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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :		(11) International Publication Number:	WO 93/03494
H01J 45/00	A1	(43) International Publication Date:	18 February 1993 (18.02.93)

(21) International Application Number: PCT/SE92/00530

(22) International Filing Date: 29 July 1992 (29.07.92)

(30) Priority data:
9102263-2 31 July 1991 (31.07.91) SE

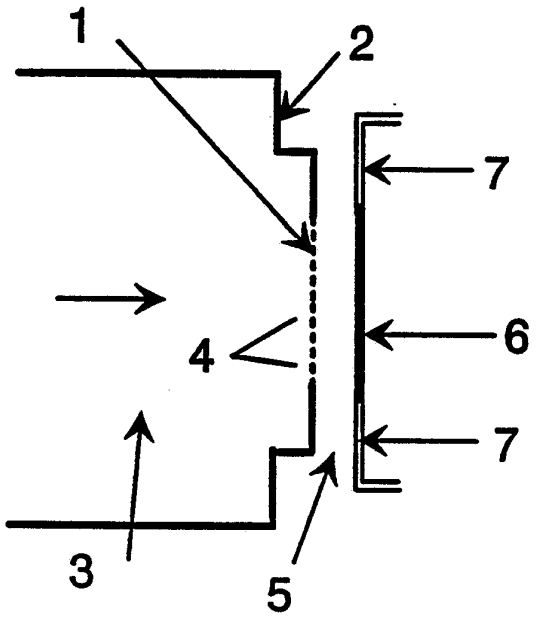
(71)(72) Applicants and Inventors: HOLMLID, Leif [SE/SE]; Anemonvägen 3, S-435 31 Mölnlycke (SE). SVENSSON, Robert [SE/SE]; Pl. 1608, S-438 00 Landvetter (SE).

(74) Agent: GÖTEBORGS PATENTBYRÅ AB; Box 5005, S-402 21 Göteborg (SE).

(81) Designated States: AU, BB, BG, BR, CA, CS, FI, HU, JP, KP, KR, LK, MG, MN, MW, NO, PL, RO, RU, SD, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IT, LU, MC, NL, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG).

Published
With international search report.

(54) Title: COLLECTOR FOR THERMIONIC ENERGY CONVERTER



(57) Abstract

Collector for thermionic energy converter of a new type with low electronic work function. A thermionic energy converter includes an emitter (6) and a collector (1) and a space (5) provided therebetween to which is supplied vapor of a thermionic material, for example cesium or other alkali metal. The emitter is heated from an external heat source so that it emits electrons to the collector. The collector is at least partly covered by a thin layer of a material, for example carbon, which is capable of interacting with the thermionic material and form excited states of this and maintain a layer of excited thermionic material on the surface of the collector. The new collector for thermionic converters exhibits a very low work function, which implies diminished losses at the energy conversion.

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COLLECTOR FOR THERMIONIC ENERGY CONVERTER

Technical field

The present invention refers to a new design of the collector in a thermionic energy converter. Such a converter consists of two electrodes: an emitter and a collector and a space provided therebetween to which is supplied vapor of a thermionic material, for example caesium or other alkali metal. When the emitter is heated it emits electrons to the collector, so that a current can be taken out by means of an external circuit between the collector and the emitter. In this way the thermal energy at the emitter is converted to electric energy.

Background of the invention

Thermionic energy converters are used to convert thermal energy at temperatures between 1200 K and 2500 K to electric energy without mechanical movable parts. A thermionic converter works as a heat machine between above stated source temperature and a drain temperature of typically 800 K. The converter consists of two electrodes of metal or other appropriate conducting material, one of them at the source temperature, the emitter, and the other at the drain temperature, the collector. The electrodes are located near each other in vacuum or at low pressure, and the emitter emits a current of electrons to the collector, by it being held at a higher temperature through supply of thermal energy from the outside, for example from a flame or other heat source. The electrodes frequently constitute a part of the external vacuum tight wall or shroud of the converter, and are separated by insulating material. In thermionic converters normally is used cesium vapor with a pressure of magnitude of 1 mbar to increase the elektron emission from the emitter and to reduce the problems with space charge in the converter, so that larger current densities can be obtained from the converter. The emission from the emitter

is increased by caesium lowering the work function for the electrons from the surface. In the same manner the work function ono the collector, which has very big importance for the function of the converter. Detailed descriptions of thermionic converters are found in the references: G.N.Hatsopoulos and E.P. Gyftopoulos, Thermionic Energy Conversion, Vol. In (MIT Press, Cambridge, MA, 1973) as well as G.N. Hatsopoulos and E.P. Gyftopoulos, Thermionic Energy Conversion, Vol. II (MIT Press, Cambridge, MA 1979).

When the converter gives an output the work function of the collectors corresponds to a loss, i.e. the electrons from the emitter lose the corresponding energy in the form of heat in the collector. the factor of merit for thermionic converters, the so called barrier index, is composed of the work function of the collector and the so called arc voltage drop in the converter. The barrier index is positive and must be as low as possible. These two parts in barrier index represents the main losses in the converter during normal operation. The work function of the collectors normally gives the largest contribution to the barrier index, and a low work function for the collector is consequently of extremely great importance for the manufacture of efficient thermionic converters. Frequently simple metals are used with work functions of 4-5 eV as collector material, for example molybdenum. In operation such a collector is covered with a thin layer of cesium metal (smaller than a simple layer of atoms, a so called monolayer) or of cesiumoxid. This layer lowers the work function of the collectors to 1,6 - 1,8 eV in normal operation.

It is further known for example through the US patent 4,747,998, that it is possible to keep an alkali metal such as caesium in a graphite container to obtain a regulated pressure of alkai metal in a thermionic converter.

The purpose of the invention and most important features

The purpose with the present invention is to achieve a thermionic energy converter of the type mentioned by way of introduction, which exhibits a very low work function of the collector which entails a more effective energy conversion in thermionic converter. This has been achieved by the collector at least partly being covered by a thin layer of a material, for example carbon, which is able to interact with said thermionic material and form electronic excited states of this, and that by operation a layer of excited thermionic material is maintained on the collector surface.

Specification of drawings

In the following the invention will be closer described with reference to an embodiment shown on the enclosed drawings.

Fig. 1 shows in a schematic vertical section an outline diagram of the collector and emitter in the thermionic converter.
Fig. 2 shows a frontal view of the collector.
Fig. 3 is a vertical section through the thermionic converter including the cesium container.
Fig. 4 shows an experimental result in the form of a current - voltage diagram for the thermionic converter.

Specification of embodiments

The collector 1 consists of a metal foil with small holes through the foil, whereby in the experimental plant the distance between the holes was typically 0,2 mm and the hole diameter 0,1 mm, i.e. a hole density of 25 per mm^2. The holes have been bored by means of a laser. Through the foil vapor of caesium or other thermionic material is brought, for example an other alkali metal, to flow with a pressure of about 1 mbar (equilbrium pressure at a temperature of 300 °C). The external surface of the foil is coated with a very thin layer of carbon,

for example in the form of graphite. The carbon can be supplied through for example chemical disintegration of hydrocarbon or through mechanical coating with graphite in colloidal form. Probably the carbon reacts in the coating with the collector material and forms a carbide. Through interaction between the cesium vapor and the carbon coated surface are formed high-energy, so called excited states of cesium atoms and cesium ions. This mechanism is documented in the references: K. Möller and L. Holmlid, Surface Sci. 204 (1988) 98, J.B.C. Pettersson and L. Holmlid, Surface Sci. 211 (1989) 263 and T. Hansson, C. Åman, J.B.C Pettersson and L. Holmlid, J. Phys. B. 23 (1990) 2163.

These states interact so strongly with each other that a layer of excited cesium can be retained on the foil.The formation of the excited states and the formation of the layer of excited cesium is faciliated by the presence of a hot carbon covered surface in the proximity of the foil, so that further excited states of cesium can be formed. Instead of carbon other materials can be used, which are capable of interacting with caesium (or other thermionic material) in the above stated manner.

A collector of this type can be realized in several different ways regarding size of the laser bored surface and its form (plan or curved, possibly cylindric). Testing of the collector and measuring of its characteristics has been carried out in an arrangement as is shown in principle in Figure 1. In this the laser bored foil is welded to a container of stainless steel. In the container a vapor pressure of cesium is maintained. the cesium vapor flows through openings 4 in the collector 1, out in the area 5 between the collector and the adjacent hot so called emitter 6. This is held by two legs 7, which also conduct the electric current which heats the emitter.

The design of the collector in the tests is shown in Figure 2. It is made of nickel foil with a thickness of 0,5 mm. The external diameter a of the collector is 10 mm, while the laser

bored holes lie within a surface b of 4x4 mm². It should be remarked that these measure statements only consider the actual embodiment, and in no way limiting for the invention. Colloidal graphite is supplied onto the collector 1 on the part of surface which is not laser bored.

The cesium is supplied to the collector from a heated reservoir, such as is shown in Figure 3. In this figure the cross section of the emitter foil 6 is shown, the collector 1 and a copper casing 8 with a heating-coil 9 which heats the collector to a temperature about 800 K. In the upper part 10 of the device in Figure 3 there is also a connection 11 for a valve 12, which can be used to choke the cesium flow from a lower container 13 to the upper 10. The cesium 14 is introduced in metallic form in the lower container 13, frequently in solid form in a glass vial. The lower container 13 is heated by means of a heat casing 15, which also holds the device in position in the vacuum chamber via an envelope 16 and three legs 17. In order to cool the lower container rapidly air or water can be pressed through the envelope 16.

The thermionic converter according to the invention shows a voltage-current-characteristic which differs from the normal for other thermionic converters. Thus for example a electron current can pass from the collector to the emitter, a so called reverse current, if the converter is connected to a voltage source with reversed polarity compared to the normal polarity when the converter gives output power. This reverse current may reach very great current densities, more than 500 A/cm². This means that the work function of the collector is smaller than 0,7 eV, from the Richardson equation for thermal electron emission. More detailed analyses of voltage-current-characteristic point out work functions between 0,5 and 0,9 eV. This implies a large reduction of the work function for collectors in thermionic converters, which until now has not been possible to reduce below approximately 1,2 eV.

With this new type of collector we have been able to attain barrier indeces in thermionic converter during brief constant operation down to 1,64 eV, for example in the experiment in Fig. 4. In this case the emitter temperature was 1680 K (1407 °C), the collector temperature 553 K (280 °C) and the distance between emitter and collector about 0,4 mm. The output corresponding to these data is 10 W/cm^2, and the work function of the collector is 0,64 eV. Pulsed operation is expected give still lower barrier index. This implies a strong reduction of barrier index from typical published values of 1,8 - 2,0 eV.

This described improved type of collector of thermionic energy converters exhibits the following characteristics:

- work function for electrons is very low from the collectoer, below 0,7 eV, which implies strongly reduced losses at the energy conversion:
- the surface layer of the collector is produced during the use in the converter by high-energy so called excited atoms and ions of caesium form a layer on the surface of the collector,
- the excited states are formed on the surface of the collector in a thin carbon layer, which can be supplied by several known methods,
- the formation of the excited states and the surface layer of excited states on the collector is faciliated through the presence of another hot surface where excited states of cesium can be formed,
- the low work function of the new the type of collector in a thermionic converter entails reduced losses and reduced so called barrier index, which to a large part consists of the work function of the collector: this implies more effective energy conversion in thermionic energy converters which use this type of collector.

The invention is of course not limited to the embodiment described and shown above but several variants are conceivable within the scope of the patent claims. As an example the

collector 1 can be designed without holes 4, and the cesium vapor can be supplied directly to the space 5 between emitter and collector. in order to obtain increased contact between the cesium vapor and the carbon layer of the collector the collector surface can be developed with irregularities such as indentations and/or bosses. In this case the collector can be made of a thicker material. Possibly even a smooth collector surface can give enough good contact between the cesium vapor and the carbon, for example if the carbon forms thread shaped outgrowths from the collector surface.

CLAIMS

1. Collector for thermionic energy converter, which converter includes two electrodes: an emitter (6) and a collector (1) and a space (5) provided therebetween to which is supplied vapor of a thermionic material for example cesium or other alkali metal,
c h a r a c t e r i z e d t h e r e i n,
that the collector (1) at least partly is covered by a thin layer of a material, for example carbon, which is capable of interacting with said thermionic material and form excited states of this, and that by operation a layer of excited thermionic material is maintained on the surface of the collector.

2. Collector according to claim 1,
c h a r a c t e r i z e d t h e r e i n,
that the collector (1) consists of a metal foil provided with several holes (4) through which vapor of said thermionic material is brought to pass.

3. Collector according to claim 1,
c h a r a c t e r i z e d t h e r e i n,
that the collector (1) in its surface facing the emitter (6) shows indentations and/or bosses to obtain additional contact between the carbon layer and the thermionic material.

4. Collector according to any or some of preceeding patent claims,
c h a r a c t e r i z e d t h e r e i n,
that said layer is constituted by for example a carbide formed after coating the collector with carbon or other appropriate material.

FIG. 1

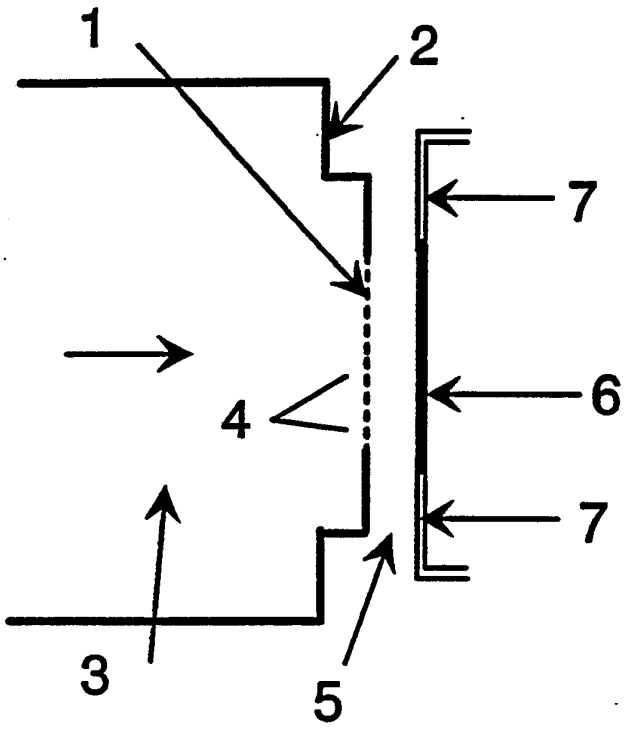


FIG. 2

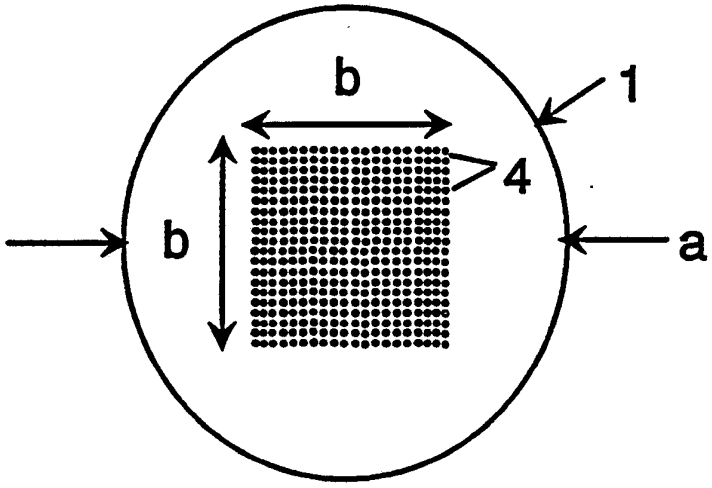


FIG. 3

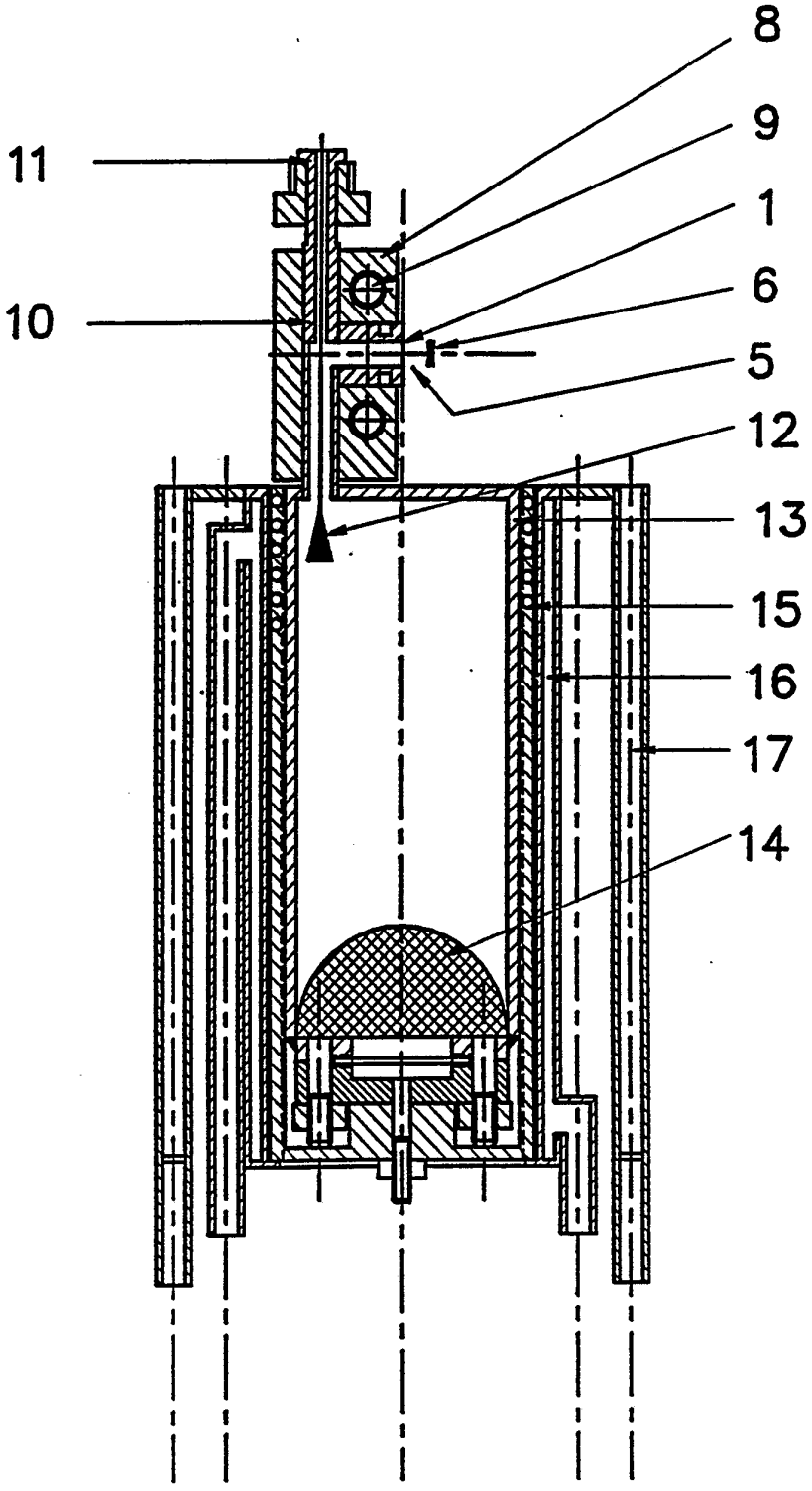
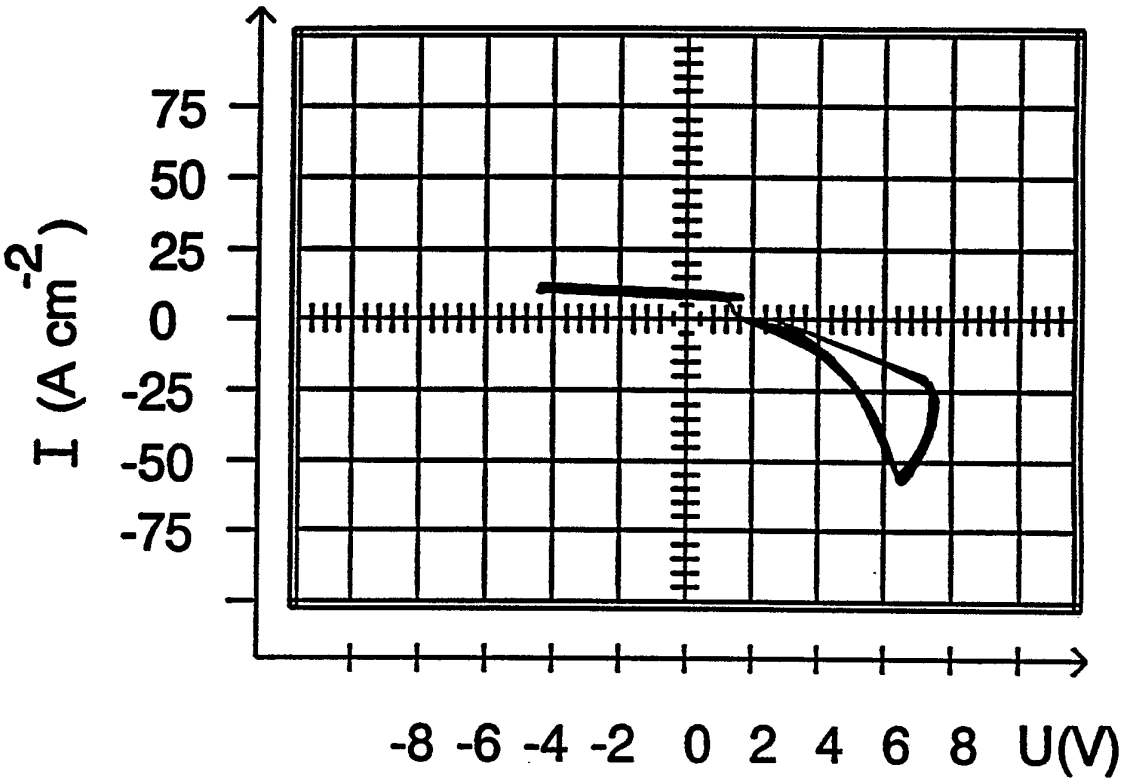


FIG. 4



INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 92/00530

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: H 01 J 45/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	H 01 J

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
A	DE 2059891 (DEUTSCHE FORSCHUNGS- UND VERSUCHSANSTALT FÜR LUFT-UND RAUMFAHRT E.V.) 15 June 1972, see claim --	1-4
A	US, A, 4747998 (DONALD M. BARRUS ET AL) 31 May 1988, cited in the application --	1-4
A	Surface Science 204, May 1988 (Holland) Kenneth Möller et al: "RATE CONSTANTS FOR CESIUM BULK DIFFUSION AND NEUTRAL DESORPTION ON PYROLYTIC GRAPHITE BASAL SURFACES: A FIELD REVERSAL KINETIC STUDY", see page 98 - page 112 cited in the application --	1-4

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
26th October 1992	02 -11- 1992
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	RUNE BENGTSSON

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	J.Phys.B: At. Mol.Opt.Phys, Vol. 23, 1990 (United Kingdom) Tony Hansson et al: "Large fluxes of highly excited caesium ions from a diffusion source", see page 2163 - page 2171 cited in the application --	1-4
A	Surface Science 211/212, 1989 (Holland) Jan B.C. Pettersson et al: "RYDBERG STATES OF CESIUM IN THE FLUX FROM SURFACES AT HIGH TEMPERATURES", see page 263 - page 270 cited in the application --	1-4

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 92/00530

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE- - 2059891	72-06-15	NONE	
US-A- 4747998	88-05-31	NONE	