

SEMICONDUCTOR DEVICE AND METAL CAP THEREFOR

This application claims foreign priority based on Japanese Patent application No. 2005-261970, filed
5 September 9, 2005, the content of which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

10 The present invention relates to a semiconductor device formed by resistance welding of a metal cap and a metal stem, and a metal cap therefor.

2. Description of the Related Art

Among semiconductor laser devices in which a
15 semiconductor laser element is mounted, there exists a product which is formed by attaching in a sealed state a metal cap to which a light transmitting material is attached by sealing and a metal stem in which a laser element is mounted, by resistance welding. Fig. 5 shows
20 a method for attaching in a sealed state a metal cap 10 to which a light transmitting material 12 is attached by sealing, and a metal stem 20 to which lead wires 22 are attached by glass sealing, by resistance welding. A flange portion 10a of the metal cap 10 is supported
25 on a lower electrode 15, and while the flange portion

10a and the stem 20 are sandwiched by applying pressure by the lower electrode 15 and an upper electrode 25 therebetween, a voltage is applied between the lower electrode 15 and the upper electrode 25, so that the
5 flange portion 10a and the stem 20 are resistance welded together at portions thereof where the flange portion 10a and the stem 20 are brought into abutment with each other.

In related arts (for example, JP-A-5-102365 and
10 JP-A-5-218217), a projection 11 is provided on a surface of the flange portion 10a which faces the stem 20, and along the full circumference of the flange surface. The projection 11 is caused to dig into a press contact surface of the stem 20 when the flange portion 10a and
15 the stem 20 are clamped together by the lower electrode 15 and the upper electrode 25, and by applying a welding voltage in that state, electric current is caused to concentrate in the portion of the projection 11 so as to weld the flange portion 10a and the stem 20 together.

20 Incidentally, when the metal cap 10 and the stem 20 are attached in a sealed state by resistance welding, there may occur a case where because a welding pressure to sandwich the metal cap 10 and the stem 20 varies, electric discharging is not ensured, and electric
25 current does not concentrate in the projection 11

provided on the metal cap 10 and hence fusing is not ensured at the portion of the projection, thereby resulting in a problem that the secure attachment by sealing is not ensured. In order to prevent the case
5 where the welding pressure to sandwich the metal cap 10 and the stem 20 varies, and in a case of a product in which stable welding is difficult, the welding pressure to sandwich the metal cap 10 and the stem 20 is strengthened so as to enable stable welding.

10 However, when the welding pressure to sandwich the metal cap 10 and the stem 20 is increased, there occurs a problem that electric discharge between the projection
11 provided on the flange portion 10a and the stem 20 does not occur, and instead, since the surface of the
15 flange portion 10a, in particular, a circumferential edge portion of the flange portion 10a is brought into contact with the stem 20, whereby an electric discharge occurs therebetween, resulting in insufficient sealing attachment properties at the portion of the projection
20 11. Also, there occurs a problem that electrodes for welding are caused to be wasted because the electrodes are damaged by the electric discharge at the circumferential edge portion of the flange portion 10a.

25 SUMMARY OF THE INVENTION

The present invention has been made in view of the above circumstances, and provides a semiconductor device which can ensure welding of a metal cap and a metal stem by resistance welding so as to increase sealing
5 attachment properties of the metal cap and the metal stem, and provides a metal cap which can be used preferably for production of the semiconductor device.

In some implementations, a semiconductor device of the invention comprising:

10 a metal cap having a flange portion being provided along an opening edge of a main body which is formed in a cap-like shape; and

a stem,

wherein a projection is provided on one of a welding
15 surface of the flange portion and a welding surface of the stem that abut on each other so as to be welded, the projection being provided along a full circumference of the one of the welding surfaces, and

the flange portion and the stem are resistance
20 welded in a state that a distance between the welding surfaces which face each other in an area radially outside a portion where the projection is provided is set larger than a distance between the welding surfaces which face each other in an area radially inside the
25 portion where the projection is provided.

In the semiconductor device,

the projection is provided on the welding surface
of the flange portion,

a distance between the welding surface of the flange
5 portion radially outside the projection and a tip end
of the projection is set larger than a distance between
the welding surface of the flange portion radially inside
the projection and the tip end of the projection, and
the welding surface of the stem is formed flat.

10 In the semiconductor device,

the projection is provided on the welding surface
of the stem,

a distance between the welding surface of the stem
radially outside the projection and a tip end of the
15 projection is set larger than a distance between the
welding surface of the stem radially inside the
projection and the tip end of the projection, and

the welding surface of the flange portion is formed
flat.

20 In the semiconductor device, a cross section of the
projection is formed in a trapezoidal shape. Accordingly,
further appropriate resistance welding is implemented.

In some implementations, a metal cap of the
invention comprising:

25 a flange portion to be attached to a stem by

resistance welding, the flange portion being provided along an opening edge of a main body which is formed in a cap-like shape,

wherein a projection is provided on a welding
5 surface of the flange portion and along a full circumference of the welding surface, and

a distance between the welding surface radially outside the projection and a tip end of the projection is set larger than a distance between the welding surface
10 radially inside the projection and the tip end of the projection.

In the metal cap, a cross section of the projection is formed in a trapezoidal shape. Accordingly, further appropriate resistance welding is implemented.

15 In the metal cap, a nickel plating is applied onto an outer surface of the main body of the metal cap. Accordingly, sealing attachment properties of the welding portion are further ensured.

20 BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B are sectional views each showing a configuration of a metal cap according to an embodiment of the invention.

Fig. 1C is a sectional view showing a configuration
25 of a metal cap of a related art.

Figs. 2A and 2B are sectional views each showing a configuration of a flange portion of the metal cap according to an embodiment of the invention.

Fig. 3 is a sectional view showing a configuration of a semiconductor device according to an embodiment of the invention.

Fig. 4 is a sectional view showing other configuration example of a metal cap and a stem according to an embodiment of the invention.

Fig. 5 is an explanatory diagram showing a method of resistance welding of a metal cap and a stem.

DESCRIPTION OF THE PRFERRED EMBODIMENTS

Hereinafter, a preferred embodiment of the invention will be described in detail based on the accompanying drawings.

Figs. 1A and 1B are sectional views showing configurations of embodiments of metal caps 30, 35 according to the invention, and Fig. 1C is a sectional view showing a configuration of a related metal cap 10 as a comparison example.

In the metal cap 30 shown in Fig. 1A, a flange portion 30a is provided along an opening edge of a main body which is formed into a cap-like shape, and a projection 31 is provided on a welding surface of the

flange portion 30a which faces a stem, the projection 31 being provided along the full circumference of the welding surface.

In the configuration of the metal cap 30 shown in Fig. 1A, a welding surface 30b radially inside the projection 31 and a welding surface 30c radially outside the projection 31 are not set at the same level in height, but are set so that the height of the welding surface 30c radially outside the projection 31 becomes higher than the height of the welding surface 30b radially inside the projection 31. In the metal cap 10 shown in Fig. 1C, welding surfaces 10b radially inside and outside a projection 11 are set at the same level in height.

An enlarged configuration of the flange portion 30a of the metal cap 30 is shown in Fig. 2A. Assuming that a height from a tip end of the projection 31 to the welding surface 30c is $\underline{a}$, and a height from the tip end of the projection 31 to the welding surface 30b is $\underline{b}$, the flange portion 30a is provided to satisfy $\underline{a} > \underline{b}$. While size and shape of the metal cap 30 vary depending upon products, and the heights $\underline{a}$, $\underline{b}$ can also be selected as required, a difference in height between the welding surface 30c radially outside the projection 31 and the welding surface 30b radially inside the projection 31 is made to be in the range from about 0.02 mm to 0.03mm with the

height of the projection 31 being 0.05mm.

As with the metal cap 30, also in the metal cap 35 shown in Fig. 1B, a welding surface 35c radially outside a projection 36 provided on the welding surface of a flange portion 35a is set higher than a welding surface 35b radially inside the projection 36.

An enlarged configuration of the flange portion 35a of the metal cap 35 is shown in Fig. 2B. Assuming that a height from a protruding end face of the projection 36 to the welding surface 35c radially outside the projection 36 is $\underline{a}$, and a height from the protruding end face of the projection 36 to the welding surface 35b radially inside the projection 36 is $\underline{b}$, the flange portion 35a is provided to satisfy $\underline{a} > \underline{b}$.

Note that while end tips of the projection 11 of the related metal cap 10 shown in Fig. 1C and the projection 31 of the metal cap 30a shown in Fig. 1A are formed in a sharp shape, in the metal cap 35 according to an embodiment of the invention, a cross section of the projection 36 is formed in a trapezoidal shape.

Fig. 3 shows a state in which the metal cap 30 shown in Fig. 1A is resistance welded to a stem 20 so as to assemble a semiconductor device for a semiconductor laser device.

In the metal cap 30 which is used in the

semiconductor device for the semiconductor laser device,
an iron-cobalt-nickel alloy is used as a base material
and a nickel plating is applied to a surface of the base
material. A light transmitting material 33 is attached
5 by sealing to a light transmitting window 32 provided
in the metal cap 30. In addition, iron is used as a base
material of the stem 20, and lead wires 22 are attached
by glass sealing. A laser element (not shown) is
installed in a heatsink 23 provided on the stem 20, and
10 the laser element and the lead wires 22 are connected
together electrically.

The metal cap 30 and the stem 20 are welded together
between the flange portion 30a and a surface of the stem
20, and an interior of the metal cap 30 is sealed
15 airtightly. Reference numeral 34 denotes a welding
portion where the flange portion 30a and the stem 20 are
welded together. In the welding portion 34, welding is
performed in such a manner that the projection 31
provided on the flange portion 30a digs into the stem
20 20, and a nickel plated coating formed on the surface
of the metal cap 30 is fused at the time of welding and
is then solidified, whereby the flange portion 30a and
the stem 20 are attached in an airtight sealed state.
The nickel plated coating works to seal the welding
25 portion 34 reliably and plays a crucial role in the

airtight sealing.

When assembling the semiconductor device, as shown in Fig. 5, the flange portion 30a of the metal cap 30 and the stem 20 are sandwiched by applying pressure by
5 a lower electrode 15 and an upper electrode 25 therebetween, and voltage is applied between the lower electrode 15 and the upper electrode 25 so as to produce an electric discharge between the flange portion 30a and the stem 20. As shown in Figs. 1A, 2A, in the metal cap
10 30 used in the semiconductor device of the embodiment, the welding surface 30c radially outside the projection 31 is made higher than the welding surface 30b radially inside the projection 31. In other words, a distance between the surface of the stem 20 and the welding surface
15 of the flange portion 30a is larger in a portion outside the projection 31 than in a portion inside the projection 31.

When the metal cap 30 is formed like this, when the flange portion 30a and the stem 20 are sandwiched by
20 applying pressure by the lower electrode 15 and the upper electrode 25 therebetween, a radially outside portion (a circumferential edge portion) of the flange portion 30a is prevented from being brought into contact with the surface of the stem 20, thereby making it possible
25 to prevent occurrence of an electric discharge between

the circumferential edge portion of the flange portion 30a and the stem 20. By suppressing the occurrence of an electric discharge at the circumferential edge portion of the flange portion 30a, electric discharge
5 is concentrated in between the projection 31 and the stem 20, thereby making it possible to ensure the welding of the flange portion 30a and the stem 20 at the portion of the projection 31. In addition, by preventing the occurrence of electric discharge at the circumferential
10 edge portion of the flange portion 30a, the electrodes are prevented from being damaged and wasted.

As to a product welding conditions of which are not stable, a welding pressure to sandwich the metal cap 30 and the stem 20 is increased so as to stabilize the welding
15 state. Even in this case, at the welding surface of the flange portion 30a, the welding surface 30c radially outside the projection 31 is made to be spaced further apart from the surface of the stem 20 than the welding surface 30b radially inside the projection 31.
20 Accordingly, the occurrence of electric discharge between the circumferential edge portion of the flange portion 30a and the stem 20 can be prevented, and more stabilized resistance welding is possible.

In addition, in the case of the metal cap 35 shown
25 in Figs. 1B and 2B, by forming a cross section of the

projection 36 provided on the flange portion 35a into the trapezoidal shape, when the metal cap 35 and the stem 20 are sandwiched by applying pressure, a resistance welding is enabled while making it difficult for the projection 36 to be caused to dig into the stem 20. Thus, when the metal cap 35 and the stem 20 are sandwiched by applying pressure by the lower electrode 15 and the upper electrode 25 therebetween, the contact of a circumferential edge portion of the flange portion 35a of the metal cap 35 with the stem 20 can be suppressed further, so that discharge current is allowed to concentrate in the projection 36 so as to enhance the sealing properties of a welding portion of the metal cap 35 and the stem 20.

In the embodiments that have been described heretofore, as described above, by the formation of the welding surfaces of the flange portions 30a, 35a of the metal caps 30, 35 which are to be resistance welded to the stem 20, the welding properties and sealing attachment properties between the metal caps 30, 35 and the stem 20 are enhanced. Fig. 4 shows an example in which a form of welding surface which is similar to those provided on the metal caps 30, 35 is provided on the stem 20.

In an embodiment shown in Fig. 4, a projection 21

is provided on a stem 20 and along the full circumference of the stem 20, at a position which faces a welding surface of a flange portion 38a of a metal cap 38, and a welding surface 20c radially outside the projection 21 is provided in a lower level than a welding surface 20b radially inside the projection 21. A difference in height between the welding surface 20b and the welding surface 20c is indicated as c. In addition, the welding surface of the flange portion 38a of the metal cap 38 is formed into a flat surface.

Thus, by providing the welding surface of the stem 20 in such a manner as to differ in height between the areas radially inside and outside the projection 21, and setting such that a height distance between the welding surface 20c in an area radially outside the projection 21 and a tip end of the projection 21 is larger than a height distance between the welding surface 20b in an area radially inside the projection 21 and the tip end of the projection 21, electric current at the time of welding can be caused to concentrate in the projection 21 so as to ensure the resistance welding of the flange portion 38a and the stem 20 together, by a similar function with the case where the aforesaid metal caps 30, 35 are used.

In this embodiment, the projection 21 is provided

on the stem 20, however, a method can be possibly adopted in which the welding surface of the stem is formed into a step-like shape similar to what has been described above and a projection is provided on the flange portion which is formed on the flat surface of the metal cap. Further, a method can also be possibly adopted in which the welding surface of the stem is formed into a flat surface and a projection is then provided on the stem, while the welding surface of the flange portion of the metal cap is formed into the aforesaid step-like shape.

In either of the two possible cases described above, the welding surfaces of the metal cap and the stem are made to face each other, and when the metal cap and the stem are sandwiched by applying pressure for welding, a distance between the facing welding surfaces is set to be larger in an area radially outside a portion where the projection is provided than an area radially inside the projection, whereby the metal cap and the stem are resistance welded together.

[Example]

Two types of metal caps having flange portions of different forms were actually resistance welded to stems to observe welding states of welding portions of the flange portion and the stems, respectively. The metal caps which were actually used were metal caps which were

formed in the ways shown in Figs. 1A, 1C, respectively,
and projections were formed into a shape having a sharp
point at a tip end thereof. Table 1 shows height
dimensions of welding surfaces of the flange portions
5 of the metal caps which were used for experiments. An
iron-cobalt-nickel alloy was used as the base material
of the metal caps, and a nickel plating was applied to
the surfaces of the metal caps. The base material of the
stems was iron. Both of the caps were formed by press
10 molding.

[Table 1]

(mm)

	Inside height <u>a</u>	Outside height <u>b</u>	<u>b-a</u>
Embodiment	0.05	0.08	0.03
Comparison example	0.06	0.06	0.00

The metal cap of the embodiment shown in Table 1
was such that the height a of a welding surface formed
15 radially inside the projection from a tip end of the
projection was 0.05mm, and the height b of a welding
surface formed radially outside the projection from the
tip end of the projection was 0.08mm. The comparison
example was such that a welding surface was formed at
20 the same height in areas radially inside and outside the
projection, and the height of the welding surface from
a tip end of the projection was 0.06mm.

[Table 2]

Welding Pressure	Voltage V	95	100	105	110	115	120	125	130	135	140
Experiment 1 (441N/588N)	Embodiment	X	X	Y	YZ	YZ	YZ	YZ	Z	Z	Z
	Comparison example	X	YZ	Z	Z	Z					
Experiment 2 (558N/735N)	Embodiment	X	X	XY	Y	Y	Y	YZ	YZ	Z	Z
	Comparison example	X	XZ	YZ	Z	Z					

Table 2 shows results of observation on welding states at welding portions when the voltage applied between electrodes was changed while sandwiching the metal caps and the stems by applying pressure. A welding machine used was a condenser type spot welding machine. The number of samples used for each voltage was three for each of the Embodiment and the Comparison Example.

Experiment 1 shows results measured when the voltage applied to the electrodes was changed while applying a welding pressure of 441N to 588N to the metal caps and the stems. Experiment 2 shows results measured when the voltage applied to the electrodes was changed while applying a welding pressure of 588N to 735N to the metal caps and the stems. When resistance welding of the metal caps and the stems is performed, the voltage was applied to the electrodes while the pressure applied to the electrodes was being gradually increased. In Experiment 1, the application of the welding pressure of 441N to 588N means that the voltage continued to be applied while the pressure was so applied.

In Table 2, a mark "X" denotes that an electric discharge was occurred between the outer circumference

of the flange portion and the stem in such a state that an abutment portion between the projection provided on the flange portion and the stem had not yet been fused (a cold weld). A mark "Z" denotes that scattering of the
5 flange portion and the stem was occurred due to electric discharge. A mark "XZ" denotes that cold weld and scattering due to electric discharge are occurred. A mark "Y" denotes that good welding was performed at the projection portion. A mark "YZ" denotes that the welding
10 state at the projection portion was good and at the same time, scattering due to electric discharge was observed. The mark "Z" shown at high voltages denotes that an overflow was occurred in the welding portion.

When comparing the metal cap of the embodiment and
15 the metal cap of the comparison example, the results of the experiments shown in Table 2 indicate that with the metal cap of the embodiment, the good welded state was obtained over a wide voltage range and that the good welded state was obtained when the welding pressure of
20 the metal cap and the stem was increased.

The results of the experiments indicate that more stabilized resistance welding was enabled by making the configuration of the flange portion of the metal cap into the form shown in Table 1, that is, by placing the welding
25 surface radially outside the projection higher than the

welding surface radially inside the projection. Also, the results of the experiments indicate that far more stabilized resistance welding was enabled by increasing the welding pressure for applying the pressure on the metal cap and the stem, and the sealing attachment properties at the welding portion is enhanced.

While in the embodiments that have been described heretofore, the semiconductor laser device is described which is assembled by resistance welding of the metal cap and the stem, the application of the invention is not limited to the semiconductor laser device and hence, the invention is commonly applied to semiconductor devices which are each assembled by resistance welding of a flange portion and a stem.

According to the semiconductor device of the invention, the secure sealing attachment of the metal cap and the stem is ensured at the welding portion, so as to provide the semiconductor device which provides good airtightness and which is highly reliable. In addition, according to the metal cap of the invention, electric current can be caused to concentrate in the projection for welding, so as to increase the reliability at the welding portion. Furthermore, even when the welding pressure is increased at the time of welding, the electric discharge between the circumferential edge

portion of the flange portion and the stem can be suppressed to thereby enable stable welding, so as to enhance the secure sealing attachment properties at the welding portion.

5 It will be apparent to those skilled in the art that various modifications and variations can be made to the described preferred embodiments of the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present
10 invention cover all modifications and variations of this invention consistent with the scope of the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A semiconductor device comprising:

a metal cap having a flange portion being provided
along an opening edge of a main body which is formed in
5 a cap-like shape; and

a stem,

wherein a projection is provided on one of a welding
surface of the flange portion and a welding surface of
the stem that abut on each other so as to be welded, the
10 projection being provided along a full circumference of
the one of the welding surfaces, and

the flange portion and the stem are resistance
welded in a state that a distance between the welding
surfaces which face each other in an area radially
15 outside a portion where the projection is provided is
set larger than a distance between the welding surfaces
which face each other in an area radially inside the
portion where the projection is provided.

20 2. The semiconductor device as claimed in claim
1, wherein

the projection is provided on the welding surface
of the flange portion,

a distance between the welding surface of the flange
25 portion radially outside the projection and a tip end

of the projection is set larger than a distance between the welding surface of the flange portion radially inside the projection and the tip end of the projection, and the welding surface of the stem is formed flat.

5

3. The semiconductor device as claimed in claim 1, wherein

the projection is provided on the welding surface of the stem,

10

a distance between the welding surface of the stem radially outside the projection and a tip end of the projection is set larger than a distance between the welding surface of the stem radially inside the projection and the tip end of the projection, and

15

the welding surface of the flange portion is formed flat.

4. The semiconductor device as claimed in any one of claims 1 to 3, wherein a cross section of the projection is formed in a trapezoidal shape.

20

5. A metal cap comprising:

a flange portion to be attached to a stem by resistance welding, the flange portion being provided along an opening edge of a main body which is formed in

25

a cap-like shape,

wherein a projection is provided on a welding surface of the flange portion and along a full circumference of the welding surface, and

5 a distance between the welding surface radially outside the projection and a tip end of the projection is set larger than a distance between the welding surface radially inside the projection and the tip end of the projection.

10

6. The metal cap as claimed in claim 5, wherein a cross section of the projection is formed in a trapezoidal shape.

15

7. The metal cap as claimed in claim 6, wherein a nickel plating is applied onto an outer surface of the main body of the metal cap.