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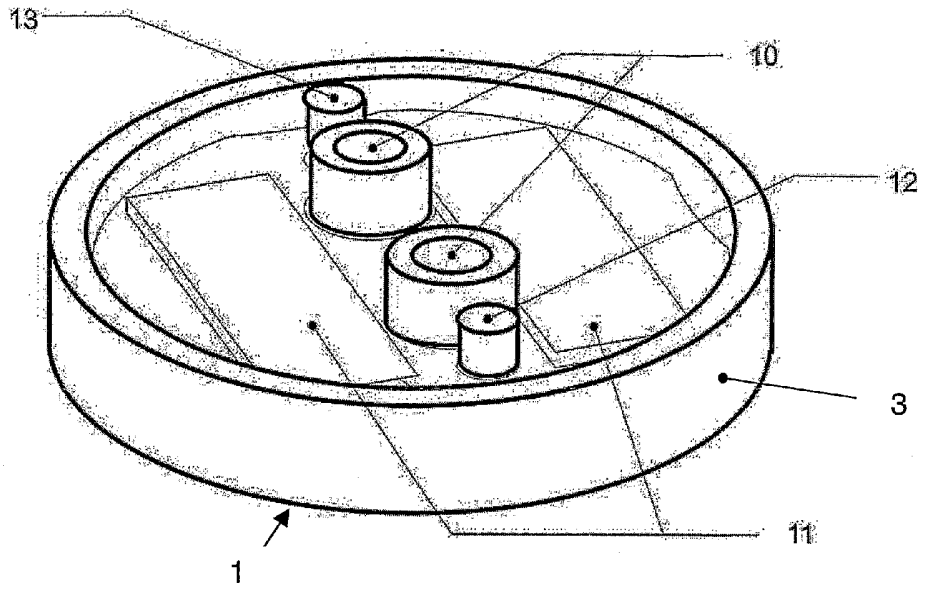
(54) Title: WEARABLE COMPUTER



(57) Abstract: A wearable computer (1) with a RF transceiver (29) and at least one sensor (23, 24, 25) comprises means for affixing the computer to an article of clothing and energy conversion means (14, 11) for converting ambient energy into computer usable energy. The features of energy conversion means (14, 11) for converting ambient energy allow on the one hand an autonomous operation without a need to replace battery cells. On the other hand the means for affixing the computer to an article of clothing guarantee the least inconveniences for a person using such wearable computers (1).

WO 2005/103923 A2

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Wearable Computer

This invention relates to a wearable computer according to the preamble of claim 1 and to a method of powering a wearable computer according to the preamble of claim 8.

The present invention covers the field of ubiquitous or wearable computing in combination with an intelligent environment, in order to allow a wide field of applications such as tourist guides, health monitoring and remembrance agents.

The publication EP 1 062 906 A1 [1] discloses a «device for medical long term supervision of persons». This device allows a wireless transmission of data which derives from a sensor as e.g. on or in a (sticking-) plaster to a device, which is carried by a person. This device is on the one hand restricted to data, which is derived from the skin or the human body itself. On the other hand the device does not allow to analyse the gathered data in an extended context of that human body.

Within the project Smart Dust paper [2] discusses the basic aims and applications of computers with a volume of some Cubic-Millimeters. In the document [3] an autonomous 16 mm^3 solar-powered node is disclosed. The teachings of these two papers can be summarized by the fact, that their degree of an autonomous operation is beyond of the requirements for a so called body area network BAN.

To get all the data for an analyse in an extended and context-dependant manner, a plurality of such devices has to be placed on defined places of the human body, which build a body area network. The best solution with the least inconveniences for a person is fixing or integrating the devices within or at the clothes. Such a solution requires that the sensors are sufficiently small, compact and washable. Furthermore they must have wireless communication facilities. A further requirement is the avoidance of any maintenance for

the operating, especially a replacement of energy-cells such as batteries should be avoided.

The present invention therefore addresses the problem to avoid the above mentioned drawbacks of the known «devices for long term supervision of persons» and to provide a wearable, autonomous operated computer, which may easily fixed within or at the clothes and furthermore enables in an extended and context-dependant manner to gather information on and to a person.

This aim is reached by a wearable computer specified in claim 1 and by a method of powering a wearable computer specified in claim 8.

According to the present invention, a wearable computer is provided with the following features:

a) the computer comprises means for affixing the computer to an article of clothing; and

b) energy conversion means for converting ambient energy into computer usable energy.

According to the present invention, a method of powering a wearable computer is provided, which allows to operate it in an autonomous mode without any need of replacements of battery cells by the characteristics:
converting ambient energy into computer usable energy, said ambient energy comprising at least two of light, heat, magnetic field and motion.
By using at least two sources of ambient energy the autonomy of a wearable computer is significantly increased.

This features for the wearable computer as well as for the method of powering a wearable computer allow to gather information and data of a person, who carries with their clothes a plurality of such wearable computers. The main

features of the present invention are summarized as follows and fulfil the following requirements:

a) Small size:

By fixing a wearable computer in the form of e.g. a sensor button at or in a cloth it becomes obvious, that the size should not exceed a volume of some mm^3 to at most 1 cm^3. This relatively small volume allows different embodiments such as a label, a button or an embroidery as a part of a clothing. An integration of one of the fore mentioned forms within a seam is also possible.

b) Low power consumption:

Since the context monitoring has to be performed continuously during the whole day in only makes sense if it can be accomplished with minimal power consumption. By extracting the energy from the environment a sensor can operate in a fully autonomous mode for months or years.

c) local processing capabilities:

By integrating a microprocessor and memory into the sensor bottom the amount of data, that needs to be transmitted, can be reduced. This reduction leads also to a reduction of energy consumption, because wireless transmission of the reduced data consumes more energy than the computation needed to make this reduction.

Further advantageous embodiments are given in dependant claims.

In the context of this paper the notion «button» includes all forms of a wearable computer according to the features of the present invention. These forms include as above mentioned a label, an embroidery, an accessoire, a casing or a cover and all other shapes, which can be fixed at or within a cloth.

The invention will now be described in preferred embodiments with reference to the accompanying drawings wherein:

Figure 1 perspective schematic view of an sensor button;

Figure 2 cross-sectional view perpendicular to the rotational axis of an sensor button;

Figure 3 cross-sectional view in direction of a rotational axis of an sensor button;

Figure 4a shape of a wearable computer in the form of a button;

Figure 4b fixing of a wearable computer by integration in an embroidery;

Figure 4c fixing of a wearable computer directly sewn on a cloth.

Fig. 1 shows perspective schematic view of a wearable computer 1. The typical dimensions of such a computer 1 in form of a button are in the range of 12mm diameter and up to 4mm thickness. Within a casing 3 there are sensor openings 12 and 13 for sensors such as microphones or photodiodes (not shown in Fig. 1). Further examples comprise sensors for measuring galvanic skin characteristics, blood volume pulse and humidity, etc. The data and information gathered by the aforementioned sensors such as hygrometer and/or a thermo-resistor and others allow in their entity a detailed analysis of the state of the wearer and his environment.

In Fig. 2 depicts in a cross-sectional view perpendicular to the rotational axis a wearable computer 1 in form of a button. The components of the computer including auxiliary components, sensors and means for converting ambient energy are protected by a casing 3 and an encapsulation 22. This protection is particular important, because the computers 1 are fixed at or in an cloth and have therefore to resist to the strains and hazards during the washing of that cloth. On a ground plane 21 is a battery 17 mounted. Its connections 19 are built with wire bonds 18, which are surrounded by a foam 16. The outer part of the computer 1 contains a helix antenna 20. Other components are identified by the reference numeral 15. In the upper part there are two solar cells 14. These solar cells 14 extract energy from the environment in order

to supply the battery 17. In table 1 further examples of energy sources are listed together with its typical values of power.

Energy source	Power	Remarks
Solar cell, outdoors	1.5 - 150 μW	cloudy - direct sun
Solar cell, indoors	0.06 - 5.7 μW	standard desk - desk lamp
Motion (shoe generator)	1 - 10 mW	piezoelectric
Motion (shoe generator)	50 - 250 mW	electro-magnetic (rotary)
Motion (inertial generator)	50 μW	torso when walking
Motion (inertial generator)	200 μW	legs when walking

Table 1: Comparison of energy sources suitable for sensor buttons.

The autonomy of the wearable computer 1 requires an optimal placement of it. Some places may diminish the comfort of the wearer, other places do not give adequate sensor data or the degree of extraction of ambient energy is not sufficient. Since the computer including sensors is in this embodiment integrated in a button and fixed to the clothing, the energy extraction from the environment is focused to motion and body heat. When the energy is extracted from the motion of a wearer, these energy sources - as e.g. an inertial generator - are best placed on body parts that are subject to high acceleration or move frequently, preferably limbs. To harvest energy form heat, one would think that the torso is the best place since its temperature is kept constant at a high level. However, the clothing prevents a temperature gradient between the sensor and its surrounding. So, only body surfaces exposed to air can be used for harvesting energy from body heat. Therefore thermoelectric generators

need to be placed in close contact to the body, integrated with clothes that are usually worn in a single layer.

Another important source of environmental energy is solar energy. Solar cells offer a greater degree of freedom, they can be placed at all points that are frequently exposed to light. The use of solar cells alone requires a placement of the sensor bottom, which is exposed to light. Therefore in preferred embodiments a combination of at least two different energy sources ensures a high level of autonomy.

On the side of power consumption table 2 discloses its typical values.

Functional Unit	**f [Hz]**	**Power [μW]**
Accelerometer	50	150-200
MEMS microphone	5000	50-80
Light sensor	2	50-100
microprocessor	20.000.000	140 - 170
RF transceiver for data transmission	1 kBit/s	100-150
total		490-700

Table 2: Typical values of power consumption for continuous operation.

From the values and the capacity of an energy storage unit as a battery 17 the person skilled in the art can easily derive the degree of autonomy in case no environmental or ambient energy is supplied, a value as an example is given by 8 J. This value is well feasible with a small lithium polymer battery. Additionally some considerations concerning energy production are given below. In case of using solar energy alone a scenario of a north European office worker is assumed as follows:

07.00	wake up;
08.00 -09.00	transfer to the office;
13.00 - 14.00	outdoor activity, such as walk for a lunch;
14.00 - 16.00	meeting in a brighter room.

By multiplying the typical values of production according to table 1 with the above mentioned time intervals it easily can be derived, that the supplied energy covers the need according to table 2 of about 0.5 to 0.7 mW. Furthermore it can be expected, that the button sensors are switched off during night, that is in the time between 20.00 and 07.00. This correspond to a duty cycle of approximately 70%.

Fig. 3 shows in cross-sectional view in direction of the rotational axis the arrangement of the further components such as the sensors: accelerometer 25, photodiode 24 and microphone 23. In this view the antenna 20 has a cylindrical shape 30. The RF transceiver 29, the microprocessor 27 and its memory module 28 are connected with wirebonds (not denoted by a reference numeral in Fig. 3). An A/D converter 26 is provided, since the data gathered from the sensors 23 and/or 24 and/or 25 have to be treated within the button 1 by the microprocessor 27.

Concerning the required dimensions on and in a sensor button reference is made to table 3. In table 3 contains a list with the typical values of the needed surface of the different components.

Component	Area [mm^2]
active die area	0.053
processor, coolRisc 88	1.5
memory	2.5 - 3
MEMS microphone	1.7 - 2.0
Micro accelerometer	6.6
photo diode	1.5
RF transceiver	10.5
external components	4
2 solar cells	34-38

Table 3: Typical area requirements of the individual components of an sensor button.

Wearable computers 1 according to the present invention are coupled with a remote central unit, either worn or placed in the wearers direct environment(which is in other words a computer system) in order to record data and information about a wearer of the plurality of wearable computers 1 and about the environment of said wearer. The treating of the gathered data by the microprocessor in the wearable computer 1 covers also some statistical analysis in order to facilitate the analysis and representation of data done by the remote central unit. This statistical analysis has also the advantage, that less data has to be transmitted from the wearable computer to the remote central unit.

Fig. 4a, 4b and 4c show different shapes or forms of the preferred embodiments of the wearable computer 1 according the present invention.

According to Fig. 4a a wearable computer 1 has the form of a button in such a way that it can be mounted on a piece of

clothing with conventional sewing techniques, e.g. stitched like a button.

Fig. 4b shows an integration in an embroidery. Another form of the wearable computer 1 is showed in Fig. 4c. In this embodiment the casing is directly sewn onto the fabric or cloth.

By fixing a wearable computer 1 at or in a cloth it becomes obvious that the size should not exceed a volume of some mm^3 to at most 1 cm^3. Furthermore the wearable computer 1 is shaped in such a way that it can be mounted on a piece of clothing with conventional sewing techniques. This means that the sensor button could embodied like an actual button a flat decorative piece to be included in embroidery or an accessoire, especially shaped to be stitched on a piece of clothing.

In the context of this paper the notion «button» includes all forms that allow the wearable computer to be attached to a piece of clothing with conventional sewing techniques. These forms include as above mentioned, an embroidery, an accessoire and all other shapes that can be stitched onto a piece on clothing.

The invention is not limited to the embodiment depicted above with a special focus on supplying with solar energy and motion. The invention can also be carried out with other elements concerning energy sources as well as sensors which have similar properties.

List of reference numerals

1	wearable computer
2	filling compound
3	casing, cover
10	holes
11	solar cells
12	sensor opening
13	sensor opening
14	solar cells
15	remaining components
16	foam
17	battery, energy storage
18	wire bonds
19	connections through the substrate (vias)
20	antenna, helix-antenna
21	ground plane
22	encapsulation
23	microphone
24	photodiode
25	accelerometer
26	A/D converter
27	Microprocessor
28	Memory module
29	RF transceiver
30	Antenna

List of acronyms

A/D Analogue/digital

BAN body area network

MEMS Microelectromechanical systems

RF Radio Frequency

References

[1] EP 1 062 906 A1
«Device for medical long term supervision of persons»,
Applicant: EADS Space Transportation GmbH
DE - 28199 Bremen.

[2] B. Warneke, M. Last, B. Leibowitz and K. S. J. Pister:
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[3] B. Warneke, M. Scott, B. Leibowitz, Z. Lixia, C. Bellew, J. Chediak, J. Kahn, B. Boser and K. Pister:
«An autonomous 16 mm^3 solar powered node for distributed wirless sensor networks».
Proceedings of the 1st IEEE International Converence on Sensors, volume 2, pages 1510-1515, June 2002[3].

[4] Kay Römer, Institute for Pervasive Computin Dept. of Computer Science ETH Zurich, Switzerland
«Tracking real-world phenomena with smart dust».
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12th April 2004.

Claims

1. A wearable computer (1) comprising a RF transceiver (29) and at least one sensor (23, 24, 25),
characterised in that
- the computer comprises means for affixing the computer to an article of clothing; and
- energy conversion means (11, 14) for converting ambient energy into computer usable energy.

2. The wearable computer (1) according to claim 1;
characterised in that
the energy conversion means (14) comprises an inertial generator and/or at least one solar cell (14) and/or a thermoelectric generator.

3. The wearable computer (1) according to claims 1 or 2;
characterised in that
the sensor (23, 24, 25) is a microphone (23) and/or a photodiode (24) and/or an acceleration sensor (25) and/or a hygrometer and/or a thermo-resistor.

4. The wearable computer (1) according to claims 1 to 3;
characterised in that
the means for affixing comprises an encapsulation (22) and a casing (3) arranged to protect the wearable computer (1) from environmental effects.

5. Wearable computer (1) according to claims 1 to 4;
characterised in that
the means for affixing comprises clothing affixing means arranged and facilitate conventional sewing techniques.

6. The wearable computer (1) according to claim 5 characterised in that the means for affixing comprises embroidery integration.

7. A system of wearable computers (1) according to anyone of the claims 1 to 6; characterised in that the wearable computers (1) are coupled via their RF transceiver (29) with a remote central unit in order to record data and information about a wearer of the plurality of wearable computers (1) and about an environment of said wearer.

8. A method of powering a wearable computer (1), comprising the steps of:
converting ambient energy into computer usable energy, said ambient energy comprising at least two of light, heat, magnetic field and motion.

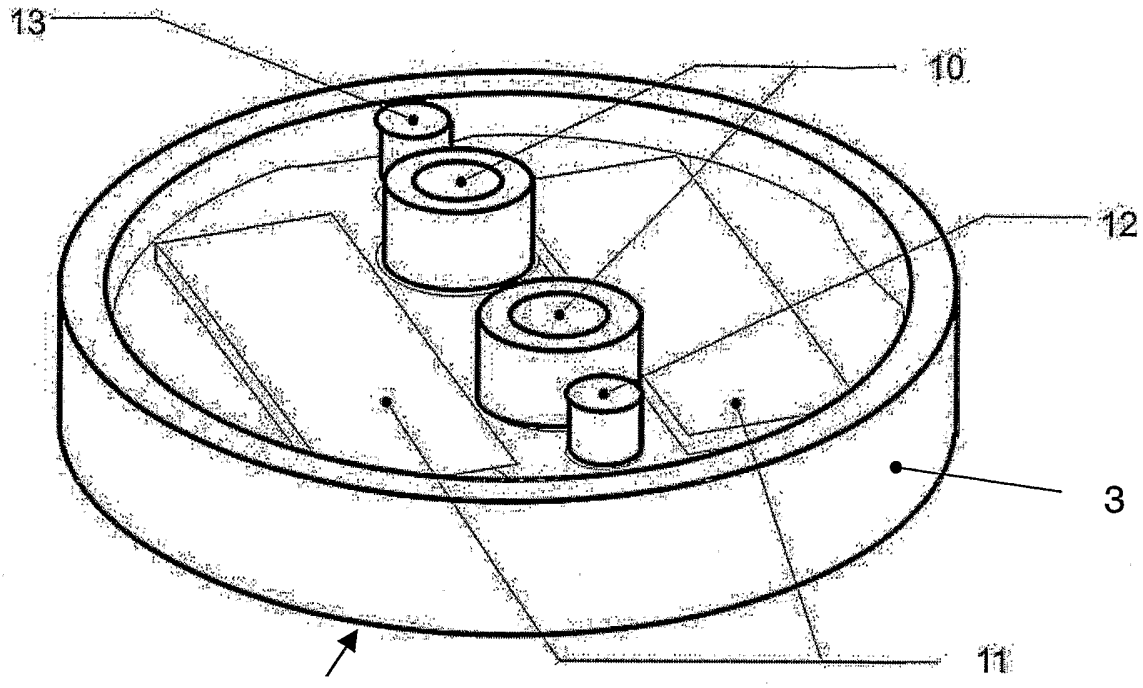

Fig. 1

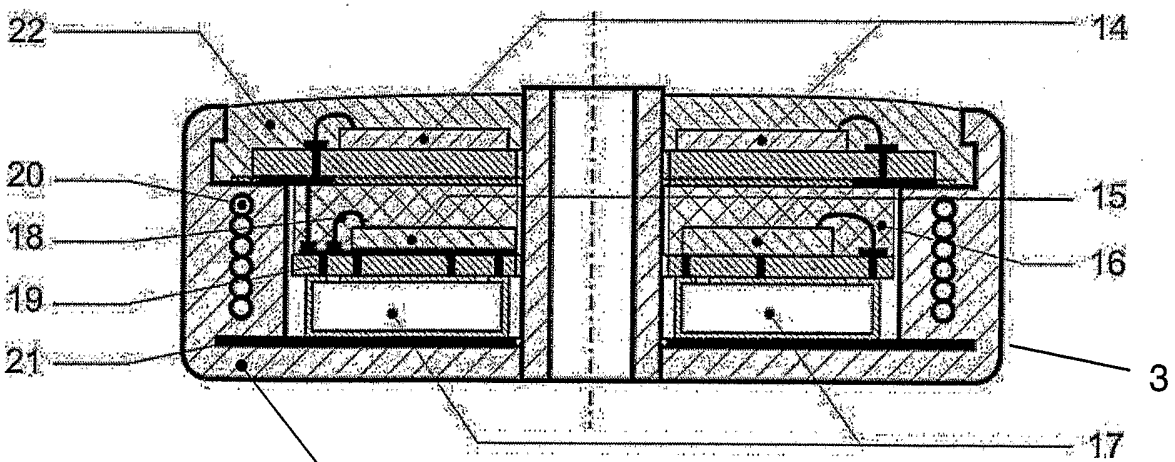

Fig. 2

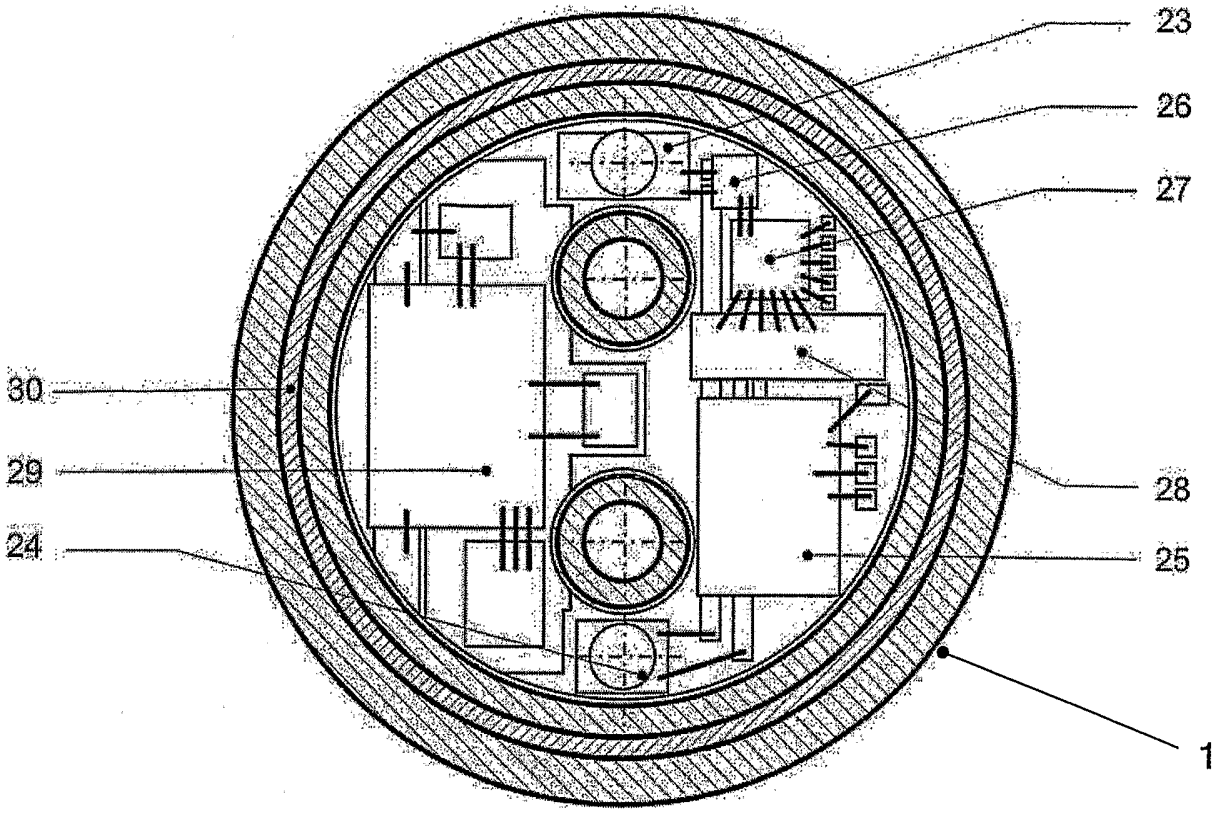

Fig. 3

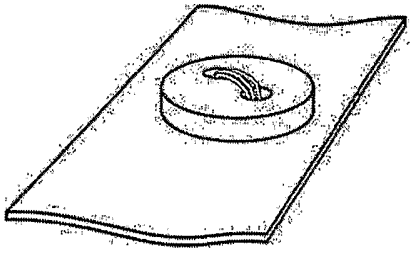

Fig. 4a

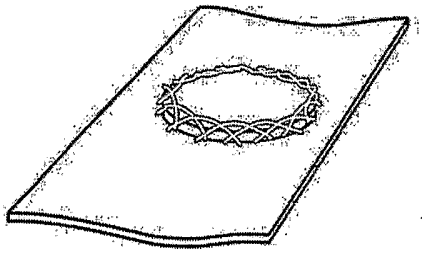

Fig. 4b

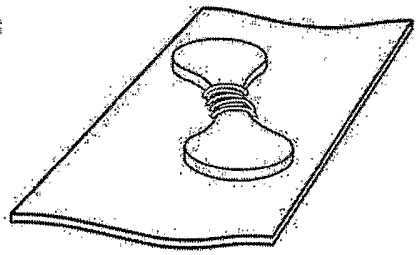

Fig. 4c