[Document Name]Description

[Title of the invention]To provide a neutron generating method and a baggage inspection device for generating neutrons, the neutron generating apparatus using same

[Technical field]

[0001]The present invention relates to a neutron generating electrode pair, a neutron generating apparatus, a neutron generating method using the same, and a baggage inspecting apparatus.

[Background of the invention]

[0002]After the simultaneous multi-terrorism on Sep. 11, 2001, a TSA (Transport Security Agency) is installed as an expert agency responsible for civil aviation security in the United States, and it is clarified that a security inspector of all airports is a Federal Staff (Official Government) and a responsibility for a security test is in a country.In addition, in countries other than the United States, a new countermeasure against an aeronautical protection has been advanced after the simultaneous polyterrorism of the United States.

[0003]In Japan, there is also a correspondence to the International Civil Aviation Treaty, 17 Annex, and "National Civil Aviation Security Program" is implemented from April 2005, and this program is used in this program. A phase is normalized, a cockpit door is reinforced, an in-line inspection system or a liquid inspection device is introduced, and a security inspection is performed on an airport person and a crew from January 2006 to enhance an air safety system.

[0004]Such enhancement of security system is an important problem, and at the same time, the inspection and strengthening of the security system currently being performed is also sought at the same time, and in particular, whether or not a dangerous material is contained and inspection of baggage of an airline user occupy an important position.

[0005]Here, conventionally, an X-ray inspection method is mainly used for the baggage inspection apparatus, and the X-ray inspection method is excellent in detection of metal, but there is a problem that it is not excellent in detection of other organic substances, chemical substances, and the like, and nuclear terrorism is considered to be feared in future. To provide a baggage inspection device capable of accurately and efficiently detecting an organic substance or a chemical substance other than metal.

[0006]As such a baggage inspection apparatus, for example, in Patent Document 1, a baggage inspection apparatus including an X-ray imaging apparatus and a neutron imaging apparatus has been proposed, and in Patent Documents 2 and 3, a low-temperature plasma fusion method and a fusion apparatus capable of generating neutrons respectively have been proposed.

[Prior art documents]

[Patent document]

[0007]

[Patent document 1]JP 2004-108994A

[Patent document 2]JP H 3-41391A

[Patent document 3]JP H 3-105284A

[Summary of the invention]

[Problem to be solved by the invention]

[0008]However, in the neutron generator of the baggage inspection apparatus disclosed in Patent Document 1, there is a problem in that the efficiency of neutron generation is not always high, and the device configuration becomes large, and there is still room for improvement.

[0009]In addition, in the low-temperature plasma fusion method described in Patent Document 2, a parallel plate type electrode is used, and a direct current bias is changed from - 100 V to - 1000 V to generate neutrons using a plasma generation pressure as a 0.001~10Torr. Other specific conditions are not explicitly described, and the efficiency, controllability and reproducibility of neutron generation are inferior.

[0010]Further, in the fusion device described in Patent Document 3, a parallel plate type electrode is used, and the electrode is evacuated to 10-4 Torr or less, and the deuterium gas is introduced from the deuterium-containing gas supply port and left at a pressure of 760 Torr (1 atm) for 10 hours. In this case, a deuterium plasma is generated at a gas flow rate of 100 sccm and a high frequency frequency of 13.56 MHz, but there is also a problem that the efficiency of neutron generation, controllability, and reproducibility are poor.

[0011]Therefore, an object of the present invention is to provide an electrode for neutron generation capable of generating neutrons with good efficiency, controllability, and reproducibility, and a neutron generator, and further to use the electrode for generating neutrons and the neutron generator. To provide a baggage inspection device capable of suppressing a device scale due to high efficiency of neutron generation and excellent in controllability and reproducibility of neutron generation.

[Means for solving the problem]

[0012]In order to solve the above problem, the present inventors have intensively studied a configuration of an electrode and a condition for discharging between electrode pairs, and as a result, the present inventor has conducted extensive studies. It has been found that an electrode pair including a first electrode including a conductor and a hydrogen storage alloy wire spirally wound on the conductor and a 2 electrode having a cylindrical shape and a mesh shape disposed around the first electrode can be used to generate neutrons with high efficiency, controllability, and reproducibility, and thus, the present invention has been completed.

[0013]In particular, the present invention provides a pair of neutron generating electrodes comprising a first electrode comprising a conductor and a hydrogen storage alloy wire helically wound on said conductor ; and a 2 cylindrical and reticulated electrode disposed around said first electrode.If a discharge is generated between electrode pairs having such a configuration in a deuterium gas atmosphere, it is possible to generate neutrons with high efficiency, controllability, and reproducibility.

[0014]2, the vacuum chamber, the exhaust device for exhausting the inside of the vacuum chamber, the deuterium gas supply device for supplying the deuterium gas into the vacuum chamber, and the conductor are disposed in the vacuum chamber. A neutron generator includes a first electrode including a hydrogen storage alloy wire spirally wound around the conductor, a pair of electrode pairs for generating neutrons including a cylindrical 2 electrode disposed around the first electrode, and a power supply unit for applying a voltage between the pair of electrodes.

[0015]In addition, the present invention is 3.
(1) evacuating the inside of the vacuum chamber ;
(2) a step of discharging by applying a voltage between the electrode pair for generating neutrons including a first electrode including a conductor and a hydrogen storage alloy wire spirally wound around the conductor in the vacuum chamber and a cylindrical and net-like 2 electrode arranged around the first electrode and having a cylindrical shape ;
(3) A method of generating a neutron includes a step of supplying a deuterium gas into the vacuum chamber for a predetermined time while maintaining a voltage application between the pair of neutron generating electrodes and discharging a discharge.

[0016]In addition, 4, the present invention provides a first electrode including a vacuum chamber, an exhaust apparatus for exhausting the inside of the vacuum chamber, a deuterium gas supply apparatus for supplying deuterium gas into the vacuum chamber, a conductor, and a hydrogen storage alloy wire spirally wound around the conductor. There is provided a baggage inspection apparatus including a neutron generation device including a pair of electrode pairs for generating neutrons including a 2 electrode in a cylindrical shape and arranged around the first electrode, and a power supply unit for applying a voltage between the pair of electrodes, and a neutron detection device.

[Effect of the invention]

[0017]According to the present invention, there is provided a neutron generating electrode pair and a neutron generating device capable of generating neutrons with high efficiency, controllability and reproducibility. To provide a baggage inspection device capable of suppressing a device scale due to high efficiency of neutron generation and excellent in controllability and reproducibility of neutron generation.

[Brief description of the drawings]

[0018]

[Fig. 1] Fig.1 is a plan showing one embodiment of the electrode pair for neutron generations of the present invention.

[Fig. 2] Fig.2 is a side view of the first electrode (anode) in the embodiment shown in Fig.1.

[Fig. 3] Fig.3 is the figure showing the principal part of one embodiment of the neutron generator of the present invention.

[Fig. 4] Fig.4 is the figure showing the entire configuration of the neutron generator of the embodiment shown in Fig.3.

[Fig. 5] Fig.5 is a plan showing one embodiment of the baggage-screening equipment of the present invention.

[Fig. 6] Fig.6 is a graph which shows the neutron measurement result in the Example of the present invention.

[Mode for carrying out the invention]

[0019]Hereinafter, preferred embodiments of the neutron generating electrode pair, the neutron generator, the neutron generating method and the baggage inspecting apparatus will be described in detail with reference to the accompanying drawings.

[0020]In the following description, the same or corresponding parts will be denoted by the same reference numerals, and redundant description will be omitted in some cases.In addition, in the following description, since the present invention is conceptually described in the drawings, the dimensions of each of the represented components and their ratios may be different from actual ones.

[0021]FIG. 1 is a top view showing an embodiment of the neutron generating electrode pair 10 of the present invention (I. e., a diagram in which a positional relationship between a first electrode (cathode) and a 2 electrode (anode) of a pair of neutron generating electrode pairs installed in a vacuum chamber to be described later is viewed from an approximately vertical upper side), and FIG. 2 is a schematic view of the same. FIG. 3 is a side view of a first electrode 1 in the embodiment shown in FIG. 1 (I. e., a first electrode of a pair of neutron generating electrode pairs placed in a vacuum chamber described later) is seen from a substantially horizontal direction ;.

[0022]FIG. 3 is a diagram showing a main portion 20 a of an embodiment of the neutron generator 20 of the present invention, and FIG. 4 is a diagram showing an overall configuration of the neutron generator 20 of the embodiment shown in FIG. 3.FIG. 5 is a top view showing an embodiment of a baggage inspection apparatus according to the present invention, and FIG. 6 is a graph showing neutron measurement results according to an embodiment of the present invention.

[0023]As shown in FIG. 1, the neutron generating electrode pair 10 of the present embodiment includes a combination of a first electrode 1 and a 2 electrode 2.As shown in FIG. 2, the first electrode 1 is constituted by a copper rod 1 a which is a conductor and a palladium (Pd) wire 1 b which is a hydrogen storage alloy wire tightly wound around a copper rod 1 a in a spiral form almost without gaps, and the 2 electrode 2 is shown in FIG. 1. It is composed of a cylindrical platinum (Pt) net (2) arranged around the first electrode (1) and open at the top and bottom.In view of making uniform the electric field of discharge and preventing the reaction of the lower metal and ions from occurring, it is preferable that the palladium wire 1 b be wound tightly on the copper rod 1 a without a gap, but it is possible to have a slight gap.

[0024]In other words, as shown in FIG. 2, in the neutron generating electrode pair 1, the neutron generating electrode pair 21 is disposed in a vacuum chamber for generating neutrons, and is viewed from an upper side in a substantially vertical direction. A copper rod 1 a, a palladium wire 1 b and a platinum net (2) are positioned in this order from the inside, and the electrode pair 1 for generating neutrons is used in a neutron generating device, a neutron generating method and a load inspection device which will be described later while maintaining this positional relationship.

[0025]More specifically, the length direction of the copper rod 1 a in the first electrode 1, the direction perpendicular to the winding direction of the palladium wire 1 b with respect to the copper rod 1 a, and the direction of the cylindrical center axis of the cylindrical Pt net constituting the 2 electrode 2 substantially coincide with each other in the direction indicated by an arrow X in FIG. 2.

[0026]Here, as a copper rod constituting the first electrode 1 of this embodiment, a copper rod having various dimensions can be used, but a copper rod having a diameter of 3 and a length of 50 is preferably used.Although there is no particular limitation on the composition of copper, it is preferable to use, for example, high-purity oxygen-free copper from the viewpoint of minimizing the emission of impurity gas.

[0027]Further, although palladium wires of various sizes can be used as the palladium wires constituting the first electrode 1 of this embodiment, it is preferable to use, for example, a palladium wire having a thickness of 1.0 to 1.5.Although there is no particular limitation on the composition of the palladium wire, it is preferable to use a material having a high purity of 99.99% by weight or more from the viewpoint that it is preferable to reduce as much as possible impurities (e.g., oxygen, H2O, CO, and S compounds) in the gas in the vacuum chamber that generates neutrons.

[0028]In the electrode pair 10 for generating neutrons according to the present embodiment, the distance between the first electrode 1 and the 2 electrode 2 (distance between the electrodes) may be appropriately adjusted according to various conditions of the neutron generation method using a neutron generator described later.When the pressure of the deuterium gas atmosphere in the neutron generator described later is, for example, 10-4 to 10-2 atm, the distance between the electrodes may be 50 to 60.Note that the pressure and the inter-electrode distance may also vary depending on the voltage used for discharging.In addition, the first electrode 1 or the 2 electrode 2 of the pair of neutron generating electrodes 10 may be provided with a lead portion for connecting to a power supply unit.

[0029]As will be described in detail later, when the electrode pair 10 for neutron generation having such a configuration is placed in a deuterium gas atmosphere and discharge is caused between the first electrode 1 and the 2 electrode 2, neutrons can be efficiently generated from the vicinity of the surface of the palladium wire 1 b of the first electrode 1.In particular, when the electrode pair 10 for neutron generation having the above-described configuration is placed in a vacuum atmosphere, and discharge is caused between the first electrode 1 and the 2 electrode 2, and deuterium gas is supplied to the vacuum atmosphere, neutrons can be efficiently generated from the vicinity of the surface of the palladium wire 1 b of the first electrode 1.

[0030]The neutron generating device 20 of the present embodiment can employ a conventionally known configuration, except that the neutron generating electrode pair 10 of this embodiment is used as the neutron generating electrode pair.As shown in FIG. 3, the neutron generator 20 of the present embodiment includes the neutron generating electrode pair 10 of the present embodiment and a vacuum chamber 22 of, e.g., stainless steel which houses the neutron generating electrode pair 10.

[0031]The vacuum chamber 22 is provided with a cylindrical cylinder 22 a having a bottomed cylindrical shape and covering the electrode pair 10 for generating neutrons. A flange 22 b integrally provided on the cylinder 22 a is provided with a lid 22 b which is disposed via a gasket (not shown) made of copper, for example, and which closes an upper opening of the cylinder 24 a by a bolt 26 and a nut 22.

[0032]The volume of the vacuum chamber 22 may be appropriately selected in accordance with various conditions of the neutron reaction method such as the distance (inter-electrode distance) between the first electrode 1 and the 2 electrode 2 of the neutron generating electrode pair 10 and the pressure and pressure, and the like.

[0033]As shown in FIG. 3, in the vacuum chamber 22, a gas inlet / outlet port 28 for connecting to an exhaust device and a deuterium gas supply device (see FIG. 4), and lead portions 30 a and 30 b for connecting the first electrode 1 and the 2 electrode 2 of the neutron reaction electrode pair 10 to the power source (the lead portion 30 a is a high voltage supply side) are provided. A lead portion 30 b is provided on the ground potential side of the high-voltage power source, and a cooling water inlet 32 and a cooling water outlet 34 for supplying and discharging cooling water, and a cooling pipe 36 connected to the cooling water inlet 32 and the cooling water outlet 34 and spirally wound through a gap are provided on an outer peripheral surface of the vacuum chamber 22.

[0034]As shown in FIG. 4, the gas inlet / outlet 28 is provided with an exhaust device 40 for exhausting the inside of the vacuum chamber 22, a deuterium gas supply device (for example, 30 atm) 42 comprising a gas cylinder for supplying deuterium gas into the vacuum chamber 22, and a first electrode 1 and a 2 electrode of the electrode pair 10 for neutron generation. A power supply unit 44 for applying a voltage is connected, the first electrode 1 is connected to the high voltage supply side of the power supply unit 44 via a lead unit 30 a, and the 2 electrode 2 is connected to the ground potential side of the power supply unit 44 via a lead unit 30 b.As the exhaust device 40 and the power supply device 44, conventionally known ones can be used.Note that one of the gas inlet and outlet 28 may be used preliminarily, and may be omitted in some cases.

[0035]As shown in FIG. 4, a flow path extending from the gas inlet / outlet 28 of the vacuum chamber 22 is provided with an adjustment valve 46 a, and is branched into 2, and one branch flow path is provided. An exhaust device 40 is connected via an adjusting valve 46 b, and a deuterium gas supply device 42 comprising a deuterium gas tank is connected to the other branch passage via a pressure gauge 48 as a pressure converter, a gas reservoir 50 as a reserve tank and an adjusting valve 46 c.Since adjustment is difficult for the heavy-hydrogen-gas supply device 42 which consists of a gas bomb at high voltage, It is preferred to employ a configuration as shown in FIG. 4, in which a gas reservoir 50 as a preliminary tank is once stored with deuterium gas at about 1 atm, and then a valve of the regulating valve 46 C is closed to continuously measure the pressure by a pressure converter of the pressure gauge 48 to keep the reaction system at a constant pressure.

[0036]In the neutron generating device 20 according to the present embodiment, similarly to the case of the neutron generating electrode pair 10, the distance between the first electrode 1 and the 2 electrode 2 (the distance between the electrodes) may be appropriately adjusted according to various conditions of the neutron generating method described later using the neutron generating device 20.When the pressure of the deuterium gas atmosphere is, for example, 10-4 to 10-2 atm, the distance between the electrodes may be 50 to 60.Note that the pressure and the inter-electrode distance may also vary depending on the voltage used for discharging.

[0037]As will be described in detail later, in the neutron generator 20 having such a configuration, a pair of electrode pairs 10 for generating neutrons is placed in a hollow chamber 22 and a discharge is generated between the first electrode 1 and the 2 electrode 2. It is possible to efficiently generate neutrons from the vicinity of the surface of the palladium wire 1 b of the first electrode 1.In particular, when the electrode pair 10 for generating neutrons is placed in a vacuum atmosphere and discharge is caused between the first electrode 1 and the 2 electrode 2, and deuterium gas is supplied to the vacuum atmosphere, neutrons can be efficiently generated from the vicinity of the surface of the palladium wire 1 b of the first electrode 1.

[0038]In particular, in the neutron generator 20 of the present embodiment having the above-described configuration, deuterium gas can be supplied continuously, and the vacuum chamber 22, I. e., the reaction system, can be maintained at a constant pressure, thereby accelerating the reaction and efficiently generating neutrons.

[0039]The neutron generation method of the present embodiment uses the neutron generation electrode pair and the neutron generation device, and includes the following steps (1) to (3) as an essential step.
(1) evacuating the inside of the vacuum chamber 22 ;
(2) In the vacuum chamber 22, a voltage is applied between the pair of neutron generating electrodes 10 of the present embodiment (I. e., between the first electrode 1 and the 2 electrode 2 among the pair of neutron generating electrodes 10) to discharge.
(3) a step of supplying a deuterium gas into the vacuum chamber 22 for a fixed period of time while maintaining voltage application between the pair of neutron generating electrode pairs 10 (I. e., between the first electrode 1 and the 2 electrode 2 among the pair of neutron generating electrode pairs 10) and discharging the same.

[0040]Further, the neutron generation method of the present embodiment includes the following steps (4) to (6) as an optional step.
(4) a step of stopping the discharge by stopping the application of voltage between the pair of neutron generating electrodes 10 (I. e., between the first electrode 1 and the 2 electrode 2 among the pair of neutron generating electrode pairs 10) ;
(5) a step of resupplying deuterium gas in the vacuum chamber 22 for a predetermined time ;
(6) A step of re-discharging a voltage between the pair of neutron generating electrode pairs 10 (I. e., between the first electrode 1 and the 2 electrode 2 among the pair of neutron generating electrode pairs 10).

[0041]Hereinafter, a neutron generation method according to the present embodiment will be described for each of these steps.First, in step (1), the vacuum chamber 22 is evacuated using an exhaust device 40.The pressure in the vacuum chamber 22 after evacuation is not particularly limited as long as it does not impair the effect of the present invention, but is preferably, for example, 10-8 to 10-6 atm, and may be, for example, about 10-6 atm.

[0042]Next, in step (2), a voltage is applied between the pair of neutron generating electrodes 10 of the present embodiment (I. e., between the first electrode 1 and the 2 electrode 2 among the pair of neutron generating electrode pairs 10) in the vacuum chamber 22 to discharge.The applied voltage is not particularly limited as long as the effect of the present invention is not impaired, but is preferably 1 to 5 kV, and may be, for example, about 3 kV.Further, the frequency may be 50 to 2000 Hz.

[0043]At this time, it is preferable that the temperature of the palladium wire 1 b portion of the first electrode 1 is controlled to be 25 ° C. to 600 ° C. by supplying cooling water into the vacuum chamber 22 using the cooling water inlet 32 and the cooling water outlet 34 or heating the heater 36 provided on the outer surface of the vacuum chamber 22.In the neutron generation method of the present embodiment, deuterium gas is stored in the palladium wire 1 B, but the range of the discharge temperature depends on the pressure, the power, the amount of deuterium, and the like, and therefore, it is necessary to change the temperature in the range of 25 to 600 ° C.

[0044]Next, the deuterium gas is supplied into the vacuum chamber 22 as the step (3) while maintaining the discharge due to the voltage application between the pair of neutron generating electrodes 10 in the step (2) (I. e., between the first electrode 1 and the 2 electrode 2 among the pair of neutron generating electrodes 10).In this case, the amount of the deuterium gas supplied may be an amount in which an atmospheric pressure in the vacuum chamber 22 is, for example, about 10-2 atm in a range of 10-4 to 10-2 atm.Such a process (1) -
After 3), neutrons are generated after a lapse of time (e.g., 1 to 2 minutes).

[0045]Further, after the steps (1) to (3), as the step (4), the electric discharge is stopped by stopping the voltage application between the pair of neutron generating electrodes 10 (that is, between the first electrode 1 and the 2 electrode 2 among the pair of neutron generating electrodes 10).

[0046]Then, as step (5), deuterium gas is resupplied to the vacuum chamber 22 for a predetermined time.The supply time at this time may be, for example, in a range of 1 to 20 minutes, for example, 1 minutes.That is, the deuterium gas is supplied into the vacuum chamber 22 for a predetermined period of time and stopped.

[0047]Thereafter, in step (6), a voltage is reapplied between the pair of neutron generating electrodes 10 (I. e., between the first electrode 1 and the 2 electrode 2 among the pair of neutron generating electrodes 10) to be re-discharged.The voltage to be reapplied may be equal to that of the above step (2) (e.g., 1 to 5 kV, e.g., 3 kV).

[0048]Again, it is preferred that the re-application of voltage is after the first electrode 1 and the 2 electrode 2 have been sufficiently cooled.This is because, although the palladium wire 1 b is overheated by discharge to release the deuterium, when the discharge is stopped and the palladium wire 1 b cools, the deuterium gas in the reaction system is absorbed again (the deuterium absorbing ability is restored).Cooling of the first electrode 1 and the 2 electrode 2 may be performed by passing cooling water through the cooling water inlet 32 and the cooling water outlet 34.

[0049]By thus reapplying a voltage to start the discharge, neutrons can be generated again.After this, we have confirmed that the generation of neutrons can be continued for several hours.Note that the number of generated neutrons can be controlled by the voltage of the discharge.As the voltage increases, the number of neutrons generated increases exponentially.

[0050]Here, the present inventor considers that the mechanism of neutron generation in the neutron generation method of the present embodiment described above is as follows.That is, the deuterium atoms supplied into the vacuum chamber 22 are first absorbed into the palladium wire 1 b of the first electrode 1 of the electrode pair 10.Thereafter, deuterium gas is released from the surface of the palladium wire 1 b by discharge, and a part thereof becomes deuterium ions.The energy of this deuterium ion reaches several keV.

[0051]A portion of the deuterium ions collide with the palladium wire 1 b, which is also referred to as a reactant, and collides with the deuterium nucleus in the deuterium gas emitted from the palladium wire 1 b.Then, a fission reaction occurs, so that division occurs.Then, deuterium is excited further by energy generated at this time, and the probability of occurrence of a nuclear reaction increases.As a result, it is believed that, even if some of the atoms collide with each other, there is very much neutrons resulting from the nuclear reaction occurring.

[0052]The reaction of the above mechanism can be represented by the following reaction scheme.D D → p(3.02MeV)+T(1.01MeV) (1) → n(2.45MeV)+3He(0.82MeV) (2).

[0053]In the reaction of Reaction Scheme (1), protons and tritium are generated.In addition, in the reaction of Reaction Formula (2), isotopes of neutrons and helium are generated.Neutrons may further collide with other atoms and generate a nuclear reaction.These reactions provide neutrons.Once the reaction starts, deuterium is continuously supplied from the inside of the palladium wire 1 b by heat reaction.

[0054]The baggage inspection apparatus 100 of the present embodiment can employ a conventionally known configuration, except that the neutron generation electrode pair 10 and the neutron generation apparatus 20 of this embodiment are used as the neutron generation electrode pair and the neutron generation device.

[0055]As shown in FIG. 5, the load inspection apparatus 100 of the present embodiment includes at least a neutron generator 20 and a neutron detector 52 of this embodiment, and has a structure of a * neutron moderator 54, a neutron reflector 56, and a neutron absorber 58 surrounding the neutron generator 20.The overall shape of this structure is a hyperboloid of revolution or a paraboloid of revolution, and neutrons are irradiated forward (in the direction indicated by arrow Y in FIG. 5) from the neutron generator 20.

[0056]Further, the baggage inspection apparatus 100 includes 2 neutron detection devices (e.g., an NE 213 neutron energy measurement device) 52, detects an energy spectrum of neutrons that are reflected in a direction of 90 degrees from the rear of a cargo that is an object to be measured 60, and analyzes a composition of a specific substance included in the baggage and an element from the detected spectrum.

[0057]Here, as the neutron moderating agent 54, plastics such as a thermoplastic resin containing rich hydrogen atoms can be used, and the thickness thereof is preferably, for example, about 15 cm.For example, Bi or a BiPb alloy may be used as the neutron reflecting material 56, and the thickness thereof is preferably about 3 cm.

[0058]In addition, as the neutron absorbing material 58, a plastic material such as a paraffin containing boron or a thermoplastic resin containing boron can be used, and a thickness thereof is preferably about 3 cm, for example.In order to further completely shield neutrons, it is also possible to cover them with a Cd metal of about 0.3 thick.

[0059]While exemplary embodiments of the present invention have been described above, the present invention is not limited thereto.For example, in the above embodiment, a case in which a copper rod is used as a conductor has been described, but various types of conductors made of various materials can be used.Further, although a case in which a palladium wire is used as a hydrogen storage alloy wire has been described, a hydrogen storage alloy wire made of various materials can be used.Hereinafter, the present invention will be described more specifically using examples.

[Examples]

[0060]Using FIG. 1 and FIG. 2, the neutron generating method described above was performed using the neutron generating electrode pair 10 of the present invention described above and the neutron generating device 20 of the present invention described above with reference to FIGS. 3 and 4.A copper rod 1 a having a diameter of 3 and a length of 50 was used, and a palladium wire 1 b having a thickness of 1.0 and a length of 100 was used.Further, a distance between the first electrode 1 and the 2 electrode 2 was set to 50.

[0061]As a step (1), the inside of the vacuum chamber 22 was evacuated to a vacuum of 10-6 atm using an exhaust device 40.Next, as a step (2), a voltage of 3 kV was applied between the first electrode 1 and the 2 electrode 2 of the neutron generating electrode pair 10 in the vacuum chamber 22 to discharge the same (50).While maintaining the discharge due to the voltage application, the deuterium gas was supplied into the vacuum chamber 22 and stopped until the atmospheric pressure in the vacuum chamber 22 reached 10-2 atm as the step (3).After a lapse of 1 to 2 minutes, neutrons were generated.

[0062]Here, as Step (4), the voltage application between the first electrode 1 and the 2 electrode 2 of the electrode pair 10 for generating neutrons was stopped, and the discharge was stopped.Then, as Step (5), deuterium gas was supplied again into the vacuum chamber 22 for 1 minutes.Thereafter, as Step (6), a voltage of 3 kV was re-applied every 100 seconds between the first electrode 1 and the 2 electrode 2 of the electrode pair 10 for neutron generation, and re-discharge was performed.Thus, a neutron generation reaction occurred, which was continued for 200 seconds here.

[0063]The neutron generation caused by this re-discharge was measured by a method of simultaneously measuring a neutron REM counter manufactured by Fuji Electric Co., Ltd., a product number : NS104 Type 014, and a neutron dosimeter manufactured by ALOKA Co., Ltd.The results are shown in FIG. 6.In the graph of FIG. 6, the horizontal axis represents time, and the vertical axis represents voltage and the number of occurrences of neutral.

[0064]As can be seen from FIG. 6, a rapid generation of neutrons is observed by the supply of voltage.By supplying a voltage, a neutron is stably generated, and 106 neutrons are obtained.At the theoretical value, the amount of neutrons generated per unit area of the palladium wire is 105.Further, the current flowing between the first electrode 1 and the 2 electrode 2 was 20 mA, and the generated power was 60 W.From this, it is found that the amount of generated neutrons is 2.5 × 106 / W.

[Industrial applicability]

[0065]A first electrode including a conductor and a hydrogen storage alloy wire spirally wound on the conductor ;A neutron reaction electrode pair including a cylindrical 2 electrode disposed around the first electrode and a second electrode having a net-like shape can be suitably used in a neutron generator, a neutron generation method, and a baggage inspection apparatus capable of generating neutrons with good efficiency, controllability, and reproducibility.

[Explanation of letters or numerals]

[0066]1 ... first electrode, 1 a ... lead bar, 1 b ... palladium line, 2 ... second electrode, 10 ... electrode pair for neutron generations, 20 ... neutron generator, 20 a ... essential part of a neutron generator, 22 ... vacuum chamber, 22 a ... cylinder, 22 b ... flange, 22 c ... covering device, 24 ... bolt, 26 ... nut, 28 ... a gas entrance and 30a, 30 b ... lead part, 32 ... inflow of cooling water, 34 ... outflow of cooling water, 36 ... heater, 40 ... exhaust system, 42 ... heavy hydrogen supply device, 44 ... An electric power unit and 46a,46b,46c ... Regulating valve, 48 ... pressure gauge, 50 ... gas reservoir, 52 ... neutron detection equipment, 54 ... neutron moderator, 56 ... neutron reflection material, 58 ... neutron absorber, 60 ... measuring object, 100 ... baggage-screening equipment.