# DETECTION METHOD FOR AIR HOLES IN WELDING SPUTTERING TARGET MATERIAL

## TECHNICAL FIELD

The present application belongs to the field of target material manufacturing techniques, and relates to a method for detecting a target material, for example, to a detection method for air holes in a welding sputtering target material.

## BACKGROUND

In the field of semiconductor industry, for the manufacturing process of sputtering target products, a target material which meets properties of a sputtering target material is generally welded to a back panel, and then rough machined, fine machined, *etc*. to be finally processed into a sputtering target product with a qualified size.

For the welding between metals, there is a problem that porosity in welding seams is difficult to control. The absorbed hydrogen cannot form air holes due to various means which are often taken in the smelting stage, but the hydrogen exists in the material in the form of H atoms. In the process of welding, the high temperature at the welding seam provides enough energy for H atoms to diffuse and form air holes. Meanwhile, with the increase of temperature at the welding seam, the solubility of hydrogen is increased rapidly, and thus the H atoms in a heat affected zone around the welding seam can also diffuse in the welding seam. In addition, the hydrogen decomposed by external water, organic matters and the like can also be absorbed by the welding seam, so the porosity in the welding seam is very difficult to control.

At the same time, the sputtering target materials are generally used in very harsh environments. Firstly, the working temperature is as high as 300 ºC to 400 ºC. Secondly, one side of a target material assembly is filled with cooling water for strong cooling, and the other side is in high vacuum of $10^{-9}$ Pa, so a huge pressure difference is formed between the two sides. If the welding seam has relatively large or many air holes, the temperature around the air holes is rapidly increased due to the heat insulation function of the air holes and is obviously higher than the peripheral area, and thus the welding seam is possibly cracked. In addition, if the welding seam has many holes which then form a through hole, water can permeate to the other side due to pressure difference, thereby damaging the sputtering equipment. Therefore, the air holes in the welding seam need to be reduced as much as possible, and air holes which possibly exist at

the welding seam need to be detected.

CN 101195183 A discloses a method for brazing through lasers with ultrasonic waves as auxiliaries. In the method, lasers are used to braze a coating metal which has a low melting point or lasers are used to braze a dissimilar metal, and simultaneously, ultrasonic waves with high-frequency vibrations are applied in welding zones which will be coagulated, thereby minimizing or avoiding the occurrences of air holes, and lowering welding cost. CN 1962153 A discloses a vacuum electronic beam welding method. The vacuum electronic beam welding method is that after the first vacuum electronic beam welding is finished, the welding assembly is kept warm under vacuum to accumulate the H atoms in the heat affected zone to the welding seam to form air holes, and then the second vacuum electronic beam welding is executed to remove the air holes. At the same time, the welded target material assemblies are quenched to prevent left H atoms from dispersing and forming air holes. However, after the welding is finished, the welding seam needs to be further detected; otherwise, it is difficult to eliminate the risk caused by air holes.

CN 101629912 A discloses a method for detecting reliability of a titanium welding seam of titanium steel composite board equipment. The method adopts a non-destructive detection method. The non-destructive detection method includes: conventional appearance inspection, iron pollution test, soap bubble inspection, helium leakage inspection, penetrant flaw detection, pressure resistance test, and hot air cycle test, where larger welding seam defects can be visually detected through the appearance inspection, the iron pollution test and the soap bubble inspection; miniature penetrating air holes, cracks and other defects like no fusion can be detected through the penetrant flaw detection and the helium leakage inspection; the reliability of the welding seam at high temperature can be detected through the hot air cycle test; and the leakage of the welding seam can be discovered through the pressure resistance test. However, the detection method detects air holes by means of penetrant flaw detection and helium leakage inspection, which cause high cost and low detection efficiency.

CN 110398537 A discloses a method for determining a type of aluminum alloy welding seam defects in an ultrasonic testing process. The method includes the following steps: (1) for 4 common aluminum alloy defects such as air holes, cracks, incomplete welding and slag inclusion, drawing a dynamic change standard diagram of the waveform during the testing process corresponding to each defect type after multiple tests as a reference feature image set of waveform change rules of aluminum alloy weld defects in the ultrasonic testing; (2) detecting the position of a weld defect of an aluminum alloy to be tested in the body of the aluminum

alloy to be tested as a target weld defect to be tested, detecting the target weld defect from the left and right directions of the defect, to obtain a reflection waveform of the target weld defect; and (3) comparing the reflection waveform obtained in step (2) with the dynamic change standard diagram drawn in step (1) to obtain similarity data, so as to determine the defect type. However, it is difficult for the ultrasonic testing to detect complex workpieces, because the surface to be detected needs to be smooth to some extent, and the gap between the probe and the surface to be detected needs to be filled with coupling agent to ensure sufficient acoustic coupling. For some castings and welds comprising coarse grains, the ultrasonic testing is difficult to apply due to the occurrence of cluttered reflection waves.

CN 103234990 A discloses a new nondestructive testing method for shape and distribution of air holes in welds. The method uses a new Nano-CT tomography system to detect a welded part, and uses X-ray source to perform 360° scanning on the welded part. X-ray attenuates to a certain extent when penetrating the welded part and the energy attenuation of X-rays passing through the air holes in the weld is obviously lower than that of the surrounding rays. Thus, multiple sets of tomographic images are obtained by receiving projection energy in different degrees of attenuation with a flat panel detector. Three-dimensional reconstruction of the multiple sets of tomographic data is built to obtain a three-dimensional detection image of air hole defects in welding seams. But the detection requires X-ray generating equipment, so the cost is high. Moreover, X-ray detection is not conducive to the health of the operator.

## SUMMARY

The following is a summary of the subject matter described herein in detail. This summary is not intended to limit the scope of the claims.

The object of the present application is to provide a detection method for air holes in a welding sputtering target material. The detection method is simple to operate and low in cost, and can distinguish air holes with a diameter as low as 0.01 mm by means of image comparison. The detection process is simple, convenient, and low in cost. The detection effect of the air holes in the sputtering target material can be ensured with lower cost and higher efficiency.

To achieve the object, the present application adopts technical solutions described below.

The present application provides a detection method for air holes in a welding sputtering target material, which includes the following steps:

(1) obtaining images of a welding target material having air holes and a welding target material having no air hole under the irradiation of red light are obtained respectively and used as a reference feature image set for detecting air hole distribution in a welding target material under red light;

(2) recording images of a welding target material to be detected under the irradiation of red light is recoded, and comparing the images with the reference feature image set obtained in step (1), to obtain air hole distribution in a welding seam of the welding target material to be detected.

The red light has a long wavelength and thus has good penetrability. When a welding target material is irradiated by red light, brightness degrees are different between the image of a welding target material having air holes and the image of a welding target material having no air hole. With the reference feature image set built, the detection image of the welding target material to be detected under the irradiation of red light is compared with the reference feature image set, so as to rapidly obtain the air hole distribution in the welding target material to be detected.

In the present application, the step of obtaining images of a welding target material having air holes under irradiation of red light includes the step of obtaining images of a welding target material having air holes with different sizes. The accuracy and sensitivity in detecting the welding target material are improved by enriching the reference feature image set.

In the present application, the red light in step (1) and the red light in step (2) each can independently select, for example, wavelengths, power, etc.

Optionally, the wavelength of the red light in step (1) is 622 nm to 770 nm, and for example, may be 622 nm, 630 nm, 640 nm, 650 nm, 660 nm, 670 nm, 680 nm, 690 nm, 700 nm, 710 nm, 720 nm, 730 nm, 740 nm, 750 nm, 760 nm or 770 nm. However, the wavelength is not limited to the values listed above, and the other values unlisted in this value range are also applicable. The wavelength is optionally 640 nm to 700 nm.

Optionally, the wavelength of the red light in step (2) is 622 nm to 770 nm, and for example, may be 622 nm, 630 nm, 640 nm, 650 nm, 660 nm, 670 nm, 680 nm, 690 nm, 700 nm, 710 nm, 720 nm, 730 nm, 740 nm, 750 nm, 760 nm or 770 nm. However, the wavelength is not limited to the values listed above, and the other values unlisted in this value range are also applicable. The wavelength is optionally 640 nm to 700 nm.

Optionally, the red light in step (1) has the same wavelength as the red light in step (2).

The power of red light is not limited in the present application. The higher the power of red light, the greater the light intensity, and the higher the accuracy of image resolution detection, but the higher the cost. Taking both accuracy and detection costs into consideration, the power of red light can be selected within the range of 10 W to 200 W, and for example, may be 10 W, 12 W, 15 W, 18 W, 24 W, 50 W, 60 W, 70 W, 80 W, 100 W, 120 W, 150 W or 200 W. However, the power is not limited to the values listed above, and the other values unlisted in this value range are also applicable.

In the present application, with the wavelength of red light under which the reference feature image set is obtained being consistent with the wavelength used in detecting the welding target material to be detected, the accuracy and sensitivity of detection are improved.

Optionally, the step of obtaining images of a welding target material in step (1) is to obtain welding seam images of the welding target material and/or welding surface images of the welding target material.

Optionally, the step of recording images of a welding target material to be detected under irradiation of red light in step (2) is to record images of a welding seam and/or a welding surface of the welding target material under irradiation of red light.

The detection method in the present application can not only detect the air holes in the welding seam of the welding target material, but also detect the air holes in the welding surface of the welding target material. The detection method is simple and easy.

Optionally, the step of recording images of a welding target material to be detected under irradiation of red light in step (2) is to record images of the welding target material to be detected under irradiation of red light while the welding target material to be detected is rotated around a central axis by 360°.

Optionally, the rotation speed of the welding target material to be detected is 8°/s to 12°/s, and for example, may be 8°/s, 9°/s, 10°/s, 11°/s or 12°/s. However, the rotation speed is not limited to the values listed above, and the other values unlisted in this value range are also applicable. The images under irradiation of red light are recorded at a frequency of 1 times/s to 3 times/s, and for example, may be 1 times/s, 2 times/s, or 3 times/s.

Optionally, the step of recording images of a welding target material to be detected under the irradiation of the red light in the present application includes the step of repeatedly recording the image at the same detection position for 1 to 5 times. Through repeated recording, the detection accuracy is improved.

The step of recording images in step (2) in the present application includes the step of recording and detecting by using a probe for detecting light intensity and/or detecting by using a camera.

Optionally, the process of recording images of a welding seam target material to be detected in step (2) further includes the step of pausing the rotation for at least 1 second every time the welding target material rotates by 8° to 12°, so as to take an image of a red light irradiation area using a camera.

The pause time in the present application is at least 1 s, and for example, may be 1 s, 2 s, 3 s, 4 s, 5 s, 6 s or 10 s. However, the pause time is not limited to the values listed above, and the other values unlisted in this value range are also applicable. The camera needs a relatively long shooting time to record clear images of the red light irradiation area, and shooting while rotating the target material is not beneficial to obtaining clear images. Similarly, too short pause time is not beneficial to obtaining clear images; and too long pause time is not beneficial to improving the detection efficiency.

As an optional technical solution of the detection method of the present application, the detection method includes the following steps:

(1) obtaining images of a welding target material having air holes and a welding target material having no air hole under the irradiation of red light in a wavelength range of 622 nm to 770 nm respectively as a reference feature image set for detecting air hole distribution in the welding target material under red light; and

(2) recording images of a welding target material to be detected under irradiation of red light with a wavelength of 622 nm to 770 nm while the welding target material to be detected is rotated around a central axis by 360° at a rotation speed is 8°/s to 12°/s, wherein images under irradiation of red light are recorded at a frequency of 1 times/s to 3 times/s, and the rotation is paused for at least 1 s every time the welding target material rotates by 8° to 12°, so as to take an image of a red light irradiation area using a camera, to obtain an air hole distribution in a welding seam of the target material to be detected.

Compared with the existing art, the present application has beneficial effects described below.

(1) In the present application, the welding target assembly is detected using red light with strong penetrability, the detection cost is low, and the operation is simple and safe.

(2) The detection method provided in the present application can not only detect air holes in the welding seam of the welding target material, but also detect air holes which may exist in the sputtering surface of the target material, and the detection limit of air holes is as low as 0.01 mm.

Other aspects can be understood after the detailed description and the drawings are read and understood.

## BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a view showing detection of a welding sputtering target material by using a detection method for air holes in a welding sputtering target material provided by the present application.

## DETAILED DESCRIPTION

The technical solutions of the present application are further described below through specific examples. Those skilled in the art should understand that the examples are merely used for helping to understand the present application and should not be regarded as the specific limitations to the present application. For detection consistency, the red light in the examples of the present application was generated by a red light lamp with a power of 50 W.

### Example 1

This example provides a detection method for air holes in a welding sputtering target material. The view showing detection by using the detection method is shown in FIG. 1, and the detection method includes the following steps.

(1) Images of a welding target material having air holes and a welding target material having no air hole were obtained under the irradiation of red light with a wavelength of 680 nm respectively and used as a reference feature image set for detecting air hole distribution in a welding target material under red light, where the step of obtaining images of the welding target material having air holes included the step of obtaining images of a welding target material

having air holes with different sizes, and the minimum diameter of the air holes with different sizes was 0.01 mm.

(2) In the process that the target material to be detected rotated around a central axis by 360 degrees, images were recorded under irradiation of red light with the wavelength of 680 nm, where the rotation speed was 10°/s, images under irradiation of red light were recorded at a frequency of 2 times/s, and the rotation was paused for 2 s every time the welding target material rotated by 10°, so as to take an image of a red light irradiation area using a camera; and the recorded images and the taken images were compared with the reference feature image set obtained in step (1), to obtain the air hole distribution in a welding seam of the target material to be detected.

The detection method can detect air holes with the diameter of greater than or equal to 0.01 mm.

Example 2

This example provides a detection method for air holes in a welding sputtering target material. The detection method includes the following steps.

(1) Images of a welding target material having air holes and a welding target material having no air hole were obtained under the irradiation of red light with a wavelength of 640 nm respectively and used as a reference feature image set for detecting air hole distribution in a welding target material under red light, where the step of obtaining images of the welding target material having air holes included the step of obtaining images of a welding target material having air holes with different sizes, and the minimum diameter of the air holes with different sizes was 0.01 mm.

(2) In the process that the target material to be detected rotated around the central axis by 360 degrees, images were recorded under irradiation of red light with the wavelength of 640 nm, where the rotation speed was 8° /s, images under irradiation of red light were recorded at a frequency of 1 times/s, and the rotation was paused for 2 s every time the welding target material rotated by 8°, so as to take an image of a red light irradiation area using a camera, and the recorded images and the taken images were compared with the reference feature image set obtained in step (1), to obtain the air hole distribution in the welding seam of the target material to be detected.

The detection method can detect the air holes with the diameter of greater than or equal to 0.01 mm.

Example 3

This example provides a detection method for air holes in a welding sputtering target material. The detection method includes the following steps.

(1) Images of a welding target material having air holes and a welding target material having no air hole were obtained under the irradiation of red light with a wavelength of 700 nm respectively and used as a reference feature image set for detecting air hole distribution in a welding target material under red light, where the step of obtaining images of the welding target material having air holes included the step of obtaining images of a welding target material having air holes with different sizes, and the minimum diameter of the air holes with different sizes was 0.01 mm.

(2) In the process that the target material to be detected rotated around the central axis by 360 degrees, images were recorded under irradiation of red light with the wavelength of 700 nm, where the rotation speed was 12°/s, images under irradiation of red light were recorded at a frequency of 3 times/s, and the rotation was paused for 2 s every time the welding target material rotates by 12°, so as to take an image of a red light irradiation area using a camera; and the recorded images and the taken images were compared with the reference feature image set obtained in step (1), to obtain the air hole distribution in the welding seam of the target material to be detected.

The detection method can detect air holes with the diameter of greater than or equal to 0.01 mm.

Example 4

This example provides a detection method for air holes in a welding sputtering target material. The detection method includes the following steps.

(1) Images of a welding target material having air holes and a welding target material having no air hole were obtained under the irradiation of red light with a wavelength of 622 nm respectively and used as a reference feature image set for detecting air hole distribution in a welding target material under red light, where the step of obtaining images of the welding target material having air holes included the step of obtaining images of a welding target material

having air holes with different sizes, and the minimum diameter of the air holes with different sizes was 0.01 mm.

(2) In the process that the target material to be detected rotated around the central axis by 360 degrees, images were recorded under irradiation of red light with the wavelength of 622 nm, where the rotation speed was 10°/s, images under irradiation of red light were recorded at a frequency of 2 times/s, and the rotation was paused for 2 s every time the welding target material rotated by 10°, so as to take an image of a red light irradiation area using a camera, and the recorded images and the taken images were compared with the reference feature image set obtained in step (1), to obtain the air hole distribution in the welding seam of the target material to be detected.

The detection method can detect air holes with the diameter of greater than or equal to 0.03 mm.

Example 5

This example provides a detection method for air holes in a welding sputtering target material. The detection method includes the following steps.

(1) Images of a welding target material having air holes and a welding target material having no air hole were obtained under the irradiation of red light with a wavelength of 770 nm respectively and used as a reference feature image set for detecting air hole distribution in a welding target material under red light, where the step of obtaining images of the welding target material having air holes included the step of obtaining images of a welding target material having air holes with different sizes, and the minimum diameter of the air holes with different sizes was 0.01 mm.

(2) In the process that the target material to be detected rotated around the central axis by 360 degrees, images were recorded under irradiation of red light with the wavelength of 770 nm, where the rotation speed was 10°/s, images under irradiation of red light were recorded at a frequency of 2 times/s, and the rotation was paused for 2 s every time the welding target material rotated by 10°, so as to take an image of a red light irradiation area using a camera, and the recorded images and the taken images were compared with the reference feature image set obtained in step (1), to obtain the air hole distribution in the welding seam of the target material to be detected.

The detection method can detect air holes with the diameter of greater than or equal to 0.02 mm.

Example 6

This example provides a detection method for air holes in a welding sputtering target material. The detection method includes the following steps.

(1) Images of a welding target material having air holes and a welding target material having no air hole were obtained under the irradiation of red light with a wavelength of 680 nm respectively and used as a reference feature image set for detecting air hole distribution in a welding target material under red light, where the step of obtaining images of the welding target material having air holes included the step of obtaining images of a welding target material having air holes with different sizes, and the minimum diameter of the air holes with different sizes was 0.01 mm.

(2) In the process that the target material to be detected rotated around the central axis by 360 degrees, images were recorded under irradiation of red light with the wavelength of 770 nm, where the rotation speed was 10°/s, images under irradiation of red light were recorded at a frequency of 2 times/s, and the rotation was paused for 2 s every time the welding target material rotated by 10°, so as to take an image of a red light irradiation area using a camera, and the recorded images and the taken images ere compared with the reference feature image set obtained in step (1), to obtain the air hole distribution in the welding seam of the target material to be detected.

The detection method can detect air holes with the diameter of greater than or equal to 0.05 mm.

Example 6

This example provides a detection method for air holes in a welding sputtering target material. The detection method includes the following steps.

(1) Images of a welding target material having air holes and a welding target material having no air hole were obtained under the irradiation of red light with a wavelength of 700 nm respectively and used as a reference feature image set for detecting air hole distribution in a welding target material under red light, where the step of obtaining images of the welding target material having air holes included the step of obtaining images of a welding target material having air holes with different sizes, and the minimum diameter of the air holes with different

sizes was 0.01 mm.

(2) In the process that the target material to be detected rotated around the central axis by 360 degrees, images were recorded under irradiation of red light with the wavelength of 640 nm, where the rotation speed was 10°/s, images under irradiation of red light were recorded at a frequency of 2 times/s, and the rotation was paused for 2 s every time the welding target material rotated by 10°, so as to take an image of a red light irradiation area using a camera, and the recorded images and the taken images were compared with the reference feature image set obtained in step (1), to obtain the air hole distribution in the welding seam of the target material to be detected.

The detection method can detect air holes with the diameter of greater than or equal to 0.05 mm.

Comparative example 1

This comparative example provides a detection method for air holes in a welding sputtering target material. The detection method includes the same steps as Example 1 except that the light used was yellow light.

When the red light is replaced by the yellow light, air holes in the welding sputtering target material cannot be detected.

Comparative example 2

This comparative example provides a detection method for air holes in a welding sputtering target material. The detection method includes the same steps as Example 1 except that the light used was green light.

When the red light is replaced by the green light, air holes in the welding sputtering target material cannot be detected.

In summary, in the present application, air holes in a sputtering target material are detected by means of red light with strong penetrability, and the air holes with diameter as low as 0.01 mm can be distinguished by means of image comparison. The detection process is simple and low in cost. The detection effect of the air holes in the sputtering target material can be ensured with lower cost and higher efficiency.

The applicant has stated that the above are only specific embodiments of the present application, but the scope of the present application is not limited thereto.

What is claimed is:

1. A detection method for air holes in a welding sputtering target material, wherein the detection method comprises the following steps:

(1) obtaining images of a welding target material having air holes and a welding target material having no air hole under the irradiation of red light respectively as a reference feature image set for detecting air hole distribution in a welding target material under red light;

(2) recording images of a welding target material to be detected under the irradiation of red light, and comparing the images with the reference feature image set obtained in step (1), to obtain air hole distribution in a welding seam of the welding target material to be detected.

2. The detection method of claim 1, wherein the red light in step (1) has a wavelength of 622 nm to 770 nm.

3. The detection method of claim 2, wherein the red light in step (2) has a wavelength of 622 nm to 770 nm.

4. The detection method of claim 3, wherein the red light in step (1) has a same wavelength as the red light in step (2).

5. The detection method of any one of claims 1 to 4, wherein the obtaining images of a welding target material in step (1) is to obtain welding seam images of the welding target material and/or welding surface images of the welding target material.

6. The detection method of any one of claims 1 to 5, wherein the recording images of a welding target material to be detected under irradiation of red light in step (2) is to record images of a welding seam and/or a welding surface of the welding target material under irradiation of red light.

7. The detection method of any one of claims 1 to 6, wherein the recording images of a welding target material to be detected under irradiation of red light in step (2) is to record images under irradiation of red light while the welding target material to be detected is rotated around a central axis by 360°.

8. The detection method of claim 7, wherein the welding target material to be detected is rotated at a speed of 8°/s to 12°/s, and images are recorded under irradiation of red light at a frequency of 1 times/s to 3 times/s.

9. The detection method of claim 8, wherein the process of recording images of a welding seam target material to be detected in step (2) further comprises a step of pausing the rotation for at least 1 second every time the welding target material rotates by 8° to 12°, so as to take an image of a red light irradiation area using a camera.

10. The detection method of any one of claims 1 to 9, wherein the detection method comprises the following steps:

(1) obtaining images of a welding target material having air holes and a welding target material having no air hole under the irradiation of red light in a wavelength range of 622 nm to 770 nm respectively as a reference feature image set for detecting air hole distribution in a welding target material under red light; and

(2) recording images of a welding target material to be detected under irradiation of red light with a wavelength of 622 nm to 770 nm while the welding target material to be detected is rotated around a central axis by 360° at a rotation speed is 8°/s to 12°/s, wherein images under irradiation of red light are recorded at a frequency of 1 times/s to 3 times/s, and the rotation is paused for at least 1 second every time the welding target material rotates by 8° to 12°, so as to take an image of a red light irradiation area using a camera, to obtain air hole distribution in a welding seam of the target material to be detected.