Notice

DESCRIPTION CN115318219A

Needle electrode discharge tube and Joule heating equipment suitable for flash Joule heating process

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适用闪光焦耳加热工艺的针状电极放电管及焦耳加热设备

[0001]

Technical Field

技术领域

[n0001]

This invention belongs to the field of electrical equipment technology, specifically relating to a needle electrode discharge tube and a Joule heating device suitable for flash Joule heating process.

本发明属于电气设备技术领域，具体涉及一种适用闪光焦耳加热工艺的针状电极放电管及焦耳加热设备。

[0003]

Background Technology

背景技术

[n0002]

Rice University has developed a new process that can extract valuable metals from electronic waste.

赖斯大学开发的一种新工艺可以从电子废物中提取有价值的金属。

This process, known as flash Joule heating, consumes 500 times less energy than current methods.

这个过程称为闪光焦耳加热，其能耗比当前方法低500倍。

Flash Joule heating was originally developed using graphene produced from carbon from sources such as waste food.

闪光焦耳加热最初是利用废物食品等来源从碳中产生的石墨烯。

However, Rice's researchers modified the methods for recovering minerals such as sodium, platinum, gold, and silver from electronic waste. The method works by heating electronic waste to a temperature of 3,400 Kelvin (5,660 degrees Fahrenheit). This involves the high-temperature evaporation of metal. Then, the gas is transported from the flash chamber to the cold trap through a vacuum. Once inside the cold trap, the metallic gas will condense back into the solid metal. The recycled metal mixture in the trap can then be further purified to produce individual metals.

然而，赖斯的研究人员调整了从电子废物中回收矿物质的方法，如钠、铂、金和银。 该方法的工作原理是将电子废物加热到3，400开尔文（5，660华氏度）的温度。 这种高温蒸发金属。 然后，气体

通过真空从闪存室输送到冷陷阱中。 一旦进入冷陷阱，金属气体就会凝结回固体金属中。 然后，可以进一步净化陷阱中的回收金属混合物，以产生单个金属。

[n0003]

In addition to recovering metals from electronic waste, researchers have also found that the flash Joule reaction reduces the lead concentration in charred remains to below 0.05 parts per million.

除了从电子废物中取回金属外，研究人员还发现，闪光焦耳反应将烧焦的遗骸中的铅浓度降低到百万分之0.05以下。

This is a safe enough level to dispose of waste in agricultural soil. The levels of other toxic metals, such as arsenic and mercury, can also be reduced by using additional flashes. Since each flash lasts less than a second, this can be done quickly. This process can transform a major source of toxic waste into a useful resource, turning the largest source of waste into a treasure trove. This will reduce the need to mine ores from remote and dangerous locations, strip the earth's surface, and exploit vast amounts of water resources.

这是一个足够安全的水平，可以将废物处理在农业土壤中。 其他有毒金属（如砷和汞）的含量也可以通过使用额外的闪光来降低。 由于每个闪光灯持续不到一秒，这可以快速进行。 这个过程可以把有毒废物的主要来源变成有用的资源，在这里最大的废物来源变成了宝藏，这将减少从偏远和危险的地方的矿石中开采、剥去地球表面和利用大量水资源的必要性。

[n0004]

For applications using flash Joule heating to produce graphene from various carbon sources, existing technologies lack discharge tubes capable of mass production of graphene, and lack Joule heating equipment that can ensure the continuous discharge efficiency of the discharge tubes. Traditional Joule heating equipment is difficult to reach temperatures above 3000K instantaneously, and the discharge energy, discharge voltage, and discharge time are uncontrollable, making it difficult to monitor the discharge temperature.

针对利用闪光焦耳加热工艺实现各种碳源生产石墨烯的场合，现有技术中缺少能够满足批量生产石墨烯的放电管，缺少能够保障放电管连续放电工作效率的焦耳加热设备，传统焦耳加热设备难以在瞬间达到3000K以上的温度，且放电能量、放电电压、放电时间不可控，放电温度难以监测。

[0007]

Summary of the Invention

发明内容

[n0005]

The purpose of this invention is to overcome at least one of the above-mentioned problems existing in the prior art and to provide a needle electrode discharge tube and a Joule heating device suitable for flash Joule heating process.

本发明的目的在于克服至少一个现有技术中存在的上述问题，提供一种适用闪光焦耳加热工艺的针状电极放电管及焦耳加热设备。

[n0006]

To achieve the above-mentioned technical objectives and effects, the present invention is implemented through the following technical solution:

为实现上述技术目的，达到上述技术效果，本发明是通过以下技术方案实现：

[0010]

This invention provides a needle-shaped electrode discharge tube suitable for flash Joule heating technology. The needle-shaped electrode discharge tube includes an upper electrode, an upper tube body, a lower tube body, and a lower electrode. Both the upper and

lower tube bodies are open tube bodies, and the outer diameter of the upper tube body matches the inner diameter of the lower tube body. The upper electrode is installed at the end of the upper tube body away from the opening, and the lower electrode is installed at the end of the lower tube body away from the opening. Each of the upper and lower electrodes has a plurality of needle-shaped electrodes evenly distributed circumferentially in the portion of its respective tube body. The positions of the needle-shaped electrodes in the upper and lower electrodes are staggered.

本发明提供一种适用闪光焦耳加热工艺的针状电极放电管，该针状电极放电管包括上电极、上管体、下管体和下电极，所述上管体和下管体均为开口管体，且上管体的外径与下管体的内径相互配合，所述上管体位于远离开口的端部安装有上电极，所述下管体位于远离开口的端部安装有下电极，所述上电极、下电极各自位于所在管体中部分形成有若干呈周向均匀分布的针状电极，所述上电极、下电极中的针状电极位置相互错开。

[n0007]

Furthermore, in the needle electrode discharge tube applicable to the flash Joule heating process described above, both the upper tube body and the lower tube body are ceramic tubes.

进一步地，上述适用闪光焦耳加热工艺的针状电极放电管中，所述上管体和下管体均为陶瓷管。

[n0008]

Furthermore, in the needle electrode discharge tube applicable to the flash Joule heating process described above, the needle electrode is a platinum electrode.

进一步地，上述适用闪光焦耳加热工艺的针状电极放电管中，所述针状电极为铂电极。

[n0009]

The present invention also provides a Joule heating device applicable to the flash Joule heating process, characterized in that: the Joule heating device includes a trolley frame, and a parallel capacitor bank is installed in the lower layer inside the trolley frame;

本发明还提供一种适用闪光焦耳加热工艺的焦耳加热设备，其特征在于：该焦耳加热设备包括推车式机架，所述推车式机架内部下层安装有并联电容组；

[0014]

The trolley-type frame has a vacuum pump, a DC contactor, an adjustable power inductor, a power resistor, a freewheeling diode, a thyristor rectifier power supply, and a low-voltage switching power supply installed in its middle layer. One end of the DC contactor's electrode is connected to the positive terminal of a parallel capacitor bank via a wire, and the other end

is connected to the adjustable power inductor via a wire. The adjustable power inductor is a power inductor whose inductance is adjustable according to the discharge time requirement, and a power resistor and a freewheeling diode protection circuit are connected in parallel at both ends.

所述推车式机架内部中层安装有真空泵、直流接触器、可调功率电感、功率电阻、续流二极管、可控硅整流电源和低压开关电源；所述直流接触器的电极一端通过导线与并联电容组的正极相连接，另一端通过导线与可调功率电感连接；所述可调功率电感为电感量根据放电时间要求可调的功率电感，两端并联有功率电阻、续流二极管保护电路；

[0015]

The upper layer inside the trolley-type frame is equipped with a vacuum experimental chamber, and needle-shaped electrode discharge tubes are installed inside the vacuum experimental chamber via discharge clamps.

所述推车式机架内部上层安装有真空实验舱，所述真空实验舱内部通过放电夹具安装有针状电极放电管。

[n0010]

Furthermore, in the Joule heating device applicable to the flash Joule heating process described above, a discharge resistor is installed in parallel on each electrode of the parallel capacitor bank, the negative terminal of the parallel capacitor bank is connected to the negative terminal interface of the vacuum experimental chamber by a wire, and the output terminal of the adjustable power inductor is connected to the positive terminal interface of the vacuum experimental chamber by a wire.

进一步地，上述适用闪光焦耳加热工艺的焦耳加热设备中，所述并联电容组的每一电极上并联安装有泄放电阻，所述并联电容组的负极由导线连接至真空实验舱的负极接口，所述可调功率电感的输出端由导线连接至真空实验舱的正极接口。

[n0011]

Furthermore, in the Joule heating equipment applicable to the flash Joule heating process described above, the vacuum pump is connected to the top cover of the vacuum experimental chamber via a vacuum pipeline, the vacuum pump provides a vacuum environment inside the vacuum experimental chamber, and the top cover of the vacuum experimental chamber is equipped with a vacuum pressure gauge and an air inlet valve.

进一步地，上述适用闪光焦耳加热工艺的焦耳加热设备中，所述真空泵由真空管路连接至真空实验舱的上盖，所述真空泵为真空实验舱内部提供真空环境，所述真空实验舱的上盖安装有真空压力表和进气阀。

[n0012]

Furthermore, in the Joule heating equipment applicable to the flash Joule heating process described above, the thyristor rectifier power supply provides charging current for the parallel capacitor bank, and the low-voltage switching power supply provides control power for the entire equipment.

进一步地，上述适用闪光焦耳加热工艺的焦耳加热设备中，所述可控硅整流电源为并联电容组提供充电电流，所述低压开关电源为整个设备提供控制电源；

[0019]

The upper back of the trolley-type frame is equipped with a circuit breaker, voltmeter, ammeter and indicator light, and the lower back of the trolley-type frame is equipped with a fast discharge switch, dual remote control switch and potentiometer.

所述推车式机架背部上方安装有断路器、电压表、电流表和指示灯，所述推车式机架背部下方安装有快速放电开关、双路遥控开关和电位器；

[0020]

The circuit breaker provides power supply switching for the entire equipment; the voltmeter is connected in parallel across the parallel capacitor bank to measure the voltage of the parallel capacitor bank.

所述断路器为整个设备提供供电通断；所述电压表并联于并联电容组两极，用于测量并联电容组电压；

[0021]

The ammeter is connected in series with the output terminal of the thyristor rectifier power supply and is used to measure the charging current of the thyristor rectifier power supply to the parallel capacitor bank.

所述电流表串联于可控硅整流电源输出端，用于测量可控硅整流电源对并联电容组的充电电流；

[0022]

The indicator light is a small incandescent lamp connected in parallel to the two poles of the parallel capacitor bank to assist in indicating the energy storage status of the parallel capacitor bank.

所述指示灯为小型白炽灯，并联于并联电容组两极，辅助指示并联电容组能量存储情况。

[n0013]

Furthermore, in the Joule heating device applicable to the flash Joule heating process described above, the fast discharge switch is connected in series with a power resistor, and the fast discharge switch is connected to the two poles of the parallel capacitor bank to quickly release the remaining electrical energy in the parallel capacitor bank.

进一步地，上述适用闪光焦耳加热工艺的焦耳加热设备中，所述快速放电开关串联有功率电阻，所述快速放电开关连接于并联电容组两极，用于快速释放并联电容组中剩余的电能；

[0024]

One of the dual-channel remote control switches is connected to the power supply interface of the thyristor rectifier power supply to control the start and stop of the thyristor rectifier power supply, and the other is connected to the control terminal of the DC contactor to control the on and off of the DC contactor.

所述双路遥控开关其中一路连接于可控硅整流电源的供电接口，用于控制可控硅整流电源的启停，另一路连接于直流接触器的控制端，用于控制直流接触器的通断；

[0025]

The potentiometer is connected to the control interface of the thyristor rectifier power supply and is used to control the output current of the thyristor rectifier power supply.

所述电位器连接于可控硅整流电源的控制接口，用于控制可控硅整流电源的输出电流大小。

[n0014]

Furthermore, in the Joule heating equipment applicable to the flash Joule heating process described above, the discharge fixture consists of a base plate, a slider, a screw bracket, a copper screw, and a spring. The slider is mounted on the base plate and can slide freely left and right on the base plate and lock at any position. A screw bracket is fixed on the slider, and a copper screw is mounted on the screw bracket. A spring is mounted on the copper screw. The copper screw has a symmetrical structure and carries a needle-shaped electrode discharge tube in the middle.

进一步地，上述适用闪光焦耳加热工艺的焦耳加热设备中，所述放电夹具由底板、滑块、螺钉支架、铜螺钉和弹簧组成，所述底板上安装有滑块，所述滑块能够在底板上左右自由滑动并能够在任意位置锁止，所述滑块上固定有螺钉支架，所述螺钉支架上安装有铜螺钉，所述铜螺钉上安装有弹簧，所述铜螺钉为左右对称结构，中间承载着针状电极放电管。

[n0015]

Furthermore, in the Joule heating equipment applicable to the flash Joule heating process described above, the Joule heating equipment is equipped with a capacitor energy storage inductor power control system for ensuring continuous discharge efficiency. The capacitor energy storage inductor power control system includes a thyristor rectifier power supply, a thyristor controller, an anti-reverse diode a, an optocoupler a, an adjustable power inductor, an inverter power controller, a needle electrode discharge tube, an optocoupler b, an anti-reverse diode b, and a capacitor bank.

进一步地，上述适用闪光焦耳加热工艺的焦耳加热设备中，所述焦耳加热设备设有用于保障连续放电工作效率的电容储能电感功率控制系统，所述电容储能电感功率控制系统包括可控硅整流电源、可控硅控制器、防反流二极管a、光耦合开关a、可调功率电感、逆变电源控制器、针状电极放电管、光耦合开关b、防反流二极管b和电容组；

[0028]

The thyristor rectifier power supply is connected to AC mains power, and the rectifier output is controlled by the thyristor controller to supply power to the capacitor bank; the capacitor bank discharges the needle electrode discharge tube through a series adjustable power

inductor, and the adjustable power inductor can adjust the inductive reactance to control the discharge time. The capacitor bank controls the power by adjusting the capacitance and the charging voltage.

所述可控硅整流电源接有交流市电，由可控硅控制器控制整流输出给电容组供电；所述电容组通过串联的可调功率电感对针状电极放电管进行放电，所述可调功率电感能够调整感抗大小以控制放电时间，所述电容组通过容量调整、充电电压的高低调整来实现控制功率；

[0029]

The inverter power controller can feed the energy stored after the power inductor is working back to the thyristor rectifier power supply for the next capacitor energy storage.

所述逆变电源控制器能够将功率电感工作后存储的能量回馈可控硅整流电源用于下次电容储能。

[n0016]

The beneficial effects of this invention are:

本发明的有益效果是：

[0031]

1. The needle-shaped electrode discharge tube provided by the present invention has a reasonable structural design. The discharge tube is mainly composed of two ceramic tubes, upper and lower. The outer wall of the upper tube can be embedded in the inner wall of the lower tube to form a working discharge space. The upper and lower detachable structure is conducive to rapid loading and unloading. The electrode in the discharge tube is a needle-shaped platinum electrode. With the help of a capacitor bank, high-voltage discharge can be achieved, and the temperature can reach more than 3000K in milliseconds.

1、本发明提供的针状电极放电管结构设计合理，其放电管主要由上下两个陶瓷管体组成，上管体外壁可以嵌入下管体内壁形成工作放电空间，上下脱开式结构有利于快速装料出料，放电管中的电极为针状铂电极，配合电容器组可实现高压放电在毫秒时间内就可以达到3000K以上的温度。

[n0017]

2. The Joule heating device provided by this invention is an ultra-high voltage discharge heating device, which has the characteristics of controllable discharge energy, discharge voltage and discharge time, and can measure discharge time and discharge temperature. The whole process is automatically controlled or manually remote controlled, and the electrical performance is safe. Compared with traditional Joule heating devices, the device has better safety and controllability, which provides a guarantee for the batch, stable and controllable preparation of graphene.

2、本发明提供的焦耳加热设备为超高电压放电加热设备，具有放电能量、放电电压、放电时间可控的特点，并可测量放电时间和放电温度，全过程自动化控制或人工遥控控制，电气性能安全，相对传统焦耳加热设备，设备安全性和可控性更好，为批量化、稳定可控制备石墨烯提供了保证。

[n0018]

3. The discharge clamp of the Joule heating device of the present invention is reasonably designed. Before use, disconnect all power supplies, check the voltmeter and indicator lights, and ensure that the capacitor is in an uncharged state.

3、本发明焦耳加热设备的放电夹具设计合理，使用前先断开所有电源，检查电压表和指示灯，保证电容处于未储能状态。

The target reactant (carbon source) is loaded into the needle electrode discharge tube. The needle electrode discharge tube is placed in the middle of the discharge fixture. The slider spacing is adjusted, and the two ends are held in place by copper screw heads. The spring is in a properly compressed state.

在针状电极放电管中装入目标反应物（碳源），将针状电极放电管置于放电夹具中间，调整滑块间距，用铜螺钉头顶住两端，弹簧处于适当压紧状态。

Place the discharge fixture in the vacuum experimental chamber, connect the two copper screws to the positive and negative electrodes in the experimental chamber with wires, and close the top cover.

将放电夹具置于真空实验舱中，将两头铜螺丝用导线连接至实验舱中的正负电极，盖好上盖。

Close the air inlet valve, connect the power supply to the equipment, turn on the circuit breaker, and turn on the vacuum pump.

关闭进气阀，接通设备电源，接通断路器，打开真空泵。

Observe the vacuum gauge reading and turn off the vacuum pump after the vacuum is reached.

观察真空表指示，待抽气至真空状态后关闭真空泵。

Turn on the first remote control switch to connect the thyristor rectifier power supply to charge the capacitor.

打开第一路遥控开关，接通可控硅整流电源为电容充电。

By observing the ammeter and voltmeter, the charging current can be adjusted using a potentiometer.

观察电流表和电压表，可用电位器调整充电电流大小。

After charging to the target voltage, turn off the first remote control switch and disconnect the thyristor rectifier power supply.

待充电至目标电压后，关闭第一路遥控开关，断开可控硅整流电源。

Turn on the second remote control switch to connect the DC contactor and instantly perform Joule discharge on the target reactant (carbon source). After the reaction is complete, turn off the second remote control switch and disconnect the DC contactor.

打开第二路遥控开关，接通直流接触器，瞬间对目标反应物（碳源）进行焦耳放电，反应完成后关闭第二路遥控开关，断开直流接触器。

After shutting off the circuit breaker and opening the air inlet valve, wait for the pressure inside the vacuum test chamber to balance with the external pressure before opening the top cover and taking out the discharge clamp.

关闭断路器，打开进气阀待真空实验舱内压力和外部平衡后，打开上盖，取出放电夹具。

Release the slider, remove the needle-shaped electrode discharge tube, and obtain the prepared graphene.

松开滑块，取出针状电极放电管，得到制备好的石墨烯。

[n0019]

Of course, any product implementing this invention does not necessarily need to achieve all of the above advantages at the same time.

当然，实施本发明的任一产品并不一定需要同时达到以上的所有优点。

[0035]

Attached Figure Description

附图说明

[n0020]

To more clearly illustrate the technical solutions of the embodiments of the present invention, the accompanying drawings used in the description of the embodiments will be briefly introduced below. Obviously, the drawings described below are only some embodiments of the present invention. For those skilled in the art, other drawings can be obtained based on these drawings without creative effort.

为了更清楚地说明本发明实施例的技术方案，下面将对实施例描述所需要使用的附图作简单地介绍，显而易见地，下面描述中的附图仅仅是本发明的一些实施例，对于本领域普通技术人员来讲，在不付出创造性劳动的前提下，还可以根据这些附图获得其他的附图。

[n0021]

Figure 1 is a schematic diagram of the needle-shaped electrode discharge tube in this invention;

图1为本发明中针状电极放电管的结构示意图；

[0038]

Figure 2 is a front view schematic diagram of the Joule heating device in this invention;

图2为本发明中焦耳加热设备的主视示意图；

[0039]

Figure 3 is a side view of the Joule heating device in this invention;

图3为本发明中焦耳加热设备部分的侧视示意图；

[0040]

Figure 4 is a schematic diagram of the discharge fixture in this invention;

图4为本发明中放电夹具的结构示意图；

[0041]

Figure 5 is a block diagram of the capacitor energy storage inductor power control system in this invention;

图5为本发明中电容储能电感功率控制系统的组成框图；

[0042]

The attached diagram lists the components represented by each number as follows:

附图中，各标号所代表的部件列表如下：

[0043]

01-Trolley-type frame, 02-Parallel capacitor bank, 03-Vacuum pump, 04-DC contactor, 05-Adjustable power inductor, 06-Power resistor, 07-Freewheeling diode, 08-SCR rectifier power supply, 09-Low-voltage switching power supply, 10-Vacuum experimental chamber, 11-Discharge clamp, 12-Bleeding resistor, 13-Negative interface, 14-Vacuum tubing, 15-Vacuum pressure gauge, 16-Inlet valve, 17-Positive 18-Circuit breaker, 19-Voltmeter, 20-Ammeter, 21-Indicator light, 22-Fast discharge switch, 23-Dual remote control switch, 24-Polypotentiometer, 25-Base plate, 26-Slider, 27-Screw bracket, 28-Copper screw, 29-Spring, 30-Needle-shaped electrode discharge tube, 301-Upper electrode, 302-Upper tube body, 303-Lower tube body, 304-Lower electrode, 305-Needle-shaped electrode.

01-推车式机架，02-并联电容组，03-真空泵，04-直流接触器，05-可调功率电感，06-功率电阻，07-续流二极管，08-可控硅整流电源，09-低压开关电源，10-真空实验舱，11-放电夹具，12-泄放电阻，13-负极接口，14-真空管路，15-真空压力表，16-进气阀，17-正极接口，18-断路器，19-电压表，20-电流表，21-指示灯，22-快速放电开关，23-双路遥控开关，24-电位器，25-底板，26-滑块，27-螺钉支架，28-铜螺钉，29-弹簧，30-针状电极放电管，301-上电极，302-上管体，303-下管体，304-下电极，305-针状电极。

[0044]

Detailed Implementation

具体实施方式

[n0022]

The technical solutions of the present invention will be clearly and completely described below with reference to the accompanying drawings of the embodiments of the present invention. Obviously, the described embodiments are only some embodiments of the present invention, and not all embodiments.

下面将结合本发明实施例中的附图，对本发明实施例中的技术方案进行清楚、完整地描述，显然，所描述的实施例仅仅是本发明一部分实施例，而不是全部的实施例。

Based on the embodiments of the present invention, all other embodiments obtained by those skilled in the art without creative effort are within the scope of protection of the present invention.

基于本发明中的实施例，本领域普通技术人员在没有作出创造性劳动前提下所获得的所有其它实施例，都属于本发明保护的范围。

[n0023]

Example 1

实施例一

[0047]

As shown in Figure 1, this embodiment provides a needle-shaped electrode discharge tube suitable for flash Joule heating process. The needle-shaped electrode discharge tube 30 includes an upper electrode 301, an upper tube body 302, a lower tube body 303, and a lower electrode 304. Both the upper tube body 302 and the lower tube body 303 are open tube bodies, and the outer diameter of the upper tube body 302 and the inner diameter of the lower tube body 303 are matched. The upper electrode 301 is installed at the end of the upper tube body 302 away from the opening, and the lower electrode 304 is installed at the end of the lower tube body 303 away from the opening. Each of the upper electrode 301 and the lower electrode 304 has a plurality of needle-shaped electrodes 305 that are uniformly

distributed in a circumferential direction in the part of its respective tube body. The positions of the needle-shaped electrodes 305 in the upper electrode 301 and the lower electrode 304 are staggered.

如图1所示，本实施例提供一种适用闪光焦耳加热工艺的针状电极放电管，该针状电极放电管30包括上电极301、上管体302、下管体303和下电极304，上管体302和下管体303均为开口管体，且上管体302的外径与下管体303的内径相互配合，上管体302位于远离开口的端部安装有上电极301，下管体303位于远离开口的端部安装有下电极304，上电极301、下电极304各自位于所在管体中部分形成有若干呈周向均匀分布的针状电极305，上电极301、下电极304中的针状电极305位置相互错开。

[n0024]

In this embodiment, both the upper tube 302 and the lower tube 303 are ceramic tubes.

本实施例中，上管体302和下管体303均为陶瓷管。

[n0025]

In this embodiment, the needle electrode 305 is a platinum electrode.

本实施例中，针状电极305为铂电极。

[n0026]

In this embodiment, the outer wall of the upper tube 302 can be embedded in the inner wall of the lower tube 303 to form a working discharge space. The detachable upper and lower structure design is conducive to rapid loading and unloading.

本实施例，上管体302外壁可以嵌入下管体303内壁形成工作放电空间，上下脱开式的结构设计有利于快速装料出料。

[n0027]

Example 2

实施例二

[0052]

As shown in Figures 2 and 3, this embodiment provides a Joule heating device suitable for flash Joule heating process. The Joule heating device includes a trolley frame 01, and a parallel capacitor bank 02 is installed in the lower layer inside the trolley frame 01.

如图2和图3所示，本实施例提供一种适用闪光焦耳加热工艺的焦耳加热设备，该焦耳加热设备包括推车式机架01，推车式机架01内部下层安装有并联电容组02。

[n0028]

The trolley-type frame 01 houses a vacuum pump 03, a DC contactor 04, an adjustable power inductor 05, a power resistor 06, a freewheeling diode 07, a thyristor rectifier power supply 08, and a low-voltage switching power supply 09 in its middle layer. One end of the DC contactor 04 is connected to the positive terminal of the parallel capacitor bank 02 via a wire, and the other end is connected to the adjustable power inductor 05 via a wire. The adjustable power inductor 05 is a power inductor whose inductance is adjustable according to the discharge time requirement, and a power resistor 06 and a freewheeling diode 07 are connected in parallel across its two ends for protection circuitry.

推车式机架01内部中层安装有真空泵03、直流接触器04、可调功率电感05、功率电阻06、续流二极管07、可控硅整流电源08和低压开关电源09；直流接触器04的电极一端通过导线与并联电容组02的正极相连接，另一端通过导线与可调功率电感05连接；可调功率电感05为电感量根据放电时间要求可调的功率电感，两端并联有功率电阻06、续流二极管07保护电路。

[n0029]

The upper part of the trolley-type frame 01 is equipped with a vacuum test chamber 10, and a needle-shaped electrode discharge tube 30 is installed inside the vacuum test chamber 10 through a discharge clamp 11.

推车式机架01内部上层安装有真空实验舱10，真空实验舱10内部通过放电夹具11安装有针状电极放电管30。

[n0030]

In this embodiment, a discharge resistor 12 is installed in parallel on each electrode of the parallel capacitor bank 02. The negative terminal of the parallel capacitor bank 02 is connected to the negative terminal interface 13 of the vacuum experimental chamber 10 by a wire. The output terminal of the adjustable power inductor 05 is connected to the positive terminal interface 17 of the vacuum experimental chamber 10 by a wire.

本实施例中，并联电容组02的每一电极上并联安装有泄放电阻12，并联电容组02的负极由导线连接至真空实验舱10的负极接口13，可调功率电感05的输出端由导线连接至真空实验舱10的正极接口17。

[n0031]

In this embodiment, the vacuum pump 03 is connected to the top cover of the vacuum test chamber 10 via the vacuum pipeline 14. The vacuum pump 03 provides a vacuum environment inside the vacuum test chamber 10. The top cover of the vacuum test chamber 10 is equipped with a vacuum pressure gauge 15 and an air inlet valve 16.

本实施例中，真空泵03由真空管路14连接至真空实验舱10的上盖，真空泵03为真空实验舱10内部提供真空环境，真空实验舱10的上盖安装有真空压力表15和进气阀16。

[n0032]

In this embodiment, the thyristor rectifier power supply 08 provides charging current for the parallel capacitor bank 02, and the low-voltage switching power supply 09 provides control power for the entire device.

本实施例中，可控硅整流电源08为并联电容组02提供充电电流，低压开关电源09为整个设备提供控制电源；

[0058]

The upper back of the trolley rack 01 is equipped with a circuit breaker 18, a voltmeter 19, an ammeter 20 and an indicator light 21, and the lower back of the trolley rack 01 is equipped with a fast discharge switch 22, a dual-channel remote control switch 23 and a potentiometer 24.

推车式机架01背部上方安装有断路器18、电压表19、电流表20和指示灯21，推车式机架01背部下方安装有快速放电开关22、双路遥控开关23和电位器24；

[0059]

Circuit breaker 18 provides power supply switching for the entire equipment; voltmeter 19 is connected in parallel across the parallel capacitor bank 02 to measure the voltage of the parallel capacitor bank 02.

断路器18为整个设备提供供电通断；电压表19并联于并联电容组02两极，用于测量并联电容组02电压；

[0060]

Ammeter 20 is connected in series with the output terminal of the thyristor rectifier power supply 08 to measure the charging current of the thyristor rectifier power supply 08 to the parallel capacitor bank 02.

电流表20串联于可控硅整流电源08输出端，用于测量可控硅整流电源08对并联电容组02的充电电流；

[0061]

Indicator light 21 is a small incandescent lamp connected in parallel to the two poles of parallel capacitor bank 02 to assist in indicating the energy storage status of parallel capacitor bank 02.

指示灯21为小型白炽灯，并联于并联电容组02两极，辅助指示并联电容组02能量存储情况。

[n0033]

In this embodiment, the fast discharge switch 22 is connected in series with a power resistor and is connected to the two poles of the parallel capacitor bank 02 to quickly release the remaining electrical energy in the parallel capacitor bank 02.

本实施例中，快速放电开关22串联有功率电阻，快速放电开关22连接于并联电容组02两极，用于快速释放并联电容组02中剩余的电能；

[0063]

One of the dual-channel remote control switches 23 is connected to the power supply interface of the thyristor rectifier power supply 08 to control the start and stop of the thyristor rectifier power supply 08, and the other is connected to the control terminal of the DC contactor 04 to control the on and off of the DC contactor 04.

双路遥控开关23其中一路连接于可控硅整流电源08的供电接口，用于控制可控硅整流电源08的启停，另一路连接于直流接触器04的控制端，用于控制直流接触器04的通断；

[0064]

Potentiometer 24 is connected to the control interface of the thyristor rectifier power supply 08 and is used to control the output current of the thyristor rectifier power supply 08.

电位器24连接于可控硅整流电源08的控制接口，用于控制可控硅整流电源08的输出电流大小。

[n0034]

As shown in Figure 4, the discharge fixture 11 consists of a base plate 25, a slider 26, a screw bracket 27, a copper screw 28, and a spring 29. The slider 26 is mounted on the base plate 25. The slider 26 can slide freely left and right on the base plate and can be locked at any position. The screw bracket 27 is fixed on the slider 26. The copper screw 28 is mounted on the screw bracket 27. The spring 29 is mounted on the copper screw 28. The copper screw 28 has a

symmetrical structure and carries the needle-shaped electrode discharge tube 30 in the middle.

如图4所示，放电夹具11由底板25、滑块26、螺钉支架27、铜螺钉28和弹簧29组成，底板25上安装有滑块26，滑块26能够在底板上左右自由滑动并能够在任意位置锁止，滑块26上固定有螺钉支架27，螺钉支架27上安装有铜螺钉28，铜螺钉28上安装有弹簧29，铜螺钉28为左右对称结构，中间承载着针状电极放电管30。

The needle-shaped electrode discharge tube 30 has connecting seats at the outer ends of the upper tube body 302 and the lower tube body 303 respectively. The inner ends of the copper screws 28 on both sides are restricted to rotate in the corresponding connecting seats. In this way, the opening and closing of the needle-shaped electrode discharge tube 30 can be realized by using the copper screws 28.

针状电极放电管30中上管体302、下管体303的外端分别设有连接座，两侧所述铜螺钉28的内端部转动限制在对应的连接座中，这样利用铜螺钉28可实现针状电极放电管30的开合。

[n0035]

As shown in Figure 5, the Joule heating equipment is equipped with a capacitor energy storage inductor power control system to ensure continuous discharge efficiency. The capacitor energy storage inductor power control system includes a thyristor rectifier power

supply, a thyristor controller, an anti-reverse diode a, an optocoupler switch a, an adjustable power inductor, an inverter power supply controller, a needle electrode discharge tube, an optocoupler switch b, an anti-reverse diode b, and a capacitor bank.

如图5所示，焦耳加热设备设有用于保障连续放电工作效率的电容储能电感功率控制系统，电容储能电感功率控制系统包括可控硅整流电源、可控硅控制器、防反流二极管a、光耦合开关a、可调功率电感、逆变电源控制器、针状电极放电管、光耦合开关b、防反流二极管b和电容组；

[0067]

The thyristor rectifier power supply is connected to AC mains power, and the rectifier output is controlled by the thyristor controller to supply power to the capacitor bank. The capacitor bank discharges to the needle electrode discharge tube through the series adjustable power inductor. The adjustable power inductor can adjust the inductive reactance to control the discharge time. The capacitor bank controls the power by adjusting the capacitance and the charging voltage.

可控硅整流电源接有交流市电，由可控硅控制器控制整流输出给电容组供电；电容组通过串联的可调功率电感对针状电极放电管进行放电，可调功率电感能够调整感抗大小以控制放电时间，电容组通过容量调整、充电电压的高低调整来实现控制功率；

[0068]

The inverter power controller can feed the energy stored after the power inductor has been in operation back to the thyristor rectifier power supply for the next capacitor energy storage, ensuring continuous discharge efficiency.

逆变电源控制器能够将功率电感工作后存储的能量回馈可控硅整流电源用于下次电容储能，保障连续放电工作效率。

[n0036]

One specific application of this embodiment is:

本实施例的一个具体应用为：

[0070]

The method for mass-producing graphene using the Joule heating equipment provided in Example 2 specifically includes the following steps:

以实施例二提供的焦耳加热设备来批量生产石墨烯的方法，具体包括如下步骤：

[0071]

1) Grind the organic carbon material and graphite into powder and sieve them through a 200-400 mesh sieve, and then dry them until the moisture content is less than 100 ppm; the organic carbon material is an organic compound with a carbon content of more than 50%, including but not limited to: coke, coke, acrylonitrile and viscose fiber.

1）将有机碳物质、石墨磨粉各自过200~400目筛进行筛分，并经过烘干，烘干至水分含量低于100ppm；有机碳物质为碳含量大于50%有机化合物，包括但不局限于：精煤、焦炭、腈纶和粘胶纤维；

[0072]

2) The treated organic carbon material and graphite powder are mechanically mixed at a mass ratio of 3~5:1 for a period of time, and then filled into the needle electrode discharge tube. The two ends are pressed with copper screws of the discharge clamp. The resistance measured by the multimeter is no greater than 1kΩ.

2）将处理后有机碳物质、石墨磨粉按质量比3~5：1机械共混一段时间，而后填充到针状电极放电管中，两头以放电夹具的铜螺钉压紧，用万用表测得电阻不大于1kΩ；

[0073]

3) Place the discharge fixture into the vacuum test chamber and continue to evacuate until the target vacuum level is less than 10 Pa;

3）将放电夹具放入真空实验舱，持续抽真空至目标真空度小于10Pa；

[0074]

4) Select a capacitor with a total capacity of 100mF in parallel, adjust the inductance to 24mH, and charge and discharge it 2-4 times at 100V under vacuum conditions; then charge it at 250V, adjust the inductance to 12mH, and operate the remote control to perform Joule fast discharge to obtain high-quality graphene deposits.

4）选用并联总容量为100mF的电容器，将电感调整至24mH，在真空条件下以100V充放电操作2-4次；再以250V电压充电，将电感调整至12mH，操作遥控器进行焦耳快速放电，即可得到高品质的石墨烯沉积物。

[n0037]

The preferred embodiments of the present invention disclosed above are merely for the purpose of illustrating the present invention.

以上公开的本发明优选实施例只是利于帮助阐述本发明。

The preferred embodiments do not describe all the details, nor do they limit the invention to specific implementation methods.

优选实施例并没有详尽叙述所有的细节，也不限制该发明仅为具体实施方式。

Obviously, many modifications and changes can be made based on the contents of this instruction manual.

显然，根据本说明书的内容，可作很多的修改和变化。

These embodiments are selected and specifically described in this specification in order to better explain the principles and practical applications of the present invention, so that those skilled in the art can better understand and utilize the present invention.

本说明书选取并具体描述这些实施例，是为了更好地解释本发明的原理和实际应用，从而使所属技术领域技术人员能很好地理解和利用本发明。

This invention is limited only by the claims and their full scope and equivalents.

本发明仅受权利要求书及其全部范围和等效物的限制。