



(11) **EP 3 007 522 B9**

(12) **CORRECTED EUROPEAN PATENT SPECIFICATION**

(15) Correction information:
Corrected version no 1 (W1 B1)
Corrections, see
Drawings
Drawing(s) deleted

(51) Int Cl.:
H05G 2/00 ^(2006.01) **G21B 1/23** ^(2006.01)

(48) Corrigendum issued on:
03.05.2017 Bulletin 2017/18

(45) Date of publication and mention
of the grant of the patent:
22.03.2017 Bulletin 2017/12

(21) Application number: **15197269.2**

(22) Date of filing: **30.05.2007**

(54) **SYSTEM FOR PRODUCING ELECTROMAGNETIC RADIATION**

SYSTEM ZUR ERZEUGUNG VON ELEKTROMAGNETISCHER STRAHLUNG

SYSTÈME POUR PRODUIRE DU RAYONNEMENT ÉLECTROMAGNÉTIQUE

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE
SI SK TR**

(30) Priority: **30.05.2006 US 809453 P**
29.05.2007 US 754928

(43) Date of publication of application:
13.04.2016 Bulletin 2016/15

(62) Document number(s) of the earlier application(s) in
accordance with Art. 76 EPC:
07853488.0 / 2 033 197

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- **ABU-ELFADL T M ET AL: "Linearized Field Theory of a Smith-Purcell Traveling Wave Tube", IEEE TRANSACTIONS ON PLASMA SCIENCE, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 32, no. 3, 1 June 2004 (2004-06-01), pages 1015-1027, XP011115883, ISSN: 0093-3813, DOI: 10.1109/TPS.2004.827612**
- **CARLSTEN B E ET AL: "TECHNOLOGY DEVELOPMENT FOR A MM-WAVE SHEET-BEAM TRAVELING-WAVE TUBE", IEEE TRANSACTIONS ON PLASMA SCIENCE, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 33, no. 1, 1 February 2005 (2005-02-01), pages 85-93, XP002485668, ISSN: 0093-3813, DOI: 10.1109/TPS.2004.841172**

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Description**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application is a divisional application of U.S. Patent Application No. 11/754,928, filed May 29, 2007, for Method and System for Controlled Fusion Reactions, now U.S. Patent No. 9,036,765 issued on May 19, 2015, claiming priority to U.S. Provisional Patent Application No. 60/809,453 entitled "Method & Apparatus for Controlled Fusion Reactions" filed May 30, 2006.

FIELD OF THE INVENTION

[0002] The present invention relates to a system for producing electromagnetic radiation incorporating a drift tube modified to enable output of higher frequencies from a high power RF source incorporating the drift tube.

BACKGROUND OF THE INVENTION

[0003] Prior art Magnetically Insulated Linear Oscillators (MILOs) are high power RF sources, which have typical outputs between 300 MHz and 3.5 GHz. For various applications, it would be desirable to provide a high power RF source that can achieve even higher frequencies. A known drift-tube RF generator is disclosed in CA 2 392 852 A1.

SUMMARY OF THE INVENTION

[0004] The present invention relates to a system for producing electromagnetic radiation incorporating a drift tube which includes a hollow cylindrical conductive element having a grating surface formed on its inner surface, with the ends of the cylindrical conductive element being radiused to minimize electrical stress buildup.

[0005] The interaction between a relativistic electron beam from an electron source passing through the inner space of the hollow element and the internal grating produces RF radiation by the Smith-Purcell Effect. The spacing, face angle and shape of the grating, and the energy of the electron beam, are determinants of the frequency of the RF radiation.

[0006] The foregoing drift tube, having a grating on the inner surface of a cylindrical drift tube, can be used advantageously to increase the frequency output of such devices as a Magnetically Insulated Linear Oscillator (MILO) beyond the aforementioned range of 300 MHz to 3.5 GHz mentioned for a MILO.

DESCRIPTION OF THE DRAWINGS

[0007]

FIG. 1 is a sectional view along the length of a combined SXE-MILO driver.

FIG. 2 is a partly sectional view along the length of the MILO RF head of **FIG. 1**.

FIG. 3A is a sectional view along the length of a Drift Tube used in the MILO RF head of **FIG. 1**, and **FIG. 3B** is an enlarged view of the circled region in **FIG. 3A** entitled "**FIG. 3B**".

DETAILED DESCRIPTION OF THE INVENTION

[0008] A list of drawing reference numbers, their associated parts and preferred materials for the parts can be found near the end of this description of the preferred embodiments.

RF Energy Drivers

[0009] **FIG. 1** shows a cross-section of a Stimulated X-ray Emitter (SXE) combined with a Magnetically Insulated Linear Oscillator (MILO) at the output (right-shown) end of the SXE. The Stimulated X-ray Emitters were first described by the inventor of this current invention in U.S. Patent No. 4,723,263. The MILO is another well known, high power RF source, similar to the Vircator. The significant difference is that it can produce much higher frequencies than the Vircator. Structurally, the major difference is the incorporation of a drift tube 122 of **FIG. 3A** and use of a Traveling Wave Electron Gun (TWEG) instead of the planar cathode 90 and grid 92 of the Vircatron. There is a resonant cavity 98 and its dimensions in conjunction with the dimensions of the drift tube 122 (**FIG. 3A**) determine the output range. Conventional MILO devices have outputs between 300 MHz and 3.5 GHz. The inventor of the present invention has experimentally verified that by

placing a grating surface on the inner face of the drift tube 122 (**FIG. 3A**), as shown in **FIG. 3B**, it is possible to generate RF at much higher frequencies than those available from a smooth bore drift tube 122. The source of this RF is due to the Smith-Purcell effect which describes the interaction of a relativistic electron beam with a grating surface 123. Outputs in the THz range are possible. The grating surface can be formed by many methods. The spacing, face angle and grating geometry all are determinants in the frequency achieved (**FIG. 3B**). It has been determined that the preferred embodiment of the drift tube grating is an internal thread as shown in **FIGS. 3A** and **3B**. By altering the thread parameters, the output frequency is changed. The ends of the Drift Tube 125 are radiused to minimize formation of undesirable electric field perturbations inside the Resonant Cavity 98.

[0010] The balance of the SXE-MILO driver is the same as the SXE-Vircator. In fact, the RF heads-Vircator and MILO- can be interchanged. As in the case of the SXE-Vircator, the TWEG of the MILO has a hollow center through which the x-rays pass. The electron output from the TWEG is compressed by the drift tube 122 and oscillates in the resonant cavity 98.

Drawing Reference Numbers

[0011] The following list of drawing reference numbers has three column. The first column includes drawing reference numbers; the second column specifies the parts associated with the reference numbers; and the third column mentions a preferred material (if applicable) for the parts.

REFERENCE NUMBER LIST	PREFERRED MATERIAL
64 Anode	Refractory Metal; Hi-Z
66 Grid	Refractory Metal
68 Cathode	Graphite (Preferred Embodiment)
70 Coaxial Capacitor	Dielectric/Metal Layers
72 Cathode Feedthrough	Ceramic & Metal
74 Grid Feedthrough	Ceramic & Metal
78 Radiation Shield	Lead
94 Anode Mesh	Refractory Metal
96 Output Window	RF Transparent Low-Z Ceramic
98 Resonant Circular Cavity	Stainless Steel or Copper
100 Mounting Flange	Stainless Steel
102 Cathode Feedthrough	Ceramic & Metal
106 Grid Feedthrough	Ceramic & Metal
110 Getter Pump	n/a
112 Getter Pump Feedthrough	Ceramic & Metal
114 MILO Cathode	Graphite
116 MILO Cathode Support	Refractory Metal
118 MILO Grid	Refractory Metal
120 MILO Grid support	Refractory Metal
122 Drift Tube	Refractory Metal
123 Grating Surface	Refractory Metal
124 Drift Tube Support	Ceramic
125 Radiused end of Drift Tube	Refractory Material
126 Internal Anode Insulator	Ceramic
142 Grid Output Terminal	Refractory Metal

[0012] The foregoing describes a drift tube where the inclusion of a grating surface on the inner surface of the tube generates higher frequencies of RF radiation.

[0013] While the invention has been described with respect to specific embodiments by way of illustration, many modifications and changes will occur to those skilled in the art. The invention is in any case defined by the appended claims

Claims

1. System for producing electromagnetic radiation with enhancement from a drift tube containing a cylindrical Smith-

Purcell structure, comprising:

- a) a magnetically insulated linear oscillator having a cylindrical resonant cavity (98) containing a traveling wave electron gun and cooperating anode (64), and further containing a drift tube (122) positioned between the traveling wave electron gun and the cooperating anode (64);
- b) the drift tube (122) being formed of a hollow cylindrical conductive element that is positioned within said resonant cavity (98) and that is electrically isolated from the traveling wave electron gun, wherein a cylindrical axis of the drift tube (122) is coaxial with a main axis of the resonant cylindrical cavity in a region between said electron gun and said anode (64);
- c) the drift tube (122) having an inner surface and a pair of ends; the hollow cylindrical conductive element being enhanced by containing a cylindrical Smith-Purcell grating surface (123) formed on the inner surface of the drift tube (122); said grating surface (123) comprising a reflection grating surface having a series of ridges spaced apart by respective grooves; said reflection grating surface extending for at least a majority of the length of the drift tube (122);
- d) the drift tube (122) being adapted so that an electron beam, from the electron gun, passes through the inner space of the drift tube and interacts with the internal Smith-Purcell grating surface (123), so as to produce RF radiation by Smith-Purcell Effect; and
- e) the drift tube (122) being further adapted so that spacing, face angle and shape of the Smith-Purcell grating surface (123), and an energy of the electron beam are determinants of the frequency of the RF radiation.

2. The system of claim 1, wherein the Smith-Purcell grating surface comprises an internal thread extending for at least a majority of length of the drift tube.
3. the system of claim 1 or 2, wherein each ridge of the reflection grating surface has a cross-section, taken along a plane passing through said cylindrical axis of the drift tube, comprising a triangle having one side parallel to said cylindrical axis.

Patentansprüche

1. System zum Herstellen elektromagnetischer Strahlung mit Verstärkung aus einer Driftröhre, die eine zylindrische Smith-Purcell-Struktur enthält, umfassend:
 - a) einen magnetisch isolierten linearen Oszillator mit einem zylindrischen Hohlraumresonator (98), der eine Wanderwellen-Elektronenkanone und eine zusammenwirkende Anode (64) enthält, und ferner eine Driftröhre (122) enthält, die zwischen der Wanderwellen-Elektronenkanone und der zusammenwirkenden Anode (64) positioniert ist;
 - b) wobei die Driftröhre (122) aus einem zylindrischen leitfähigen Hohlelement gebildet ist, das innerhalb des Hohlraumresonators (98) positioniert ist und gegenüber der Wanderwellen-Elektronenkanone elektrisch isoliert ist, wobei eine Zylinderachse der Driftröhre (122) coaxial mit einer Hauptachse des zylindrischen Hohlraumresonators in einer Region zwischen der Elektronenkanone und der Anode (64) verläuft;
 - c) wobei die Driftröhre (122) eine Innenfläche und ein Paar Enden aufweist; wobei das zylindrische leitende Hohlelement dadurch verstärkt ist, dass es eine zylindrische Smith-Purcell-Gitteroberfläche (123) enthält, die auf der Innenfläche der Driftröhre (122) gebildet ist; wobei die Gitteroberfläche (123) eine Reflexionsgitteroberfläche mit einer Reihe von Leisten umfasst, die durch jeweilige Nuten beabstandet sind; wobei sich die Reflexionsgitteroberfläche über zumindest einen Großteil der Länge der Driftröhre (122) erstreckt;
 - d) wobei die Driftröhre (122) so ausgelegt ist, dass ein Elektronenstrahl aus der Elektronenkanone den Innenraum der Driftröhre passiert und mit der internen Smith-Purcell-Gitteroberfläche (123) interagiert, um eine HF-Strahlung durch Smith-Purcell-Effekt herzustellen;
 - e) wobei die Driftröhre (122) ferner so ausgelegt ist, dass Abstand, Flankenwinkel und Form der Smith-Purcell-Gitteroberfläche (123) und eine Energie des Elektronenstrahls Determinanten der Frequenz der HF-Strahlung sind.
2. System nach Anspruch 1, wobei die Smith-Purcell-Gitteroberfläche zumindest ein Innengewinde umfasst, das sich über zumindest einen Großteil der Länge der Driftröhre erstreckt.
3. System nach Anspruch 1 oder 2, wobei jede Leiste der Reflexionsgitteroberfläche einen Querschnitt entlang einer

Ebene, die die Zylinderachse der Driftröhre passiert, aufweist, umfassend ein Dreieck mit einer Seite parallel zur Zylinderachse.

5 Revendications

1. Système de production d'un rayonnement électromagnétique avec amélioration à partir d'un tube de glissement contenant une structure de Smith-Purcell cylindrique, comprenant :

a) un oscillateur linéaire magnétiquement isolé ayant une cavité résonante cylindrique (98) contenant un pistolet à électrons à onde progressive et une anode de coopération (64), et contenant en outre un tube de glissement (122) positionné entre le pistolet à électrons à onde progressive et l'anode de coopération (64) ;

b) le tube de glissement (122) étant formé d'un élément conducteur cylindrique creux qui est positionné dans ladite cavité résonante (98) et qui est électriquement isolé du pistolet à électrons à onde progressive, un axe cylindrique du tube de glissement (122) étant coaxial avec un axe principal de la cavité résonante cylindrique dans une zone située entre ledit pistolet à électrons et ladite anode (64) ;

c) le tube de glissement (122) ayant une surface interne et une paire d'extrémités ; l'élément conducteur cylindrique creux étant amélioré en contenant une surface de diffraction cylindrique de Smith-Purcell (123) formée sur la surface interne du tube de glissement (122) ; ladite surface de diffraction (123) comprenant une surface de diffraction de réflexion ayant une série de nervures espacées par des rainures respectives ; ladite surface de diffraction de réflexion s'étendant sur au moins une majorité de la longueur du tube de glissement (122) ;

d) le tube de glissement (122) étant adapté de sorte qu'un faisceau d'électrons, issu du pistolet à électrons, passe par l'espace interne du tube de glissement et interagisse avec la surface de diffraction interne de Smith-Purcell (123), de façon à produire un rayonnement RF par effet de Smith-Purcell ;

et

e) le tube de glissement (122) étant en outre adapté de sorte que l'espacement, l'angle de face et la forme de la surface de diffraction de Smith-Purcell (123), et une énergie du faisceau d'électrons, soient des déterminants de la fréquence du rayonnement RF.

2. Système selon la revendication 1, dans lequel la surface de diffraction de Smith-Purcell comprend un filetage interne s'étendant sur au moins une majorité de la longueur du tube de glissement.

3. Système selon la revendication 1 ou 2, dans lequel chaque nervure de la surface de diffraction de réflexion possède une section transversale, prise le long d'un plan passant par ledit axe cylindrique du tube de glissement, comprenant un triangle ayant un côté parallèle audit axe cylindrique.

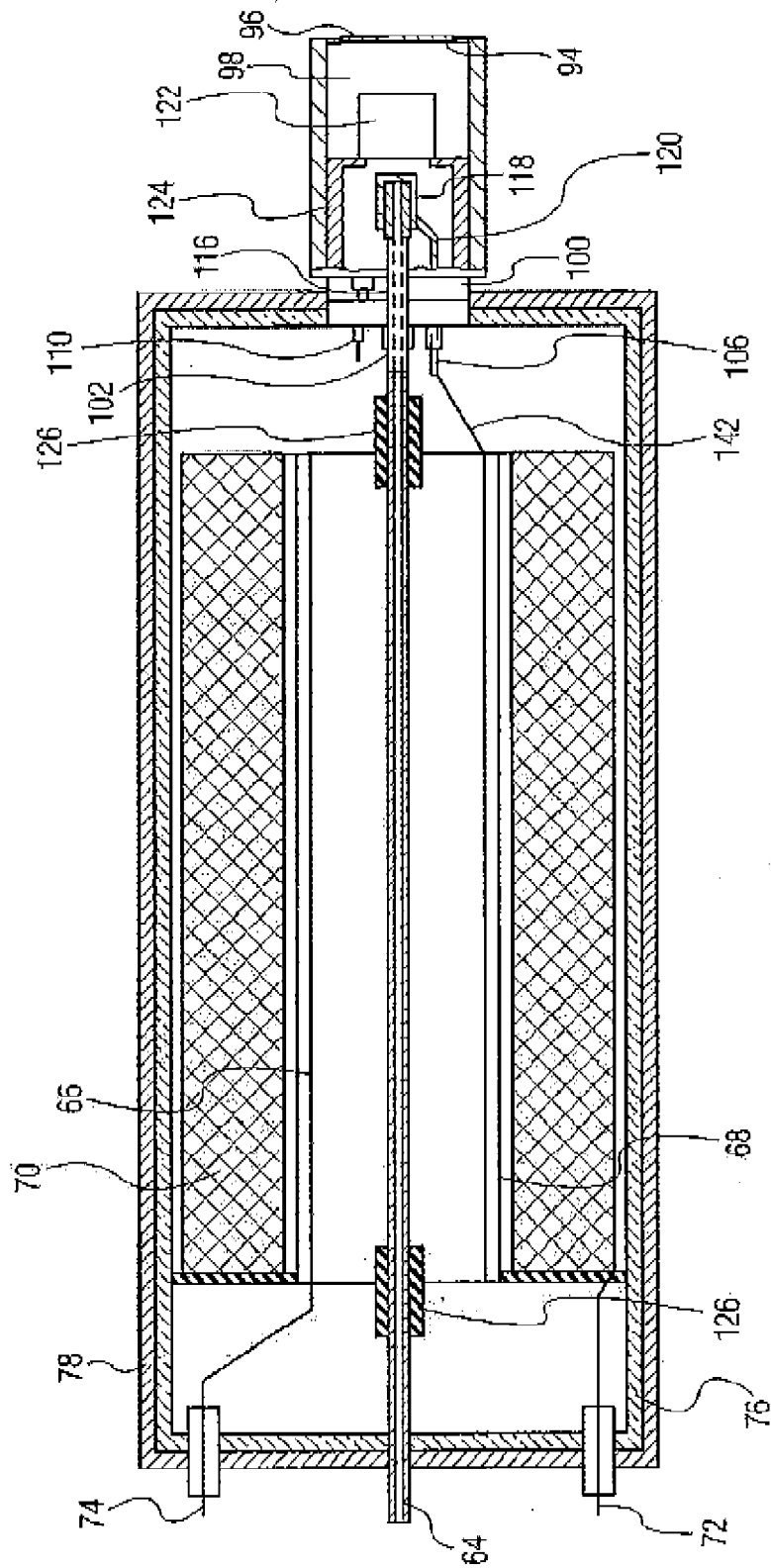
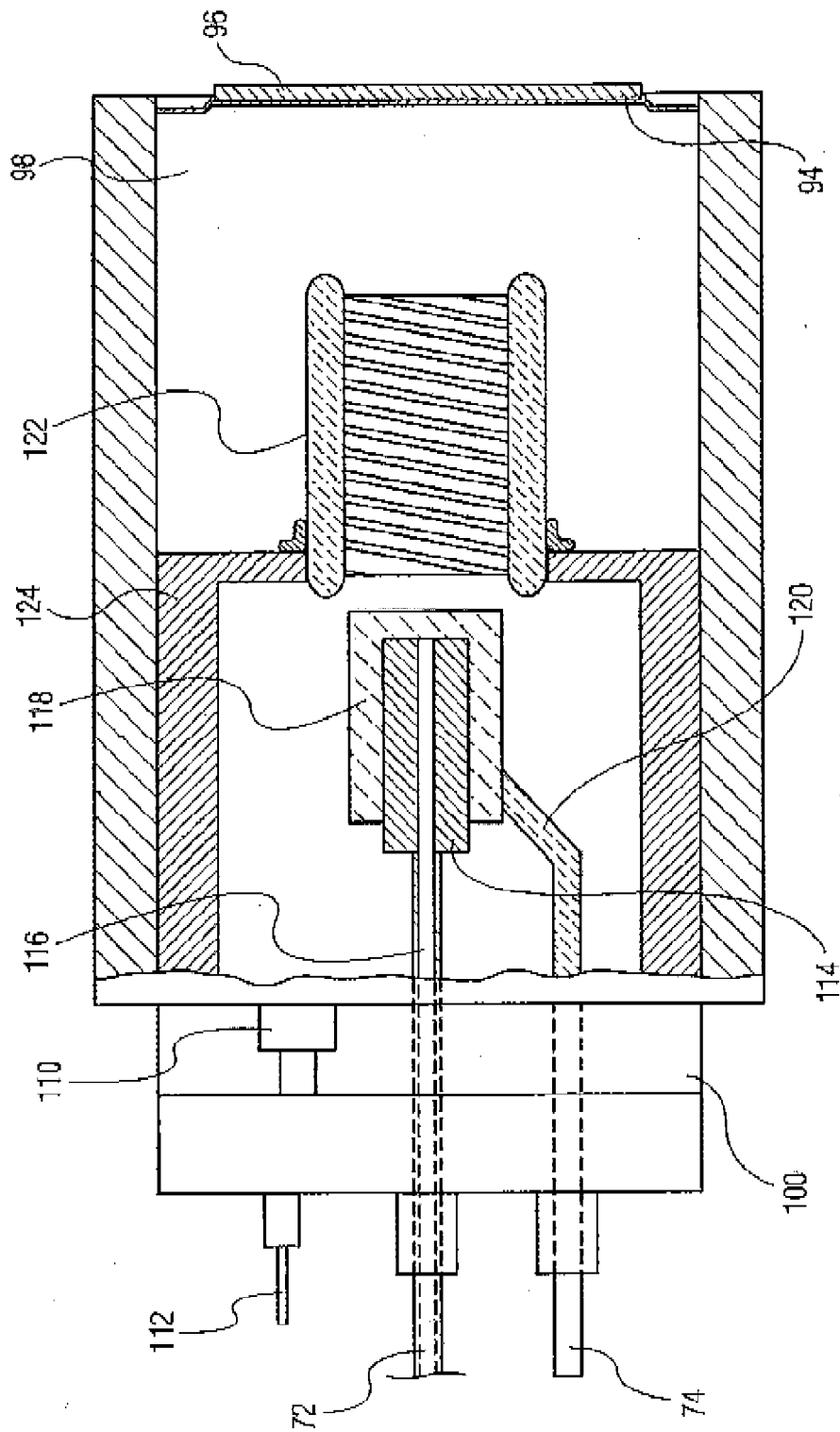


FIG. 1



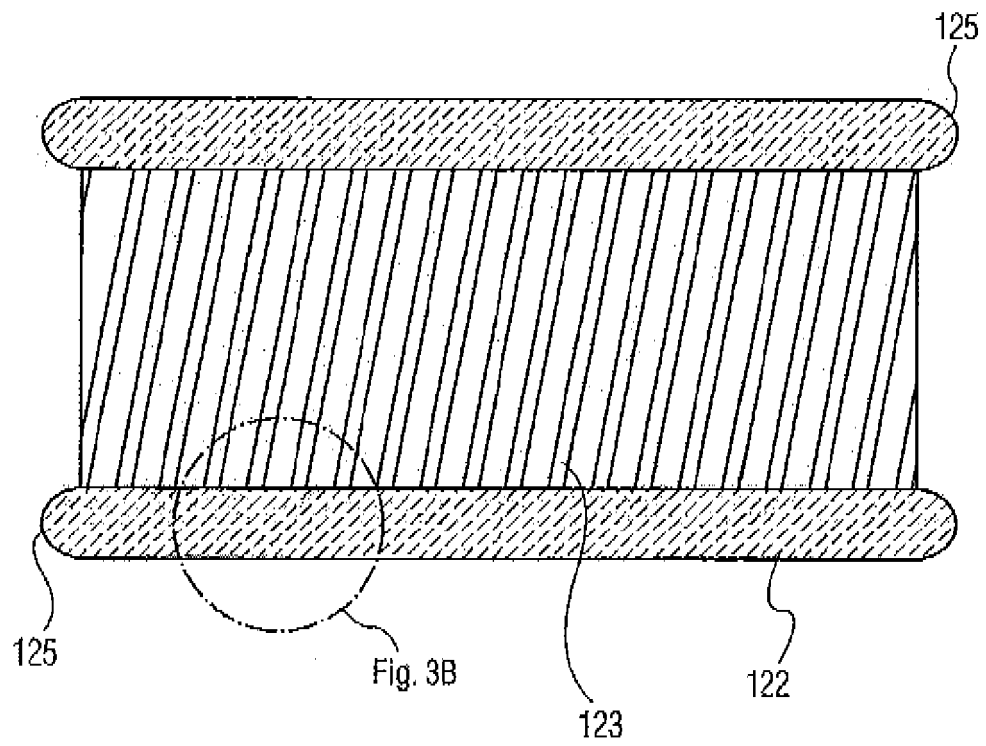


FIG. 3A

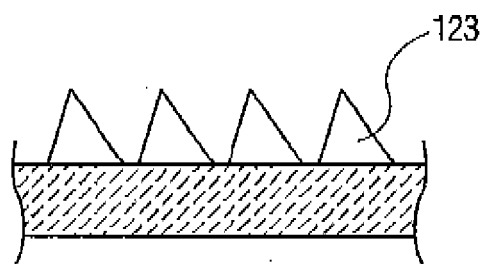


FIG. 3B

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 75492807 A [0001]
- US 9036765 B [0001]
- US 809453 P [0001]
- CA 2392852 A1 [0003]
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