

## **A metal rod inside a radio frequency electrode assembly and radio frequency electrode assembly**

### **Technical field**

The present invention relates to radio frequency electrode assemblies, particularly to a metal rod structure inside a radio frequency electrode assembly and a radio frequency electrode assembly comprising the metal rod.

### **Background**

Radio frequency electrodes are widely used in semiconductor film deposition equipment. During the film deposition process, the frequency and power of the radio frequency electrodes can precisely control the ion energy and density, thereby achieving the adjustment of quality and performance of the film. Specifically, the radio frequency electrodes activate atoms or molecules in the deposition gas by providing high-frequency electrical energy, causing them to deposit on a substrate surface to form a film. The radio frequency electrodes can provide a stable high-frequency electric field, giving the atoms or molecules in the deposition gas sufficient energy to be fully activated, which facilitates the uniform deposition and excellent crystallization performance of the film.

In addition, radio frequency electrodes are widely used in semiconductor surface cleaning processes. During the semiconductor manufacturing process, various impurities and harmful substances often adhere to the semiconductor surface, which requires cleaning to improve device performance. Radio frequency electrodes excite ions in the cleaning solution by providing high-frequency electrical energy, thereby achieving cleaning of the semiconductor surface. Therefore, radio frequency electrodes play an important role in semiconductor film deposition equipment and are crucial for controlling the quality and performance of the films.

The radio frequency electrode device in semiconductor film deposition equipment is used to generate a radio frequency electric field to assist in controlling the film deposition process. In this process, the metal rod in the radio frequency electrode assembly plays a crucial role. The metal rod is generally made of highly conductive materials such as copper or aluminum. These materials have excellent conductivity and corrosion resistance, enabling effective transmission of radio frequency signals and maintaining the stability of the equipment.

More specifically, the metal rod, as a conductive medium, can effectively transmit radio frequency signals to help generate and maintain radio frequency electric fields. It is usually fixed in a suitable position on the electrode device to provide stable support and ensure that the electrode device is in the correct position. In some cases, the metal rod can also serve as a cooling channel to help transfer and disperse the heat generated during equipment operation, thereby maintaining stable equipment operation. In addition, the metal rod can also act as a shield to reduce the impact of external electromagnetic interference on the equipment, and reduce potential radiation damage to operators.

In semiconductor film deposition equipment, the design and manufacturing of metal rods need to consider factors such as their size, shape, material, and their position in the equipment. These factors directly affect the performance and stability of the equipment. Therefore, designing reasonable metal rods is crucial for optimizing the performance of semiconductor film deposition equipment.

However, in the prior art, the metal rod enclosed within an externally insulated support component is usually directly abutted to subsequent radio frequency electrode components, while its front end is directly connected to the electrode plate on the heater inside the semiconductor process chamber. During the process, the temperature of the heater rises to an extremely high level, and the metal rod also needs to conduct high-power radio frequency signals to the heater. For example, in common film deposition processes, it is necessary to conduct more than 3000W of radio frequency power to the electrode plate on the heater at a temperature of 650°C or even higher, which often leads to the burnout of the metal rod, causing equipment damage, affecting the control of process parameters, and requiring frequent replacement of the metal rod, which brings inconvenience to equipment maintenance.

In order to overcome the above shortcomings of the prior art, there is an urgent need in this field for a metal rod inside a radio frequency electrode assembly and a radio frequency electrode assembly, for optimizing the device structure of the metal rod, adding thermal insulation components to reduce heat conduction within the metal rod, while relieving stress caused by thermal expansion and contraction due to temperature changes, extending the service life of the metal rod and reducing the frequency of radio frequency electrode device faults.

## Summary

A brief overview of one or more aspects is provided below to provide a basic understanding of these aspects. The summary is not an exhaustive overview of all aspects envisaged, and is neither intended to identify the key or decisive elements of all aspects nor to attempt to define the scope of any or all aspects. The sole purpose of the summary is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

In order to overcome the above shortcomings of the prior art, the present invention provides a metal rod inside a radio frequency electrode assembly, enclosed within an electrode support component, wherein one end of the metal rod is connected to a radio frequency electrode plate within a heater, another end of the metal rod is connected to a subsequent radio frequency component, the metal rod is cut into two sections with a gap at a position enclosed by the electrode support component, and the two sections of the metal rod are connected by a metal spring plate.

In an embodiment, preferably, in the metal rod inside the radio frequency electrode assembly provided by the present invention, the metal spring plate comprises a plurality of parallel-connected metal spring plates.

In an embodiment, preferably, in the metal rod inside the radio frequency electrode assembly provided by the present invention, at least one of the plurality of parallel-connected metal spring plates is provided with a bending portion.

In an embodiment, preferably, in the metal rod inside the radio frequency electrode assembly provided by the present invention, the plurality of parallel-connected metal spring plates comprises two metal spring plates with the same shape and placed in parallel.

In one embodiment, preferably, in the metal rod inside the radio frequency electrode assembly provided by the present invention, both of the two metal spring plates with the same shape and placed in parallel are provided with bending portions, and the bending portions are disposed in the gap between the two sections of the metal rod and not in contact with the two sections of the metal rod on both sides thereof.

In an embodiment, preferably, in the metal rod inside the radio frequency electrode assembly provided by the present invention, the two sections of the metal rod are in flat strip shapes and ends of the two metal spring plates are in straight strip shapes, at connections between the two sections of the metal rod and the two metal spring plates,

thereby clamping each section of the metal rod between the ends of the two metal spring plates, and then fixing the connections with bolts.

In an embodiment, preferably, in the metal rod inside the radio frequency electrode assembly provided by the present invention, a steel block is further provided at the connections between the two sections of the metal rod and the two metal spring plates, and on an opposite side of nuts of the bolts, and a shape and a size of the steel block are matched with shapes and sizes of the flat strip shapes of the two sections of the metal rod, thereby fastening the connections between the two sections of the metal rod and the two metal spring plates.

In an embodiment, preferably, in the metal rod inside the radio frequency electrode assembly provided by the present invention, a contact area between the metal rod and the metal spring plates is within a range of  $6.37 \text{ mm}^2$  to  $37.8 \text{ mm}^2$ .

In an embodiment, preferably, in the metal rod inside the radio frequency electrode assembly provided by the present invention, the metal spring plate is elastic, and a gap space is left around the bending portion of the metal spring plate when the radio frequency electrode is assembled, for it to deform and release stress.

Another aspect of the present invention also provides a radio frequency electrode assembly, comprising a metal rod as described in any of the above embodiments. The metal rod is cut into two sections at a position enclosed by the electrode support component, and the two sections of the metal rod are connected by a metal spring plate, which can effectively reduce temperature and provide thermal insulation, preventing damage to the metal rod due to excessive temperature at the electrode plate, further extending the service life of the radio frequency electrode assembly and reducing production costs.

### **Brief Description of the Drawings**

The above features and advantages of the present invention will be better understood after reading the detailed description of the embodiments of the present invention in conjunction with the following figures. In the figures, components are not necessarily drawn to scale, and components having similar related features may have the same or similar reference numerals.

Fig. 1 is a schematic diagram of the assembly structure of a metal rod inside a radio

frequency electrode assembly according to an embodiment of the prior art;

Fig. 2 is a physical photo of a burnt metal rod according to an embodiment of the prior art;

Fig. 3 is a schematic diagram of the assembly structure of a metal rod inside a radio frequency electrode assembly according to an embodiment of the present invention; and

Fig. 4 is a schematic diagram of the device structure of a partial enlargement of the metal rod at area A in Fig. 3 according to an embodiment of the present invention.

For clarity, a brief explanation of the reference numerals is provided below:

|     |                                                |
|-----|------------------------------------------------|
| 101 | metal rod                                      |
| 102 | subsequent radio frequency electrode component |
| 103 | support component                              |
| 201 | burnt metal rod                                |
| 301 | support component                              |
| 401 | first metal rod                                |
| 402 | second metal rod                               |
| 403 | first metal spring plate                       |
| 404 | second metal spring plate                      |
| 405 | steel block                                    |
| 406 | bolt                                           |

### **Detailed Description of Embodiments**

The implementations of the present invention are described below by specific embodiments. Those skilled in the art can easily understand other advantages and effects of the present invention from the contents disclosed in the description. Although the description of the present invention is introduced together with preferred embodiments, it does not mean that the features of the present invention are limited to the embodiments. On the contrary, the purpose of introducing the present invention in combination with the embodiments is to cover other options or modifications that may be extended based on the claims of the present invention. In order to provide a deep understanding of the present invention, the following description will contain many specific details. The present invention can also be practiced without using these details. In addition, in order to avoid

confusion or ambiguity of the key points of the present invention, some specific details are omitted in the description.

In the description of the present invention, it should be noted that, unless otherwise specified and defined, the terms "installation", "connection" and "joining" should be understood in a broad sense. For example, they can be fixed connection, removable connection or integrated connection; mechanical connection or electrical connection; as well as direct connection, indirect connection through intermediate media or internal connection of two components. For those skilled in the art, the specific meaning of the above terms in the present invention can be understood in specific cases.

In addition, the words "up", "down", "left", "right", "top", "bottom", "horizontal" and "vertical" used in the following description should be understood as the orientation shown in this paragraph and the relevant drawings. This relative terms are only for convenience of explanation, and does not mean that the described device needs to be manufactured or operated in a specific direction, so it should not be understood as a limitation of the present invention.

It is understood that although the terms "first", "second", "third", etc. can be used here to describe various components, regions, layers and/or parts, these components, regions, layers and/or parts should not be limited by these terms, and these terms are only used to distinguish different components, regions, layers and/or parts. Therefore, a first component, area, layer and/or part discussed below can be referred to as a second component, area, layer and/or part without departing from some embodiments of the present invention.

Fig. 1 is a schematic diagram of the assembly structure of a metal rod inside a radio frequency electrode assembly according to an embodiment of the prior art.

As shown in Fig. 1, in the prior art, the metal rod 101 enclosed within an externally insulated support component 103 is usually directly abutted to a subsequent radio frequency electrode component 102, while its front end is directly connected to the electrode plate on a heater inside the semiconductor process chamber.

During the process, the temperature of the heater rises to an extremely high level, and the metal rod also needs to conduct high-power radio frequency signals to the heater. For example, in common film deposition processes, it is necessary to conduct more than 3000W of radio frequency power to the electrode plate on the heater at a temperature of

650°C or even higher, which often leads to the burnout of the metal rod. Please refer to Fig. 2.

Fig. 2 is a physical photo of a burnt metal rod according to an embodiment of the prior art.

As shown in Fig. 2, the burnout or damage of metal rods can cause equipment damage, which affects the control of process parameters, and thus requires frequent replacement of burnt metal rods 201, bringing inconvenience to equipment maintenance.

In order to overcome the above shortcomings of the prior art, the present invention provides a metal rod inside a radio frequency electrode assembly and a radio frequency electrode assembly, which optimizes the device structure of the metal rod, and adds thermal insulation components to reduce heat conduction within the metal rod, while relieving stress caused by thermal expansion and contraction due to temperature changes, extending the service life of the metal rod and reducing the frequency of radio frequency electrode device faults.

Fig. 3 is a schematic diagram of the assembly structure of a metal rod inside a radio frequency electrode assembly according to an embodiment of the present invention.

Please refer to Fig. 3, a metal rod inside a radio frequency electrode assembly provided by the present invention is enclosed within an electrode support component 301, one end of the metal rod is connected to a radio frequency electrode plate within a heater, another end of the metal rod is connected to a subsequent radio frequency component. The specific structure of the metal rod at A in Fig.3 can be seen in Fig. 4.

Fig. 4 is a schematic diagram of the device structure of a partial enlargement of the metal rod at area A in Fig. 3 according to an embodiment of the present invention.

Please refer to Fig. 4, the metal rod provided by the present invention is cut into two sections with a gap at a position enclosed by the electrode support component, namely the first metal rod 401 and the second metal rod 402 in Fig. 4. The two sections of the metal rod are connected by a metal spring plate.

For example, metal spring plates can be made of copper material, which has good electrical and thermal conductivity.

In a preferred embodiment, in the metal rod inside the radio frequency electrode assembly provided by the present invention, the metal spring plate comprises a plurality of parallel-connected metal spring plates.

Understandably, a plurality of parallel-connected metal spring plates can increase the number of channels that current flows in the metal rod, thereby reducing the current value flowing through each individual spring plate. Taking two parallel-connected metal spring plates as an example, the current  $I$  flowing through each spring plate is  $1/2$  of that in the original structure. According to the heat formula  $Q=I^2R$ , the heat generated by the current on a single spring plate is  $1/4$  of the heat generated by the original structure, and the thin spring plate structure is more conducive to heat dissipation, therefore using a plurality of parallel-connected metal spring plates to connect the two ends of the metal rod can achieve better heat insulation and dissipation effects, reduce the heat conduction of the metal rod itself, and decrease the probability of the burnout thereof.

Further, more preferably, in an embodiment, in the metal rod inside the radio frequency electrode assembly provided by the present invention, at least one of the plurality of parallel-connected metal spring plates is provided with a bending portion.

Understandably, the bending portion on the metal spring plate can extend the heat conduction length of the spring plate as much as possible within a limited space, thereby achieving a better heat dissipation effect.

In the embodiment shown in Fig. 4, the plurality of parallel-connected metal spring plates comprises two metal spring plates with the same shape and placed in parallel, namely the first metal spring plate 403 and the second metal spring plate 404 in Fig. 4.

As shown in Fig. 4, in the embodiment, the first metal spring plate 403 and the second metal spring plate 404, and both of the metal spring plates are provided with bending portions at their middle positions. The bending portions are disposed in the gap between the first metal rod 401 and the second metal rod 402 and not in contact with the two sections of the metal rod on both sides thereof.

It is easy to understand that placing the bending portions in the gap between the two metal rods can save assembly space, thereby making minimal changes to the existing electrode device structure and facilitating production and manufacturing.

Preferably, the metal spring plates are elastic, and gap spaces are left around the bending portions of the metal spring plates when the radio frequency electrode is assembled. On one hand, this allows for faster heat dissipation, and on the other hand, these gap spaces can be used to accommodate deformation and release stress during thermal expansion and contraction due to temperature changes.

It should be noted that the shape, quantity, and arrangement of the bending portions of the corresponding metal spring plates in this embodiment are only illustrative descriptions, which are intended to clearly display the preferred embodiment of the metal rod device structure in the radio frequency electrode assembly provided by the present invention, rather than limiting the scope of protection of the present invention. In fact, it can also adopt more spring plates or other forms of structures that can extend the heat conduction length. Any device structure that achieves a similar heat insulation and dissipation effect can be applied to the metal rod of the electrode assembly provided by the present invention, and should also be included within the scope of protection of the present invention.

In a preferred embodiment, with continued reference to Fig. 4, the metal rod inside a radio frequency electrode assembly provided by the present invention, the two sections of the metal rod are in flat strip shapes and ends of the two metal spring plates are in straight strip shapes, at connections between the two sections of the metal rod and the two metal spring plates, thereby clamping each section of the metal rod between the ends of the two metal spring plates, and then fixing the connections with bolts 406.

Further, more preferably, as shown in Fig. 4, a steel block 405 is further provided at the connections between the two sections of the metal rod and the two metal spring plates, and on an opposite side of nuts of the bolts, and the shape and size of the steel block 405 are matched with the shape and size of the flat strip of the two sections of the metal rod, thereby fastening the connections between the two sections of the metal rod and the two metal spring plates.

The setting of this connection can increase the contact area between the metal spring plates and the metal rod. For example, in the embodiment of the present invention, the contact area between the metal rod and the metal spring plate is within a range of  $6.37 \text{ mm}^2$  to  $37.8 \text{ mm}^2$ .

Those skilled in the art can understand that increasing the contact area at the joint can reduce the contact resistance, thereby reducing the heat generated by the contact, and further enhancing the cooling and heat insulation effect of the electrode metal rod provided by the present invention.

It should be noted that the connection method between the metal rod and the metal spring plate is only provided as an illustrative example, which is intended to offer a

preferred and feasible implementation approach, rather than limiting the scope of protection of the present invention. In fact, other assembly methods that can connect and secure the metal rod and the metal spring plate, or connection structures that can achieve a similar effect of reducing contact heat generation, can all be applied to the metal rod of the radio frequency electrode assembly provided by the present invention, and should also be included within the scope of protection of the present invention.

Another aspect of the present invention also provides a radio frequency electrode assembly, comprising a metal rod as described in any of the above embodiments. The metal rod is cut into two sections at a position enclosed by the electrode support component, and the two sections of the metal rod are connected by a metal spring plate, which can effectively reduce temperature and provide thermal insulation, preventing damage to the metal rod due to excessive temperature at the electrode plate, further extending the service life of the radio frequency electrode assembly and reducing production costs.

The previous description of the present invention is provided to enable any person skilled in the art to make or use the present invention. Various modifications to the present invention will be apparent to those skilled in the art, and the universal principles defined herein can be applied to other variants without departing from the spirit or scope of the present invention. Therefore, the present invention is not intended to be limited to the examples and designs described herein, but should be granted the widest scope consistent with the principles and novel features disclosed herein.

## **Claims**

1. A metal rod inside a radio frequency electrode assembly, enclosed within an electrode support component, wherein one end of the metal rod is connected to a radio frequency electrode plate within a heater, another end of the metal rod is connected to a subsequent radio frequency component, the metal rod is cut into two sections with a gap at a position enclosed by the electrode support component, and the two sections of the metal rod are connected by a metal spring plate.

2. The metal rod according to claim 1, wherein the metal spring plate comprises a plurality of parallel-connected metal spring plates.

3. The metal rod according to claim 2, wherein at least one of the plurality of parallel-connected metal spring plates is provided with a bending portion.

4. The metal rod according to claim 2, wherein the plurality of parallel-connected metal spring plates comprises two metal spring plates with same shape and placed in parallel.

5. The metal rod according to claim 4, wherein both of the two metal spring plates with same shape and placed in parallel are provided with bending portions, and the bending portions are disposed in the gap between the two sections of the metal rod and not in contact with the two sections of the metal rod on both sides thereof.

6. The metal rod according to claim 5, wherein the two sections of the metal rod are in flat strip shapes and ends of the two metal spring plates are in straight strip shapes, at connections between the two sections of the metal rod and the two metal spring plates, thereby clamping each section of the metal rod between the ends of the two metal spring plates, and then fixing the connections with bolts.

7. The metal rod according to claim 6, wherein a steel block is further provided at the connections between the two sections of the metal rod and the two metal spring plates,

and on an opposite side of nuts of the bolts, and

a shape and a size of the steel block are matched with shapes and sizes of the flat strip shapes of the two sections of the metal rod, thereby fastening the connections between the two sections of the metal rod and the two metal spring plates.

8. The metal rod according to claim 6, wherein a contact area between the metal rod and the metal spring plates is within a range of  $6.37 \text{ mm}^2$  to  $37.8 \text{ mm}^2$ .

9. The metal rod according to claim 3 or claim 5, wherein the metal spring plate is elastic, and a gap space is left around the bending portion of the metal spring plate when the radio frequency electrode is assembled.

10. A radio frequency electrode assembly, comprising a metal rod according to any one of claims 1 to 9.