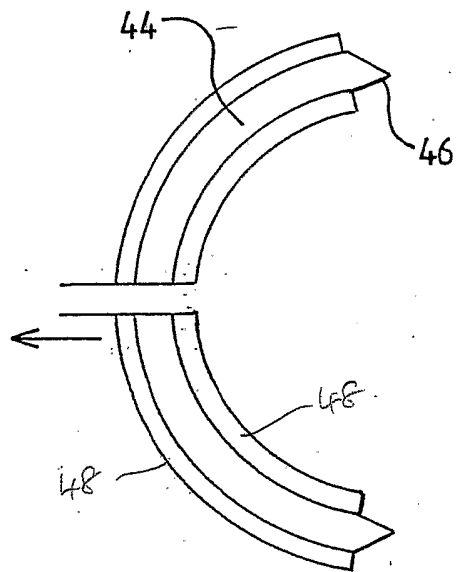
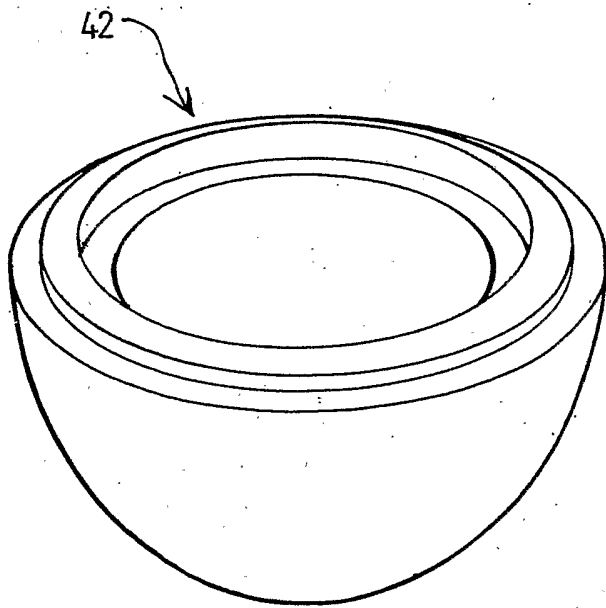


FIG 4a

FIG 4b

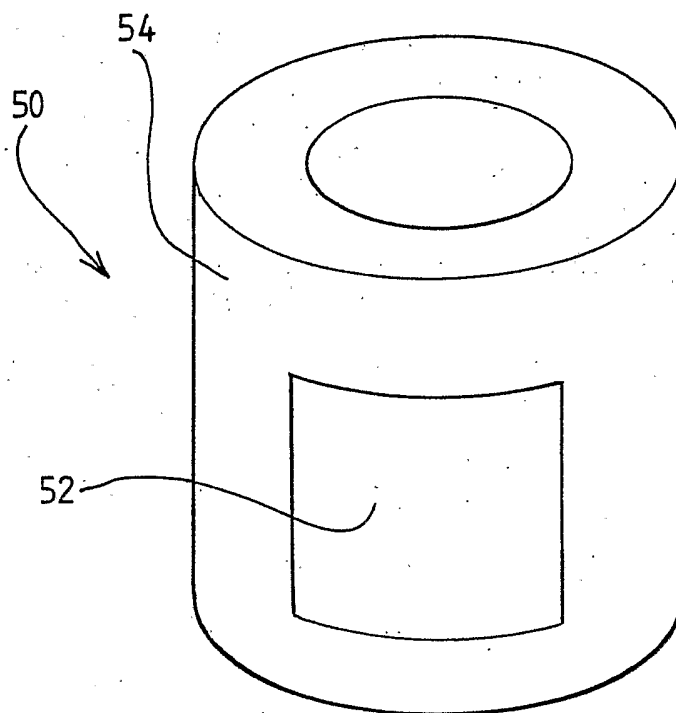


FIG 5a

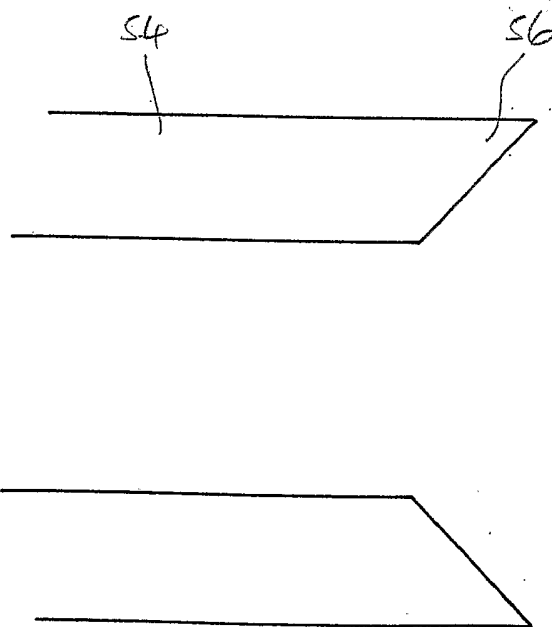


FIG 5b

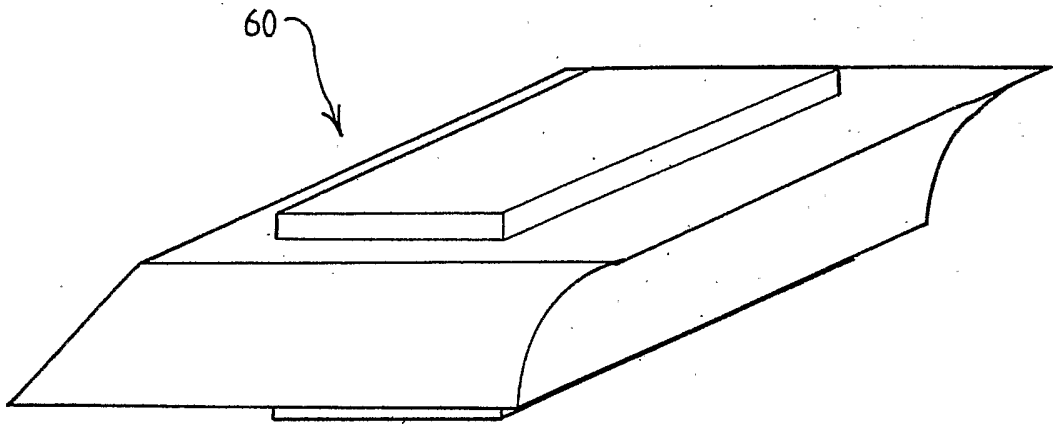


FIG 6a

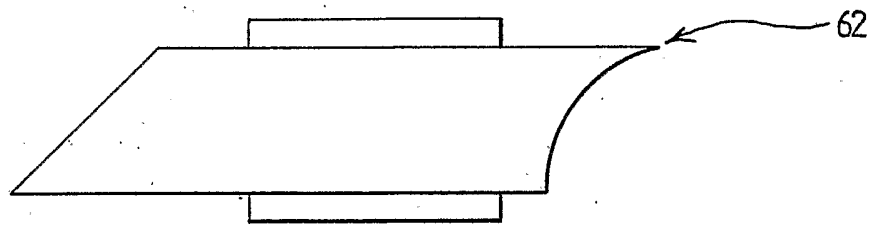


FIG 6b

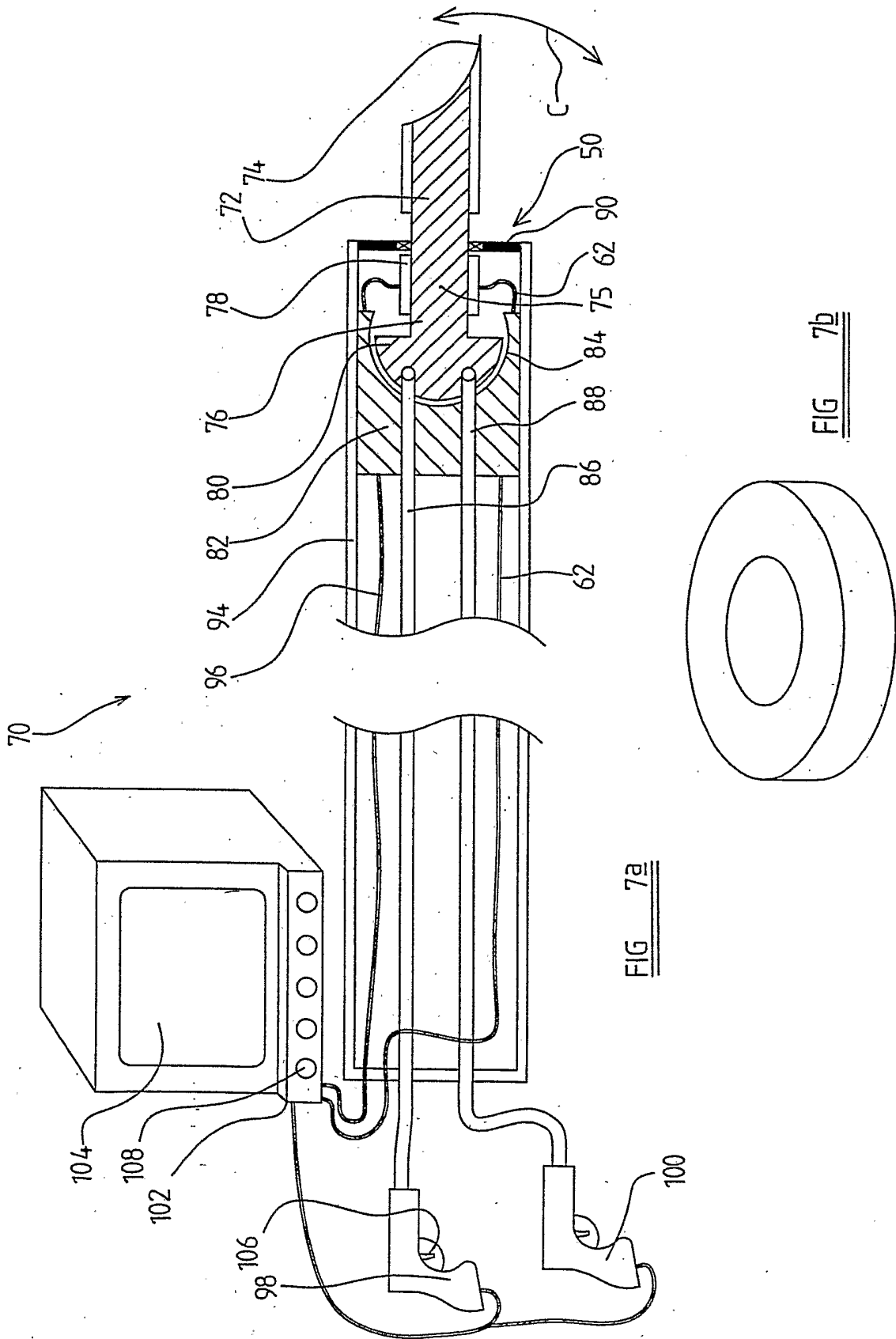


FIG 7a

FIG 7b