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(54) Title: A FLUID FLOW SENSOR AND A METHOD FOR ITS MANUFACTURING

(57) Abstract: The present relates to a fluid flow sensor comprising a thermoelectric device having: - a first member (1) having a surface to be exposed to a fluid flow, to change its temperature along a temperature range; - a second member (2) submitted to a temperature different to the temperatures of said temperature range, and thermally isolated from said first member (1); and - n-doped (Ne) and p-doped (Pe) thermoelectric elements connected so that a differential in the temperatures between the first (1) and second (2) members causes the generation of an electrical signal at the output electrodes (E1, E2), by the Seebeck effect, without applying any energy power to the fluid flow sensor, so that the fluid flow sensor is energetically autonomous. The invention also relates to a method for manufacturing the sensor, to a fluid flow detection device including the sensor and to uses of the detection device.

A FLUID FLOW SENSOR AND A METHOD FOR ITS MANUFACTURING

Technical field

5   The present invention generally concerns, in a first aspect, to a fluid flow sensor comprising a thermoelectric device, and more particularly to a sensor configured and arranged to detect, by convection, very small flow variations.

        A second aspect of the invention concerns to a fluid flow detection device comprising the sensor of the first aspect of the invention.

10   A third aspect of the invention relates to a method for the manufacturing of the sensor of the first aspect of the invention.

        A fourth and a fifth aspects of the invention relate to uses of the fluid flow detection device of the second aspect of the invention.

15 State of the art

        Different kinds of miniaturized fluid flow sensors are known, generally using a resistive element heated at a temperature by means of an electrical current, due to the Joule effect, and the changes in said temperature caused by the circulation of a gas flow are used as the flow indicators.

20   Some of said fluid flow sensors are described in US6763710B2 and US6813944B2, which disclose the use of different kind of temperature sensors, including thermopiles (i.e. a thermoelectric device), and a heating element, such as a resistive heating element.

        Said kind of sensors require the use of an electrical current for performing the fluid flow detections.

25   Some other miniaturized fluid flow sensors comprising a thermoelectric device are disclosed in US6443003B1 and in WO03062134A1, all of them including a heater, implemented whether in the form of a resistor or by other means, such as by injecting current into thermoelectric elements to generate heat by the Peltier effect.

        Some bibliographic references reflecting the state of the art regarding fluid flow sensors

30 are listed at the end of the present section, and the main features of most of them are indicated in the table below.

Material	Configuration	Gas	Resolution	Range	Power consumption	Ref.
Ni in Si_3N_4	Hot layer/Calorimetric	Air	<1%	0-20 m/s	50mW	[2]
Pt CNT	Hot thread	N_2 gas		0-3 m/s		[3]
Si and Si_3N_4	Calorimetric	N_2 gas		0-10 mL/min	600mW	[4]

pSi and Si_3N_4	Hot layer	Air		0-30 m/s		[5]
Pt Si_3N_4	Calorimetric	Air	P_{in} dependent	0-4 m/s	2-20mW	[6]
Pt Pirex	Hot layer	CO_2 gas	0.3 m/s	0-20 m/s	14mW	[7]
Au polyimide	Hot layer	N_2 gas	10 mL/min	0-200 mL/min		[8]
Pt Au Si_3N_4	Calorimetric	Air		0-32 m/s		[9]
Ti/Pt ceramic	Calorimetric	Air	0.3 m/s	0-8 m/s	100mW	[10]
Ti/Pt Si_3N_4	Hot layer	Air		0-11 m/s	15-150mW	[11]
Cr/Pt/Ni/Pt polyamide	Hot thread	Air	P_{in} dependent	P_{in} dependent	P dependent	[12]
Cr/Au polyamide	Hot layer	N_2 gas		0-6 m/s		[13]
Cr/Ni/Pt polyamide	Hot layer	Air	0.1 m/s	0-15 m/s	30mW	[14]
Cr/Ni Si_3N_4	Hot thread	N_2 gas	2cm/s	0-1.6 m/s		[15]
Pt	Hot thread	Air		7-40 m/s		[16]
Ge/Si_3N_4/SiO_x	Calorimetric	Air	1cm/s	0-5 m/s	0.25-5.8 mW	[17]

In thermo-resistive sensors (the most common types of fluid flow sensors), as stated above, a metal element is heated by Joule effect to inject current, and the evolution of its temperature is monitored by measuring its resistance. As can be seen in the table above, said sensors require energy consumption in the order of 10-50 mW, depending on the characteristics of the sensor, to achieve detections having a resolution lower than 1 cm/s.

Several other flux sensors can be find in the literature ([18], [19]) using thermoelectric elements to sense temperature differences between areas of the chip with different thermal masses, all of them also needing to use a heater.

Thermal flow sensors typically require to heat the central membrane and operate either measuring the power required to maintain a temperature difference (calorimetric) or injecting a constant power in the membrane and measuring the establish temperature gradient.

For example, in one of the most recent flow sensor device presented by Buchner et al. [20], they use as thermopile a 300nm p-doped polysilicon as one thermopile material and WTi (90% W/10% Ti) with a thickness of 200 nm as the second thermopile material. The polycrystalline structure of both layers limits the carriers mobility and therefore a considerable thickness should be maintained to restrain the impedance. In terms of thermal contact, using thick thermoelectric films the resulting system presents a high heat capacity and a large thermal link.

Reference [1] discloses a micropower thermoelectric generator, energetically non-autonomous, and that is focused in the design of a thermoelectric device only for power generator purposes, i.e. the thermoelectric elements must have a low electrical resistivity, and a high electrical mobility and conductivity. The thermoelectric elements of the device there disclosed also have a high thermal conductivity (of about 60 W m^{-1} K^{-1}), and although it is suggested that said thermal conductivity could be reduced if the thickness of the Si membrane

was reduced, it is also stated that it would cause an increase of the internal electrical resistance, which is clearly a limiting factor for power generation where the load should ideally have the same resistance as the internal resistance of the chip, as clearly stated in reference [1] where when referring to such an undesired increase of the internal electrical resistance, the requirement of the use of complex signal conditioning steps to power output devices is also stated. The above mentioned suggestion is inferred from open circuit measurements performed in a thermoelectric characterization stage of the generator disclosed in Reference [1]. In Reference [1], said open circuit measurements are not performed at all (not even suggested) to characterize or design a fluid flow sensor but only a micropower thermoelectric generator.

Therefore, reference [1] teaches away from using or modifying the device there disclosed for providing a fluid flow sensor.

On the other hand, regarding the use of SOI (Silicon On insulator) substrates, up to the knowledge of the present inventors only few examples of flow sensors use SOI substrates, but none as thermoelectric sensor. In most of them, the SOI substrates are used to fabricate microelectromechanical structures with the capability to measure the gas velocity (and therefore the flux) through the deformation induced by momentum transfer of the gas [21].

To sum up, all the fluid flow sensors of the state of the art, including those comprising a thermoelectric device, require, for their operation, the inclusion of a heater to heat the fluid to be sensed, and are therefore energetically non-autonomous, while offering a low resolution.

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5   Description of the invention

It is necessary to provide an alternative to the state of the art which covers the gaps found therein, by providing a fluid flow sensor which does not require the inclusion of a heater, neither an electrical heater nor any other kind of heater, and which clearly improves the detection resolution offered by the fluid flow sensors of the state of the art.

10   To that end, the present invention relates, in a first aspect, to a fluid flow sensor comprising a thermoelectric device, which, in contrast to the known devices, comprises, in a characteristic manner:

- a first member having a surface to be exposed to a fluid flow, wherein said first member is configured and arranged to change its temperature, in time and space, by

15   convection from said fluid flow or a variation thereof, along a temperature range; wherein said first member has a calorific capacity, at room temperature, below 1500 nJ/K, preferably below 700 nJ/K, and is composed of a thermally conductive material in thin film form having a thickness between 10 and 80 nm;

- a second member submitted to a temperature which is different to the temperatures

20   included in said temperature range, and substantially thermally isolated (i.e. with a very low thermal conductance. i.e. 10^{-6}-10^{-9} W/K) from said first member; wherein said second member has a calorific capacity at least two orders of magnitude higher than the one of the first member, more preferably three orders of magnitude higher, and more preferably between three and five orders of magnitude higher; and

25   - at least one n-doped thermoelectric element and one p-doped thermoelectric element connected electrically in series between two output electrodes and thermally in parallel between said first and second members, and having a thermal conductivity below 5 W m^{-1} K^{-1}, and preferably around or below 2 W m^{-1} K^{-1}, such that a differential in the temperatures between said first and second members causes the generation of an electrical signal at said

30   output electrodes, by the Seebeck effect, without applying any energy power to the fluid flow sensor, so that the fluid flow sensor is energetically autonomous, said electrical signal being representative of said temperatures differential and therefore also being representative of said fluid flow, or of said variation thereof, to which said surface of the first member is to be exposed.

It must be stated that the meaning of the terms "thermally in parallel" is that currently

35   accepted in the scientific field, i.e. with a similar meaning as with resistances in electricity. See, for example "Thermoelectric System in Different Thermal and Electrical Configurations: Its

Impact in the Figure of Merit", by Alexander Vargas-Almeida et. Al., Instituto Politécnico Nacional, SEPI ESIME-CUL, Entropy 2013, 15(6), 2162-2180.

The temperature variation between first member and second member is also produced both in time and in space. In time, because the time constant (time it takes to reach the temperature of the fluid) of first and second members are remarkably different, for example 20-50 ms for first member and tens of seconds for second member. This produces an instantaneous temperature difference that produces a voltage output. In space, because first and second members are spatially separated.

By means of the above mentioned thermal connection of the n-doped and p-doped thermoelectric elements, they have therefore one end (or one end of each thermoelectric element segment when they are formed by a plurality of segments electrically connected in series but thermally connected in parallel) thermally connected (i.e. in thermal contact) to the first member and thus submitted to the temperature of the first member, and another end (or another end of each thermoelectric element segment when they are formed by a plurality of segments electrically connected in series but thermally connected in parallel) thermally connected (i.e. in thermal contact) to the second member and thus submitted to the temperature of the second member.

No input electrodes are provided in the sensor of the present invention, as no electrical current is needed to be applied to the thermoelectric elements, which thus operate only by the Seebeck effect, not by the Peltier effect (in contrast to the sensor of US6443003B1).

None heater is included in the sensor of the first aspect of the invention, neither electrical nor of any other type, because, as indicated above, the fluid flow sensor of the first aspect of the invention is energetically autonomous, thanks to the particular arrangement, characteristics and properties of the different elements thereof (calorific capacity, thermal conductivity, etc.), which have been duly indicated above.

The above mentioned substantial thermal isolation, i.e. very low thermal conductance, is required to ensure that a sufficient temperature increase or decrease is produced from small fluid flow variations, so that the sensor generates a sufficient voltage for providing the detection of said small fluid flow variations.

Preferably, the fluid flow sensor of the first aspect of the invention is a gas flow sensor.

For a preferred embodiment, the above mentioned first member has a calorific capacity, at room temperature, below 1500 nJ/K, preferably below 700 nJ/K. This reduced calorific capacity ensures a reduce time constant, thus allowing to perform real-time or near real-time measurements.

For an embodiment, the second member has a calorific capacity at least two orders of magnitude higher than the one of the first member, more preferably three orders of magnitude

higher, and more preferably between three and five orders of magnitude higher. This high difference in the calorific capacities of the first member and the second member causes significant variations in temperature to external perturbations, as the first member will take a much less time (generally, only a few ms) than the second member to reach a steady-state temperature.

All of the above will cause a quasi-instantaneous temperature variation between the thermoelectric joints, i.e. between the first and the second members, which will result in the creation of a potential difference between them, which can be measured after an amplification stage.

According to an embodiment, the first member is composed of any thermally conductive material in thin film form having a thickness between 10 and 80 nm.

For an implementation of said embodiment, said thermally conductive material is Si-based, Silicon Nitride or Silicon Oxide.

Regarding the thermoelectric elements, they have, for an embodiment, a thermal conductivity below 5 W m^{-1} K^{-1}, and preferably around or below 2 W m^{-1} K^{-1}.

Preferably, the thermoelectric elements are semiconductor layers having a thickness between 10 nm and 50 nm, and a doping level below 10^{18} cm^{-3} to maximize the Seebeck coefficient to achieve maximum voltage generation to a given temperature variation. The sensor of the present invention, when connected to an ultra-low power electronic system, external or integrated into the same chip into which the sensor is built, is able to detect variations of less than 1 mK at room temperature.

Said semiconductor layers are generally made of a monocrystalline and/or polycrystalline Si-based or Si compatible material, such as alloys of SiGe, Mg-, Ni-, MgSiSn, MnSiSn, MgMn- silicides or of any other Si-based material.

A novelty of the present invention is the use, for some embodiments, of polycrystalline materials as thermoelectric element, and the possibility of a controlled doping by ion implantation or 'in-situ' during the growth of the ultrathin layers.

According to an embodiment, both the thin film and at least a portion of each of the thermoelectric semiconductor layers are suspended from the second member.

Generally, the second member is made of Silicon.

For an embodiment, the second member forms a non-planar frame defining a central opening over which the thin film and said at least a portion of each of the thermoelectric semiconductor layers are suspended.

Preferably, the fluid flow sensor of the first aspect of the invention is CMOS compatible.

The extremely low thermal mass per unit area of membrane light mass paved by the use of monocrystalline thin films in the sensor of the first aspect of the present invention,

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according to some embodiments, provides the intended results of allowing to detect low flows or flow variations without needing to use a heater, and thus providing a fluid flow sensor which is energetically autonomous. The use of SOI to define the monocrystalline legs of the thermopiles, maintaining an appropriate carrier mobility, permits to drastically reduce the thermal link of the central membrane while keeping a moderate electrical impedance. The reduced thermal link is the base to escape from the necessity to heat the central membrane that the rest of the sensors present in the literature require.

The design of the fluid flow sensor of the first aspect of the invention is based on ultrathin membrane structures or suspended structures, simultaneously maximizing the contact area with the gas and the thermal insulation.

Another critical aspect of the fluid flow sensor is that when working in open circuit, the impedance of the pn junctions is not a critical issue for the sensor operation, and therefore materials, doping levels and ultrathin thicknesses have been chosen in order to optimize the sensitivity of the thermoelectric device for generating temperature differences to small variations of an external variable, in this case of a fluid flow, generally a gas flow.

A second aspect of the invention relates to a method for manufacturing the fluid flow sensor of the first aspect, comprising performing a CMOS MEMS surface micromachining step for fabricating, over the above mentioned second member, the above mentioned first member and thermoelectric elements.

A third aspect of the invention concerns to a fluid flow detection device, comprising:

- at least one sensor according to the first aspect of the invention, and

- an electronic system electrically connected to the above mentioned two output electrodes to receive electrical signals generated by the thermoelectric elements, said electronic system being adapted to condition and process said received electrical signals and provide an output signal based on the result of said processing.

For an embodiment of the fluid flow detection device of the third aspect of the present invention, said electronic system comprises memory means storing calibration data relating temperature variations with fluid flow variations, the electronic system being adapted to calculate said output signal, which is related to an absolute or a relative fluid flow measurement, based on a comparison with said calibration data of data related to temperature variations calculated from the received electrical signals through the Seebeck coefficient of the fluid flow sensor.

For a preferred embodiment of the fluid flow detection device of the third aspect of the present invention, the device further comprises a support to which the air flow sensor is attached, wherein said support comprises coupling means for its removable coupling to a user's nose or mouth so that the surface of the first member to be exposed to a fluid flow is

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arranged to be exposed to user's breath, wherein the device is configured and arranged to detect apnea and hypopnea.

For a preferred embodiment, the electronic system of the fluid flow detection device of the second aspect of the present invention is adapted to perform a monitoring of fluid flow variations in real time or near-real time.

Several uses of the fluid flow detection device of the second aspect of the invention are provided by the fourth and the fifth aspects of the present invention, including a use for detecting apnea and hypopnea and a use for detecting gas leaks.

For the use for detecting apnea and hypopnea, the flow sensor is placed near the mouth and/or nose of a user to detect its breath exhalation flow, and the electronic system of the detection device is adapted to generate an alarm signal when no breath flow is detected during a predetermined time.

Brief description of the drawings

The previous and other advantages and features will be more fully understood from the following detailed description of embodiments, with reference to the attached drawings, which must be considered in an illustrative and non-limiting manner, in which:

Figure 1(a) is a plan view of the fluid flow sensor of the present invention, for an embodiment associated to a cantilever-like suspended structure;

Figure 1(b) is a cross-sectional perspective view of a portion of the device of Figure 1(a) included in the illustrated dashed line area;

Figure 2 is a plan view of the fluid flow sensor of the present invention, for another embodiment for which a central membrane is suspended over a central opening defined in a silicon massive frame. Dotted region denotes the region liberated by using surface micromachining;

Figure 3 is a plan view of the fluid flow sensor of the present invention, for a further embodiment, similar to the one of Figure 2 but where all the thermoelectric elements are electrically connected in series and extend up to the centre of the central membrane. Dotted region denotes the region liberated by using surface micromachining;

Figure 4a shows the fluid flow sensor of the present invention for the same arrangement as in Figure 2, which has been modelled according to the finite element (FE) method for obtaining temperature values along time for the three indicated locations;

Figure 4b is a graph showing the transient heating behaviour of the device of the first aspect of the invention at the three different locations indicated in Figure 4b, obtained by using FE modelling;

Figure 5a is a graph showing the temperature gradient produced by different flow

velocities for the sensor of the present invention according to the arrangement of Figure 4a (shown in a decreased view within the graph), which has been obtained also by FE modelling;

Figure 5b shows steady state temperature maps representing the average temperatures at different locations of the central membrane of the device, for the arrangement of Figure 4a, as a function of the air flux velocity, for different flow velocity scenarios, wherein the map has been obtained also by FE modelling;

Figure 6 is a graph showing a steady-state measurement of the sensing voltage generated by a gas flowing over the sensor of the present invention in the lower gas flow range (0 to 3 mm/s), also for the arrangement of Figure 4a and by using FE modelling;

Figure 7 is a graph showing the time dependent thermoelectric voltage variation upon a flux variation over the surface of the sensor, also for the arrangement of Figure 4a and by using FE modelling; and

Figure 8 is a graph showing the time dependent breath air flow variation, corresponding to a respective voltage variation, of the fluid flow detection device of the second aspect of the present invention for an embodiment for which the device is configured and arranged to detect apnea and hypopnea.

Detailed description of several embodiments

Figure 1 shows a first embodiment of the fluid flow sensor of the present invention, comprising a thermoelectric device which comprises:

- a first member or central membrane 1, having a surface to be exposed to a fluid flow, wherein the central membrane 1 is configured and arranged to change its temperature by convection from said fluid flow or a variation thereof, along a temperature range;

- a second member 2, in the form of a rectangular frame (for the illustrated embodiment), which is submitted to a temperature which is different to the temperatures included in the above mentioned temperature range, and substantially thermally isolated from the central membrane 1; and

- one n-doped thermoelectric layer Ne and one p-doped thermoelectric layer Pe (in the form of very thin elongated strips) connected electrically in series between two electrodes E1, E2 and thermally in parallel between the central membrane 1 and the frame 2.

The frame 2, usually a silicon massive frame, has a through opening A over which, for the embodiment of Figure 1, the membrane 1 and most of the length of each of the thermoelectric semiconductor layers Ne, Pe are suspended from the frame 2, according to a cantilevered-like suspended arrangement.

The frame 2 is locate over a substrate, generally made of silicon, and the through opening A1 extends into a recessed central portion of the substrate liberated by surface

micromachining. In fact, the whole device is manufactured, preferably, by surface micromachining.

The embodiment illustrated in Figure 1 is a simple version of the sensor of the invention, which can be modified by adding a plurality of further n-doped Ne and p-doped Pe thermoelectric layers connected electrically in series between the two output electrodes E1, E2 and thermally in parallel between the central membrane 1 and the frame 2.

Another embodiment of the sensor of the invention is shown in Figure 2, in this case for an arrangement for which the central membrane 1 is suspended over the opening A, but not in a cantilevered-like structure but attached to inner edges of the frame 2 by four corresponding groups of n-doped Ne and p-doped Pe thermoelectric layers (in the form of very thin and narrow elongated strips), where the thermoelectric layers Ne, Pe of each group are connected electrically in series between two corresponding output electrodes E1, E2; E3, E4; E5, E6 and E7, E8, through respective electrically conductive pads t, and thermally in parallel between the central membrane 1 and the frame 2.

In this case, each group of thermoelectric layers is electrically independent from the others, providing thus four respective independent measurements, one per pair of output electrodes E1, E2; E3, E4; E5, E6 and E7, E8. However, if said electrodes are connected such that all the n-doped Ne and p-doped Pe thermoelectric layers are serially connected, a single measurement is provided between the end electrodes of said electrical connection, for example between output electrodes E1 and E2, using all the thermoelectric layers.

A further embodiment of the sensor of the invention is shown in Figure 3, where in this case, as mentioned above, all the n-doped Ne and p-doped Pe thermoelectric layers are serially connected between two end output electrodes E1, E2, through several intermediate electrodes Ei.

The embodiment of Figure 3 further differs from the one of Figure 2 in that the pads t which connect the n-doped Ne and p-doped Pe thermoelectric layers to the central membrane 1 are closer to the centre of the membrane 1, being thus the n-doped Ne and p-doped Pe thermoelectric layers longer than the ones of Figure 2.

For all the above embodiments, the number thermoelectric layers is just illustrative and can be adapted to the sensing requirements of the specific application.

The arrangement of Figure 3 maximizes the thermoelectric signature with respect to the one of Figure 2, as will be stated below based on Figure 4.

The present inventors have modelled, by using FE modelling, the thermal behaviour of the sensor of the present invention for the arrangement of Figure 2, when it is used to measure a breath flux of air (humid air at 310K). The central membrane 1, originally at ambient temperature (293.16K), experiences a fast heating due to the convection through hot air of

exhalation. Final temperature difference depends on the air velocity.

Figure 4b shows the temperature evolution evaluated at the different locations indicated in Figure 4a, i.e. at the border of the silicon massive frame 2 (T3), at the sensing part of the membrane 1 (T2), and at the centre of the membrane 1 (T1), while a transient heating behaviour is promoted by a heat flux of humid air at human body temperature.

From the results obtained and shown in the graph of Figure 4b, it can be stated that at the centre of the membrane 1 (T1) the temperature variation is higher than at the sensing part of the membrane 1 (T2). From this results, the arrangement of Figure 2 has been improved and modified to arrive at the optimized arrangement of Figure 3, which places the sensing part much closer to the centre of the membrane 1. I.e., due to the parabolic resulting profile of Figure 4b said optimized design of the sensor (shown in Figure 3) has been provided, which accounts for the maximum temperature gradient.

As shown in figure 4b if the flux velocity is maintained along time, the system reaches a thermal steady-state, and then each temperature gradient can be associated to a given air flux velocity.

The FEM experiment is ran for a series of different air flux velocities (1mm/s to 1m/s), obtaining different temperature gradients as shown in Figure 5 (a) between the regions identified in Figure 4a, i.e. for T1-T3 and for T2-T3. Figure 5 (b) shows the temperature maps in the free standing membrane 1 as a function of the air flux velocity for some selected steady states of the experiment. The sensor massive frame 2 is fixed at 293,16K and gas temperature is the human temperature of about 310K.

The high sensitivity of the sensor of the present invention can be appreciated in the graphs of Figures 6 and 7.

Particularly, the graph illustrated by Figure 6 shows a steady-state measurement of the sensing voltage generated by a gas flowing over the sensor of the present invention in the lower gas flow range (0 to 3 mm/s), also for the arrangement of Figure 4a and by using FE modelling.

The graph of Figure 7 shows the time dependent thermoelectric voltage variation upon a flux variation over the surface of the sensor, also for the arrangement of Figure 4a and by using FE modelling.

The graph of Figure 8 shows the output signal provided by the fluid detection device of the second aspect of the invention when applied to detect apnea and hypopnea during sleep, for an experimental embodiment using the arrangement of Figure 4a, by attaching a support (not shown) on which the air flow sensor is attached to the nose or mouth of a user such that the surface of the first member 1 is arranged to be exposed to user's breath (generally in parallel to the breath stream, although other arrangements of said surface non-parallel to the

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breath stream are also embraced by the present invention).

As shown in Figure 8, thanks to the high sensitivity of the fluid flow sensor included in the fluid flow detector, in contrast to the conventional apnea resistance-based sensors, the one of the present invention allows providing such accurate measurements and following such quick air flow changes that even hypopnea episodes (i.e. breath flow variations around 30% of the normal night breathing) can be detected, therefore constituting a new platform to monitor obstructive sleep apnea (OSA).

A person skilled in the art could introduce changes and modifications in the embodiments described without departing from the scope of the invention as it is defined in the attached claims.

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Claims

1.- A fluid flow sensor, comprising a thermoelectric device, **characterised in that** said thermoelectric device comprises:

- a first member (1) having a surface to be exposed to a fluid flow, wherein said first member (1) is configured and arranged to change its temperature, in time and in space, by convection from said fluid flow or a variation thereof, along a temperature range; wherein said first member (1) has a calorific capacity, at room temperature, below 1500 nJ/K, preferably below 700 nJ/K, and is composed of a thermally conductive material in thin film form having a thickness between 10 and 80 nm;

- a second member (2) submitted to a temperature which is different to the temperatures included in said temperature range, and substantially thermally isolated from said first member (1); wherein said second member (2) has a calorific capacity at least two orders of magnitude higher than the one of the first member (1), more preferably three orders of magnitude higher, and more preferably between three and five orders of magnitude higher; and

- at least one n-doped thermoelectric element (Ne) and one p-doped thermoelectric element (Pe) connected electrically in series between two output electrodes (E1, E2) and thermally in parallel between said first (1) and second (2) members, and having a thermal conductivity below 5 W m^{-1} K^{-1}, and preferably around or below 2 W m^{-1} K^{-1}, such that a differential in the temperatures between said first (1) and second (2) members causes the generation of an electrical signal at said output electrodes (E1, E2), by the Seebeck effect, without applying any energy power to the fluid flow sensor, so that the fluid flow sensor is energetically autonomous, said electrical signal being representative of said temperatures differential and therefore also being representative of said fluid flow, or of said variation thereof, to which said surface of the first member (1) is to be exposed.

2.- A fluid flow sensor according to claim 1, wherein said thermoelectric elements (Ne, Pe) are semiconductor layers having a thickness between 10 nm and 50 nm, and a doping level below 10^{18} cm^{-3} to maximize the Seebeck coefficient.

3.- A fluid flow sensor according to claim 2, wherein the semiconductor layers are made of a monocrystalline and/or polycrystalline Si-based material.

4.- A fluid flow sensor according to claim 3, wherein the semiconductor layers are made of SiGe, Mg-, Ni-, MgSiSn, MnSiSn, MgMn- silicides, or their alloys.

5.- A fluid flow sensor according to claim 2, 3 or 4, wherein said thin film (1) and at least a portion of each of the thermoelectric semiconductor layers (Ne, Pe) are suspended from the second member (2).

6.- A fluid flow sensor according to claim 5, wherein said second member (2) is made of Silicon.

7.- A fluid flow sensor according claim 5 or 6, wherein the second member (2) forms a non-planar frame defining a central opening (A) over which said thin film (1) and said at least a portion of each of the thermoelectric semiconductor layers (Ne, Pe) are suspended.

8.- A fluid flow sensor according to any of the previous claims, which is CMOS compatible.

9.- A fluid flow detection device, comprising:

- at least one sensor according to any of the previous claims, and

- an electronic system electrically connected to said two output electrodes (E1, E2) to receive electrical signals generated by the thermoelectric elements (Ne, Pe), said electronic system being adapted to condition and process said received electrical signals and provide an output signal based on the result of said processing.

10.- A fluid flow detection device according to claim 9, wherein said electronic system comprises memory means storing calibration data relating temperature variations with fluid flow variations, the electronic system being adapted to calculate said output signal, which is related to an absolute or a relative fluid flow measurement, based on a comparison with said calibration data of data related to temperature variations calculated from the received electrical signals through the Seebeck coefficient of the fluid flow sensor.

11.- The fluid flow detection device of any of claims 9 and 10, further comprising a support to which the air flow sensor is attached, wherein said support comprises coupling means for its removable coupling to a user's nose or mouth so that the surface of the first member (1) to be exposed to a fluid flow is arranged to be exposed to user's breath, wherein the device is configured and arranged to detect apnea and hypopnea.

12.- The fluid flow detection device according to any of claims 9 to 11, wherein said electronic system is adapted to perform a monitoring of fluid flow variations in real time or near-real time.

13.- A method for manufacturing the fluid flow sensor of any of claims 1 to 8, comprising performing a CMOS MEMS surface micromachining step for fabricating, over said second member (2), said first member (1) and said thermoelectric elements (Ne, Pe).
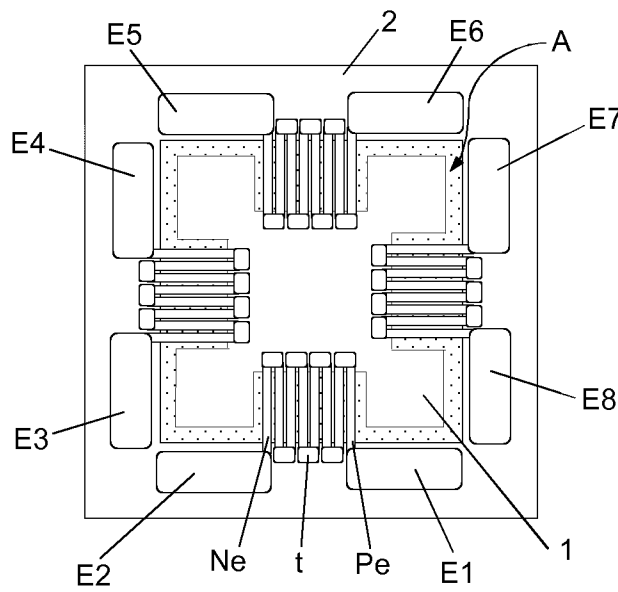
14.- Use of a fluid flow detection device according to claim 9, for detecting apnea and hypopnea.

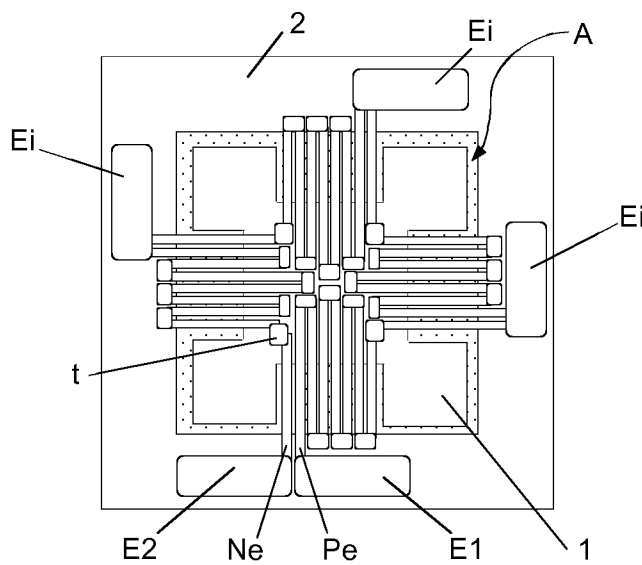15.- Use of a fluid flow detection device according to claim 9, for detecting gas leaks.
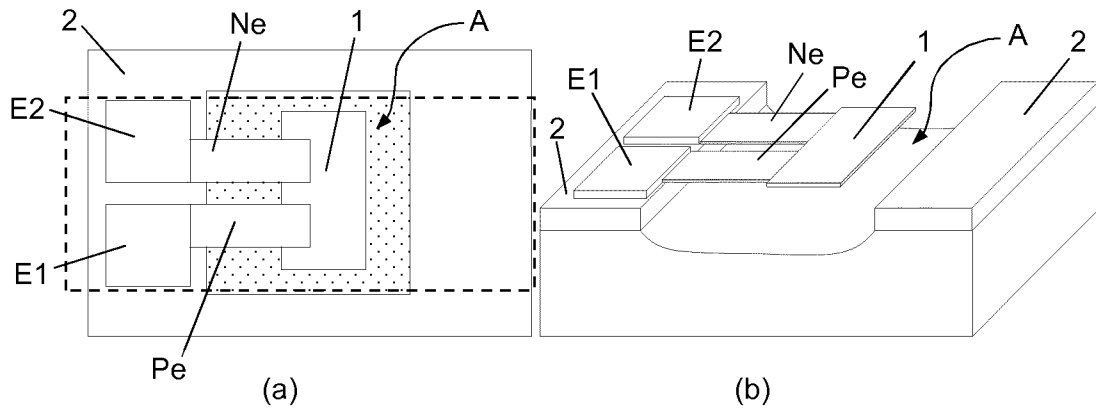
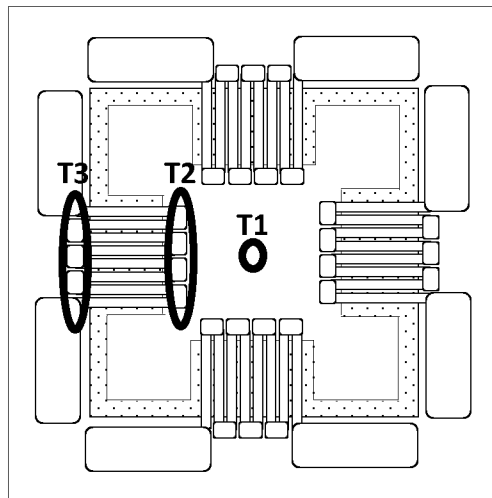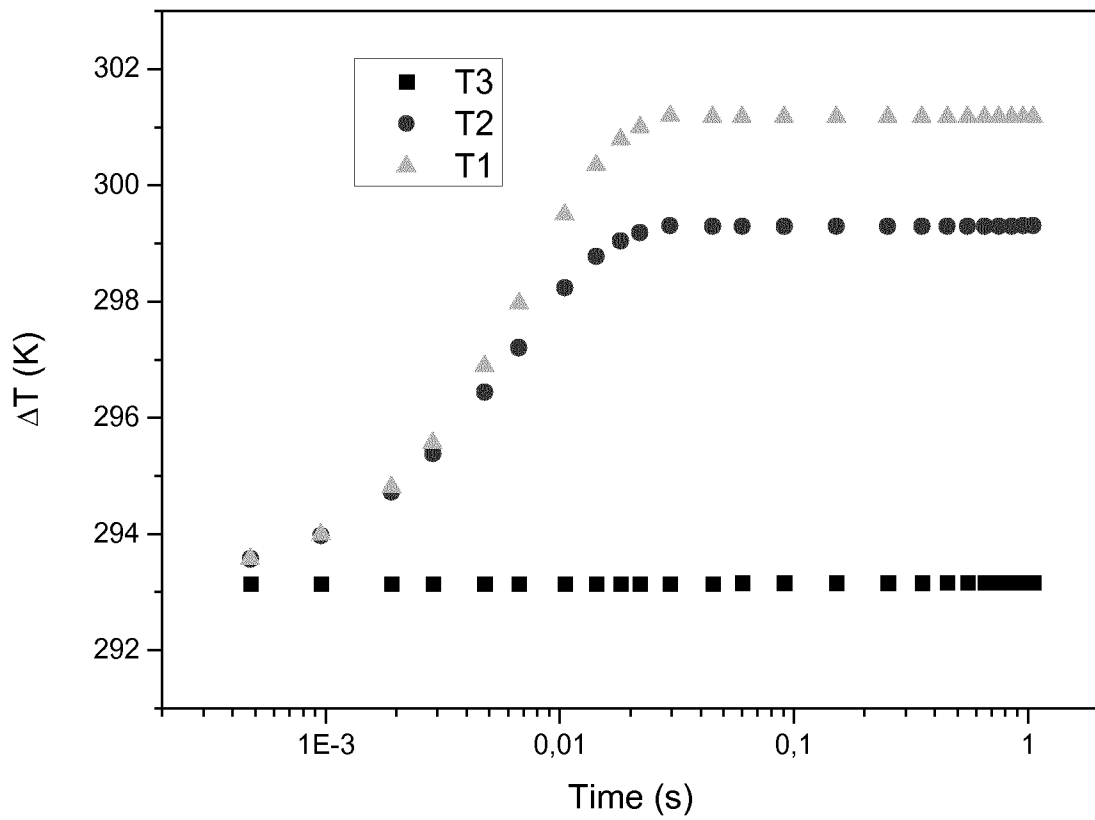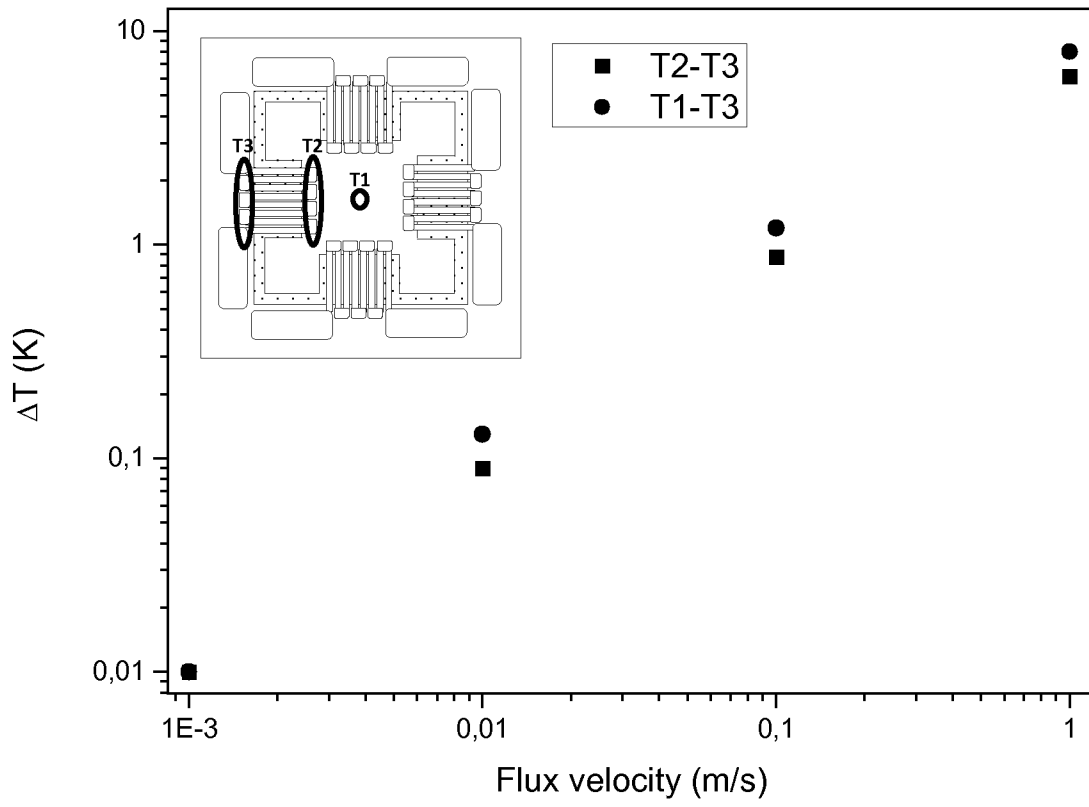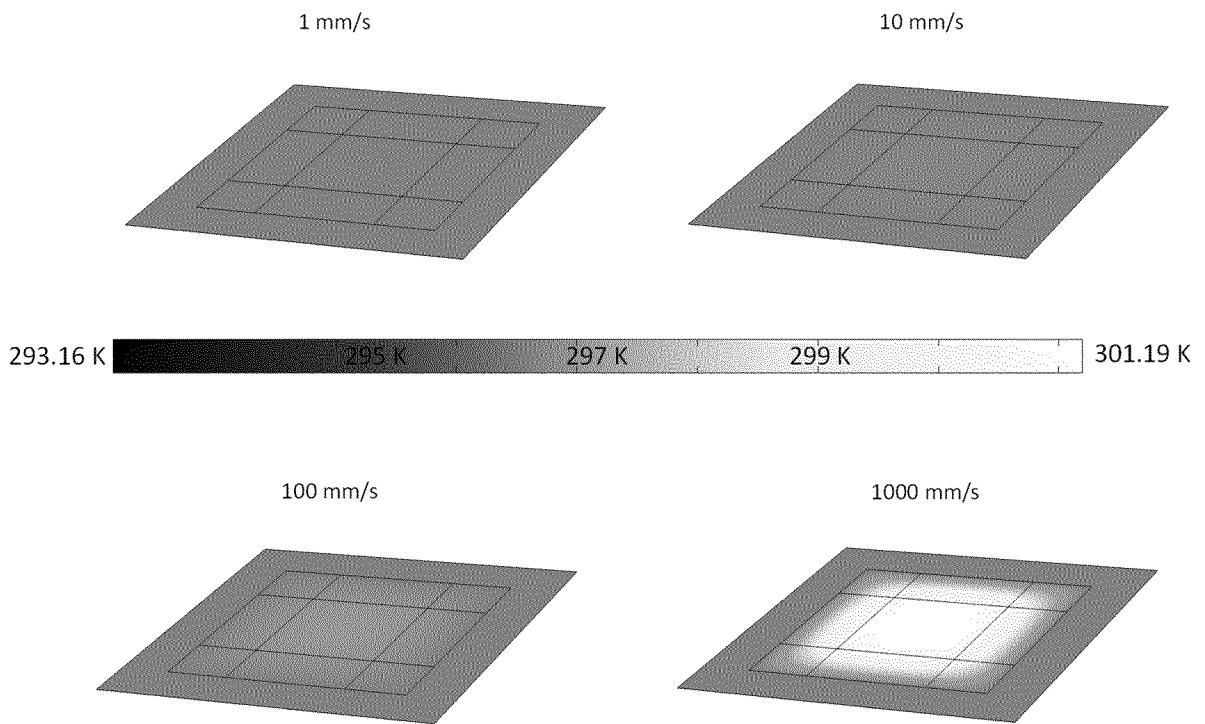**Fig. 1**

Fig. 2

Fig. 3

Fig. 4a

Fig. 4b

Fig. 5a

1 mm/s   10 mm/s

293.16 K   295 K   297 K   299 K   301.19 K

100 mm/s   1000 mm/s

Fig. 5b
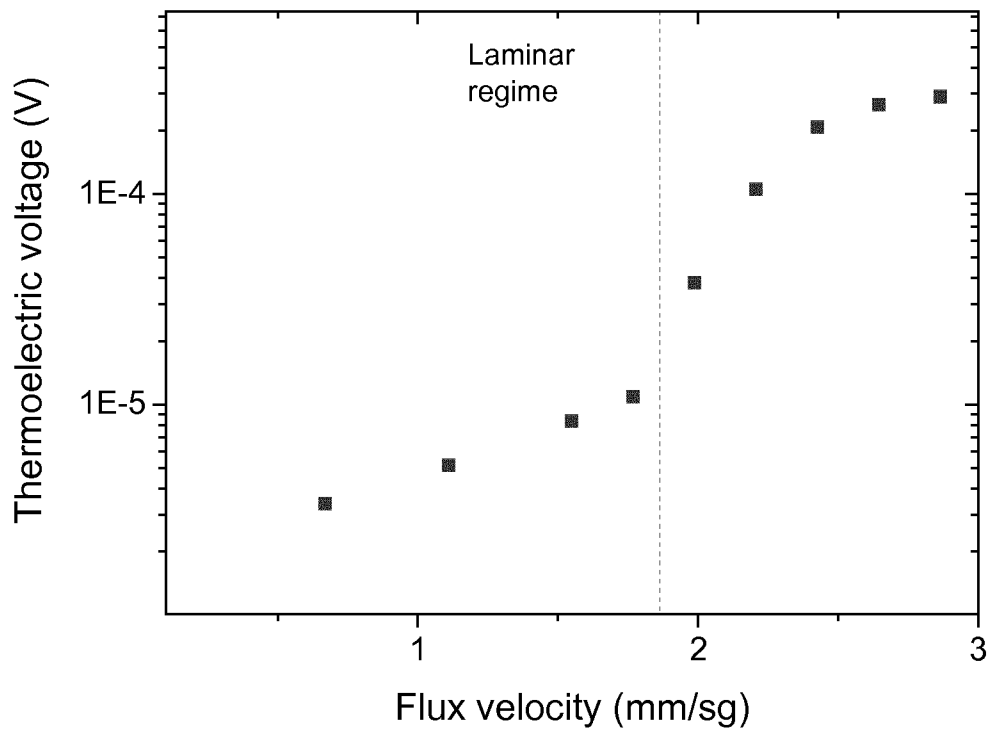
Fig. 6
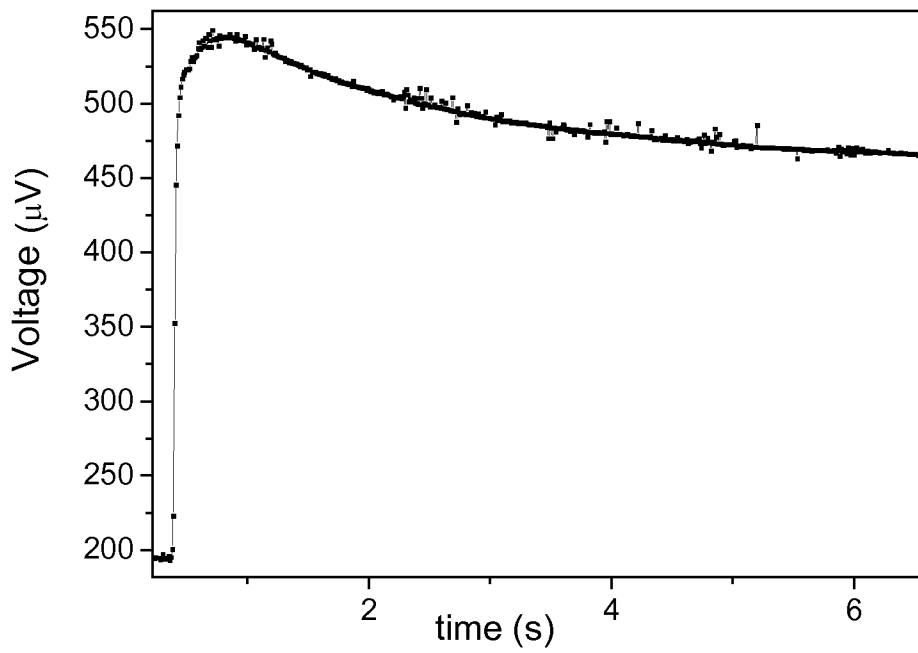
Fig. 7

Fig. 8

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01K7/02   G01K13/02   G01F1/684   G01F1/688
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01K   G01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/078753 A1 (MEHREGANY MEHRAN [US] ET AL) 1 April 2010 (2010-04-01) abstract figures 1-5 paragraphs [0033] - [0045] paragraphs [0064] - [0093] ----- -/--	1-15

[X] Further documents are listed in the continuation of Box C.   [X] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
16 May 2017	24/05/2017

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

C(Continuation).   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	A. P. Perez-Marin ET AL: "Micropower thermoelectric generator from thin Si membranes", Nano Eneregy, 30 December 2013 (2013-12-30), pages 73-80, XP055304968, DOI: http://dx.doi.org/10.1016/j.nanoen.2013.12.007 Retrieved from the Internet: URL:http://ac.els-cdn.com/S2211285513001973/1-s2.0-S2211285513001973-main.pdf?_tid=5443ee22-80d5-11e6-a66e-00000aacb35f&acdnat=1474556621_4b0d9455abb82d28ed4499d252337d88 [retrieved on 2016-09-22] abstract figures 1, 2, 3, 4a, 4b page 75, right-hand column - page 78, right-hand column -----	1-15
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			DK 2751531	T3	18-01-2016
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