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(54) Title: MEMS MICROPHONE DEVICE AND ELECTRONICS APPARATUS

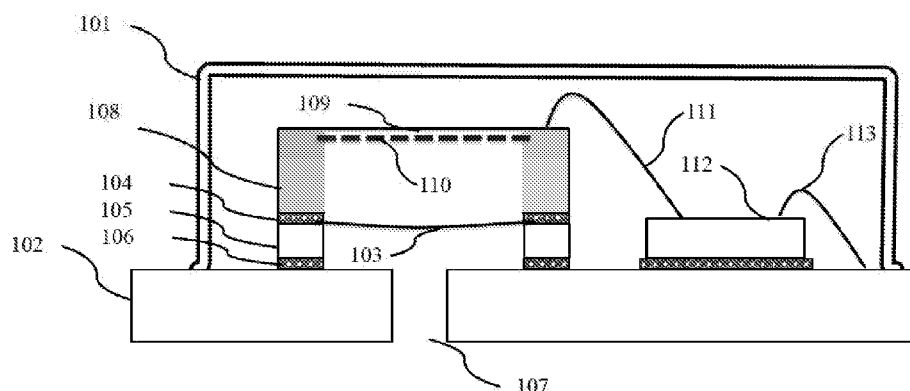


FIG. 1

(57) Abstract: The present invention discloses a MEMS microphone device and an electronics apparatus. The MEMS microphone device comprises: a substrate; a MEMS microphone element placed on the substrate; a cover encapsulating the MEMS microphone element together with the substrate; and an acoustic port for the MEMS microphone element, wherein a compliant membrane is provided to seal the acoustic port, and the membrane has a mechanical stiffness lower than that of the diaphragm of the MEMS microphone element.



MEMS MICROPHONE DEVICE AND ELECTRONICS APPARATUS

FIELD OF THE INVENTION

The present invention relates to the field of MEMS microphone, and more specifically,
5 to a MEMS microphone device and an electronics apparatus.

BACKGROUND OF THE INVENTION

A Micro-Electro-Mechanical System, or MEMS, is a technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of micro-fabrication. A MEMS microphone
10 element is a microphone made by the MEMS technology. A MEMS microphone element can be first manufactured and then it is encapsulated into a MEMS microphone device on a substrate. The MEMS microphone device can further be assembled into an electronics apparatus such as a mobile phone, a pad, a laptop and so on.

Because of the small size of the MEMS microphone element, the environment of
15 manufacturing will influence the performance of an electronics apparatus which has a MEMS microphone device.

Generally, a MEMS microphone device has an acoustic port to let the sound pressure come into the MEMS microphone element and interact with its diaphragm. Dusts or particles can enter the acoustic port and thus the performance of the MEMS microphone device may be
20 degraded.

In the prior art, some technicians use a filter with mesh holes at the acoustic port to protect the MEMS microphone element. In order to relieve the influence of the dust or particle, technicians try to reduce the size of the mesh holes of the acoustic port or to use a rigid plate filter for the acoustic port. However, this will degrade the performance of the MEMS microphone
25 device, such Signal-Noise-Ratio (SNR).

In addition, due to fabrication process constraints, it is just feasible to fabricate very large mesh holes currently, for example, the sizes of which are about 100 μ m or more. By using

such a filter, killer particles for a MEMS microphone element of 2~5 μ m, such as PM 2.5 particles, cannot be blocked out efficiently.

Furthermore, the dimension of such a filter will influence the performance of the MEMS microphone device. For example, with the increasing of the thickness of the filter, the SNR may decrease. For example, with the size reduction of the mesh holes of the filter, the SNR may also decrease. For example, with the thickness increase of the filter, the frequency response of the MEMS microphone device may be deviated.

US patent No. 9,438,972 B2 discloses a Silicon based MEMS microphone, a system and a package with the same, which is hereby incorporated herein by reference.

US Patent No. 8,447,057 B2 discloses packages and methods for packaging MEMS microphone devices, which is hereby incorporated herein by reference.

X. Yang, et al, Micromachined membrane particle filters, p. 137-142, Micro Electro Mechanical Systems Conference, Feb. 1998 discloses several particle membrane filters with circular, hexagonal and rectangular through holes, which is hereby incorporated herein by reference.

Therefore, there is a demand in the art that a new solution for a MEMS microphone device shall be proposed to address at least one of the problems in the prior art.

SUMMARY OF THE INVENTION

One object of this invention is to provide a new technical solution for a MEMS microphone device.

According to a first aspect of the present invention, there is provided a MEMS microphone device, comprising: a substrate; a MEMS microphone element placed on the substrate; a cover encapsulating the MEMS microphone element together with the substrate; and an acoustic port for the MEMS microphone element, wherein a compliant membrane is provided to seal the acoustic port, and the membrane has a mechanical stiffness lower than that of the diaphragm of the MEMS microphone element.

Optionally or alternatively, the acoustic port is provided in the substrate or the cover.

Optionally or alternatively, an ASIC for the MEMS microphone element is also sealed by the substrate, the cover and the compliant membrane.

Optionally or alternatively, the compliant membrane is made of at least one of the followings: silicon, polysilicon, silicon nitride, silicon oxide, polymer, plastics, elastomer, metal,
5 alloy, metallic glass, or dielectrics, which have a higher elongation or ultimate strength than that of silicon materials.

Optionally or alternatively, the compliant membrane has a Young's modulus of less than 100GPa.

Optionally or alternatively, the compliant membrane is flat or is pre-buckled in rest
10 position.

Optionally or alternatively, the compliant membrane is air permeable.

Optionally or alternatively, the compliant membrane is water-proofing.

Optionally or alternatively, the substrate is a printed circuitry board or flexible PCB.

According to a second aspect of the present invention, there is provided an electronics
15 apparatus comprising a MEMS microphone device according to the present invention.

According to an embodiment of this invention, the present invention can reduce the influence of the outside particles on the MEME microphone element.

Further features of the present invention and advantages thereof will become apparent from the following detailed description of exemplary embodiments according to the present
20 invention with reference to the attached drawings.

BRIEF DISCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and, together with the description thereof, serve to explain the principles of the invention.

25 Fig. 1 is a schematic diagram of a MEMS microphone device according to a first embodiment of the present invention.

Fig. 2 is a schematic diagram of a MEMS microphone device according to a second embodiment of the present invention.

Fig. 3 is a schematic diagram of a MEMS microphone device according to a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Various exemplary embodiments of the present invention will now be described in detail with reference to the drawings. It should be noted that the relative arrangement of the components and steps, the numerical expressions, and numerical values set forth in these embodiments do not limit the scope of the present invention unless it is specifically stated otherwise.

The following description of at least one exemplary embodiment is merely illustrative in nature and is in no way intended to limit the invention, its application, or uses.

Techniques, methods and apparatus as known by one of ordinary skill in the relevant art may not be discussed in detail but are intended to be part of the specification where appropriate.

In all of the examples illustrated and discussed herein, any specific values should be interpreted to be illustrative only and non-limiting. Thus, other examples of the exemplary embodiments could have different values.

Notice that similar reference numerals and letters refer to similar items in the following figures, and thus once an item is defined in one figure, it is possible that it need not be further discussed for following figures.

In this invention, the inventors have proposed to use a compliant membrane at an acoustic port of a MEMS microphone device to relieve the impact of particles (or dust) on the performance of the device.

Embodiments of this invention will be described with reference to the drawings.

<First Embodiment>

Fig. 1 shows a schematic diagram of a MEMS microphone device according to a first embodiment of the present invention.

As shown in Fig. 1, the MEMS microphone device comprises a substrate 102, a MEMS microphone element 108, a cover 101 and an acoustic port 107 for the MEMS microphone

element 108. The MEMS microphone element 108 is placed on the substrate 102. The cover 101 encapsulates the MEMS microphone element 108 together with the substrate 102.

As shown in Fig. 1, a compliant membrane 103 is provided to seal the acoustic port 107. The membrane 103 has a mechanical stiffness lower than that of the diaphragm 109 of the
5 MEMS microphone element 108.

Generally, the environment of manufacturing a MEMS microphone device can be kept clean (or dust-free). However, it is difficult to maintain a clean environment during transportation to another place and assembling it into an electronics apparatus. In the prior art, dust or particles can enter the MEMS microphone element via the acoustic port and thus the performance of the
10 MEMS microphone device is degraded.

In addition, in the prior art, a filter with small holes is used to filter particle. On the one hand, it is difficult to manufacture the filter with very small holes. It may increase the cost. On the other hand, when the holes get smaller, they will cause an additional noise, which will degrade the performance such as SNR.

15 In the embodiment, a compliant membrane is used to block or filter dust or particles at the acoustic port. In this way, particles can be blocked at the acoustic port. In the later procedures of manufacture such assembly of an electronics apparatus, the environment requirement will not be so strict and thus the cost may be reduced.

Furthermore, during usage of the electronics apparatus, the MEMS microphone device
20 may maintain in a better condition because of the sealing of the compliant membrane. This will be benefit to the user. For example, the mesh holes of the above-said prior art filter may be blocked by larger particles. In this situation, the performance of the MEMS microphone device may be degraded drastically.

For example, the compliance of the membrane can be much higher than that of the
25 diaphragm of the MEMS microphone element. That is, the mechanical stiffness of the membrane 103 is much lower than that of the diaphragm 109 of the MEMS microphone element 108.

Generally, the MEMS microphone element is made of silicon, the Young's modulus of which is about 170GPa. Because the compliance of the membrane will be inversely proportional to its Young's modulus, the material of the membrane 103 can have a Young's modulus lower

than that of the diaphragm 109 in case that the membrane 103 has a similar size and thickness as of the diaphragm 109. For example, the compliant membrane 103 has a Young's modulus of less than 100GPa; preferably less than 50GPa; and further preferably less than 20GPa.

For example, it can be silicon, polysilicon, silicon nitride, silicon oxide, polymer,
5 plastics, elastomer, metal, alloy, metallic glass, or dielectrics, which have a higher elongation or ultimate strength than that of silicon materials.

Preferably, a thin film of polymer/plastics with Young's modulus of 100kPa~20GPa can be used.

Preferably, the compliant membrane 103 is flat in rest position. Alternatively, the
10 compliant membrane 103 is pre-buckled in rest position. For example, the compliant membrane 103 has a low initial in-plane tensile stress through compressive.

In an example, the compliant membrane 103 is air permeable so that the ambient pressures in two sides of the membrane can be balanced. In this way, the influence by the ambient changes will be reduced or relieved.

15 For example, the compliant membrane can be water-proofing. In this way, a water-proofing electronics apparatus can be made and/or the likelihood that the microphone device of an electronics apparatus is damaged by water or humidity is lowered.

In this embodiment, the compliant membrane must not have a ventilation hole and thus water-proofing and/or dust-proofing can be achieved.

20 As shown in Fig. 1, the MEMS microphone device also includes a ASIC 112 for the MEMS microphone element 108. The ASIC is also sealed by the substrate 102, the cover 101 and the compliant membrane 103.

In this embodiment, the acoustic port 107 is provided in the substrate 102, for example. The substrate 102 can be a printed circuitry board or flexible PCB.

25 As shown in Fig.1, the compliant membrane 103 is attached to a support 105. The support 105 is sandwiched between the substrate 102 and the MEMS microphone element 108 via die attachment 104, 106 such as glue. The MEMS microphone element 108 has a flexible diaphragm 109 and a rigid backplate 110, for example. The MEMS microphone element 108 is

connected to the ASIC 112 via wire 111 and the ASIC is connected to the substrate 102 via wire 113.

<Second Embodiment>

Fig. 2 shows a schematic diagram of a MEMS microphone device according to a second
5 embodiment of the present invention. The MEMS microphone device in Fig. 2 is similar with that in Fig. 1. The repetitive parts in Fig. 2 are marked with the same reference numbers and thus the description thereof are omitted.

In the embodiment of Fig. 2, a filter 114 of the prior art can be provided at the acoustic
port 107 together with the compliant membrane 103. In this way, the performance of the device
10 may further be improved.

<Third Embodiment>

It would be understood by a person skilled in the art, although Figs. 1 and 2 shows the
acoustic port 107 is provided in the substrate 102, it can be also provided in the cover 101.

Fig. 3 shows a schematic diagram of a MEMS microphone device according to a third
15 embodiment of the present invention, in which a acoustic port 207 is provided in the cover 201.

As shown in Fig. 3, the cover 201 is mounted on the substrate 202. The MEMS
microphone element 208 with a diaphragm 209 is placed on the substrate 202 and is encapsulated
by the cover 201 and the substrate 202.

A acoustic port 207 is provided in the cover 201. A compliant membrane 203 is
20 provided to seal the acoustic port 207. The membrane 203 has a mechanical stiffness lower than
that of the diaphragm 209 of the MEMS microphone element 208.

The description for repetitive parts in Fig. 3 are omitted.

In the embodiments of the present invention, the prior art filter with mesh holes can be
omitted. However, it can also be conceived that the prior art filter with mesh holes and the
25 compliant membrane can be combined in a MEMS microphone device. This may provide a
further effect. For example, the prior art filter with mesh holes is provided at the acoustic port and
the compliant membrane is provided between the filter and the MEMS microphone element.

<Fourth Embodiment>

The MEMS microphone device according to any embodiment of this invention can be used in an electronics apparatus such as a mobile phone, a pad, a laptop and headset and so on.

Although some specific embodiments of the present invention have been demonstrated in detail with examples, it should be understood by a person skilled in the art
5 that the above examples are only intended to be illustrative but not to limit the scope of the present invention.

CLAIMS

What is claimed is:

1. A MEMS microphone device, comprising:

a substrate;

5 a MEMS microphone element placed on the substrate;

a cover encapsulating the MEMS microphone element together with the substrate; and

an acoustic port for the MEMS microphone element,

wherein a compliant membrane is provided to seal the acoustic port, and the membrane has a mechanical stiffness lower than that of the diaphragm of the MEMS microphone element.

10 2. The MEMS microphone device according to claim 1, wherein the acoustic port is provided in the substrate or the cover.

3. The MEMS microphone device according to claim 1 or 2, wherein an ASIC for the
15 MEMS microphone element is also sealed by the substrate, the cover and the compliant membrane.

4. The MEMS microphone device according to any of claim 1-3, wherein the compliant
20 membrane is made of at least one of the followings: silicon, polysilicon, silicon nitride, silicon oxide, polymer, plastics, elastomer, metal, alloy, metallic glass, or dielectrics, which have a higher elongation or ultimate strength than that of silicon materials.

5. The MEMS microphone device according to any of claim 1-4, wherein the compliant
membrane has a Young's modulus of less than 100GPa.

25 6. The MEMS microphone device according to any of claim 1-5, wherein the compliant membrane is flat or is pre-buckled in rest position.

7. The MEMS microphone device according to any of claim 1-6, wherein the compliant membrane is air permeable.

5 8. The MEMS microphone device according to any of claim 1-7, wherein the compliant membrane is water-proofing.

9. The MEMS microphone device according to any of claim 1-8, wherein the substrate is a printed circuitry board or flexible PCB.

10 10. An electronics apparatus comprising a MEMS microphone device according to any of claim 1-9.

1/2

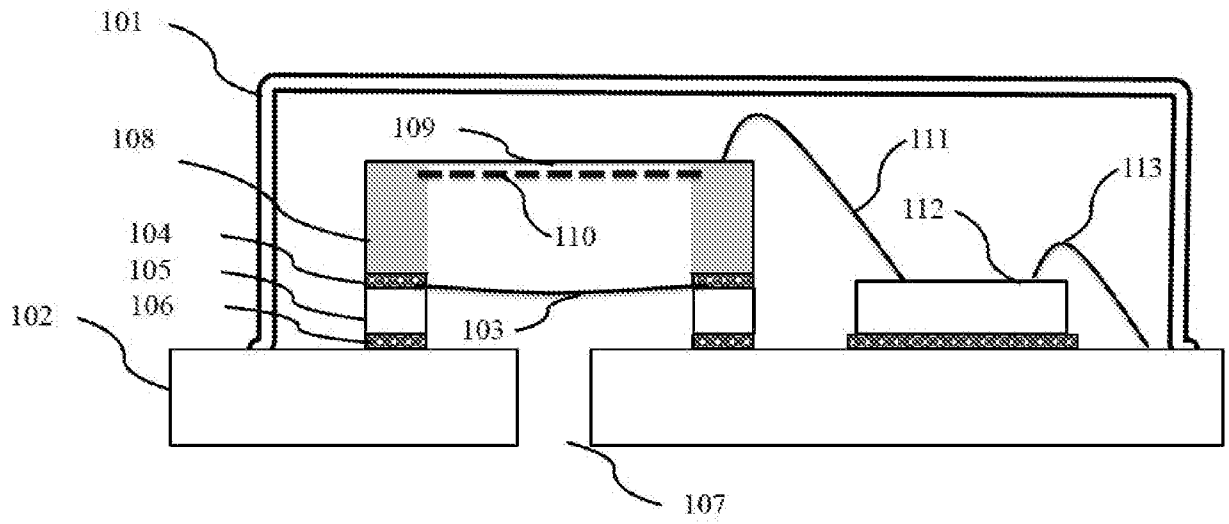


FIG. 1

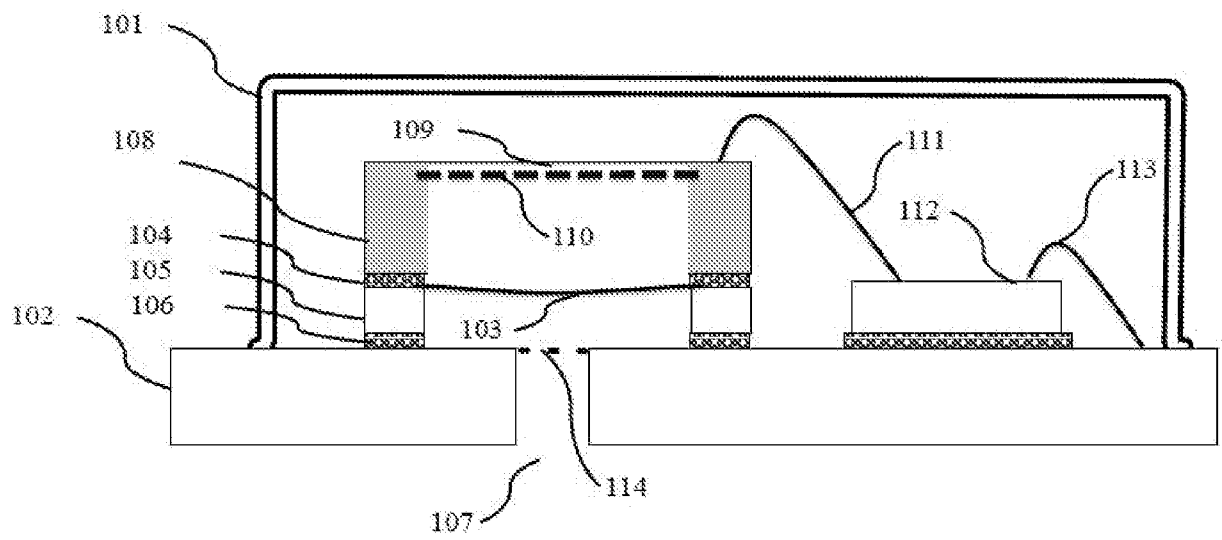


FIG. 2

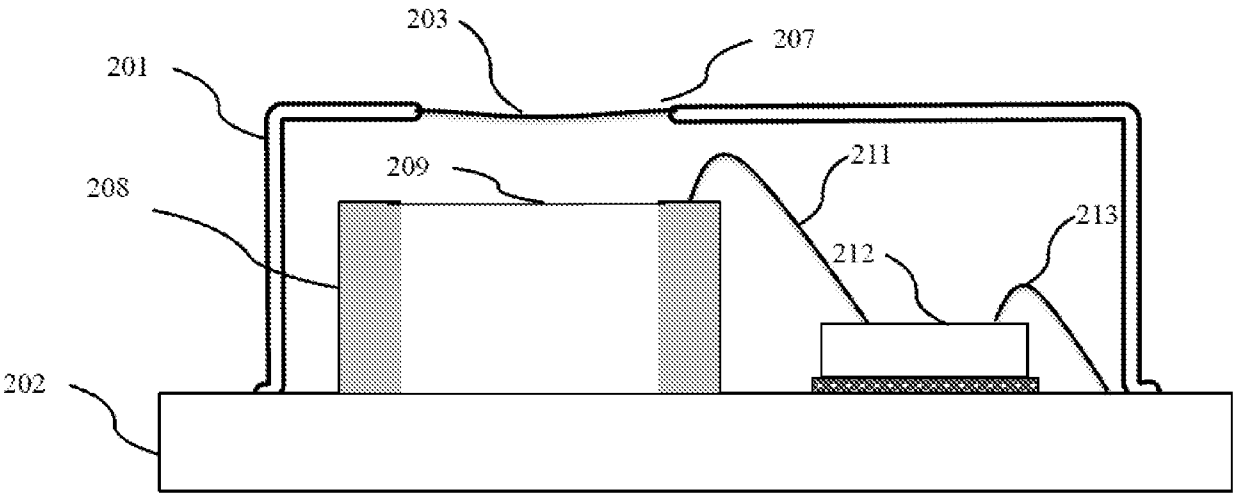


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2016/101473

A. CLASSIFICATION OF SUBJECT MATTER

H04R 19/04(2006.01)i

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)

H04R

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)

CNABS;CNTXT;CNKI;VEN;USTXT;EPTXT;WOTXT;JPTXT:anti, prevent+, particle, microphone, dustproof, dust, membrane, compliant, mems

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 204733381 U (ACUTI MICROSYSTEMS CO., LTD.) 28 October 2015 (2015-10-28) description, paragraphs [0027]-[0036], figures 2 and 5	1-10
X	CN 204334948 U (UNIV NORTHEAST PETROLEUM) 13 May 2015 (2015-05-13) description, paragraphs [0007]-[0011], figure 1	1-10
A	CN 104760924 A (IEA ELECTRO ACOUSTIC CO., LTD.) 08 July 2015 (2015-07-08) the whole document	1-10
A	JP 08307990 A (FOSTER ELECTRIC CO., LTD.) 22 November 1996 (1996-11-22) the whole document	1-10
A	US 8447057 B2 (ANALOG DEVICES INC ET AL.) 21 May 2013 (2013-05-21) the whole document	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

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06 July 2017

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2016/101473

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	204733381	U	28 October 2015	None			
CN	204334948	U	13 May 2015	None			
CN	104760924	A	08 July 2015	None			
JP	08307990	A	22 November 1996	JP	3611371	B2	19 January 2005
				JP	H08307990	A	22 November 1996
US	8447057	B2	21 May 2013	US	2012237073	A1	20 September 2012