

TITLE OF THE INVENTION

PROCESS FOR ADJUSTING THE RESISTANCE OF A CHIP RESISTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to a process for adjusting the resistance of a chip resistor. More specifically, the present invention relates to a process for performing such a resistance adjustment by laser trimming.

2. Description of the Related Art:

Typically, a conventional chip resistor comprises an insulating chip substrate having a top surface formed with a resistor film covered by a protective coating which includes an undercoat layer formed on the resistor film, a middle coat layer formed on the undercoat layer, and an overcoat layer formed on the middle coat layer. Each end of the chip substrate is provided with a terminal electrode in electrical conduction with the resistor film. Such a chip resistor is disclosed in Japanese Patent Application Laid-open No. 4-102302 for example.

For resistance adjustment, the above Japanese document also proposes to trim the resistor film together with the undercoat layer of the protective coating by laser beam irradiation before the middle coat layer is formed. More specifically, the resistor film and the undercoat layer is irradiated with a laser beam while the chip substrate and a laser beam generator are moved intermittently relative to each other, thereby forming a trimming groove in the resistor film and the undercoat layer. Such laser

trimming continues until the adjusted resistance of the chip resistor falls in a tolerable range.

Conventionally, the laser beam for trimming is collected by a lens system of the laser beam generator to have a collected beam diameter of $45\text{-}55\mu\text{m}$ for forming a trimming groove which has a width of $50\text{-}60\mu\text{m}$. Further, the pitch for relative intermittent movement between the chip substrate and the laser beam generator lies normally in the range of $3\text{-}6\mu\text{m}$, and a laser beam shot takes place every time the relative movement stops. However, such a laser trimming process has been found to have the following problems.

The amount of materials of the resistor film and the undercoat layer vaporized by laser beam irradiation increases with an increasing width (i.e., collected laser beam diameter) of the trimming groove. Further, the energy required for each laser beam shot increases with an increasing laser beam diameter. Moreover, the number of laser beam shots required for resistance adjustment increases with a decreasing pitch for relative intermittent movement between the chip substrate and the laser beam generator, so that such a decrease of the pitch results in a higher frequency of material vaporization.

Since the trimming groove width of $50\text{-}60\mu\text{m}$ is relatively large, the amount of materials vaporized by laser beam irradiation is also relatively large, so that a relatively large amount of vaporized materials deposits on the undercoat layer of the protective coating. Further, since the pitch for relative movement between the chip substrate and the laser beam generator

is relatively small, material vaporization takes place frequently, which also increases the amount of vaporized materials deposited on the undercoat layer. Due to such material deposition, the resistance of the chip resistor may deviate from an intended value beyond tolerable limits, so that the number of rejectable products increases.

The above-described problem may be overcome by washing the chip substrate with an acid or pure water. However, this countermeasure adds to the cost of production.

Further, since the laser beam diameter is relatively large, the total energy required for laser trimming becomes also large. The energy requirement becomes also higher due to the fact that the pitch for relative movement between the chip substrate and the laser beam generator is as small as $3-6\mu\text{m}$ (increasing the number of laser beam shots required for laser trimming). These factors also add to the cost of production.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention is to provide a laser trimming process which overcomes or reduces the above-described problems of the prior art laser trimming process.

According to one aspect of the present invention, there is provided a process for adjusting the resistance of a chip resistor which comprises: an insulating chip substrate, a resistor film formed on the chip substrate, and an undercoat layer formed on the resistor film; the process comprising the steps of: forming a trimming groove in the resistor film and the undercoat layer by irradiating these with a laser beam while causing the chip substrate and the laser beam to move intermittently relative to each other; characterised that the laser beam is collected so that the trimming groove has a width of $15\text{-}45\mu\text{m}$, and that the chip substrate and the laser beam are moved intermittently relative to each other at a pitch of $7\text{-}15\mu\text{m}$.

Preferably, the laser beam may have a collected beam diameter of $10\text{-}40\mu\text{m}$ and an output of $0.15\times 10^{-3}\text{-}0.5\times 10^{-3}\text{W}$ per shot.

In practice, the laser beam may be moved relative to the chip substrate which is held stationary. Alternatively, the chip substrate may be moved relative to the laser beam which is held stationary.

According to another aspect of the present invention, there is provided a process for adjusting the resistance of a chip resistor which comprises: an insulating chip substrate, a resistor film formed on the chip substrate, and an undercoat

layer formed on the resistor film; the process comprising the steps of: forming a trimming groove in the resistor film and the undercoat layer by irradiating these with a laser beam while causing the chip substrate and the laser beam to move intermittently relative to each other; characterised in that the chip substrate and the laser beam are intermittently relative to each other at a larger pitch before a final stage of laser trimming wherein a measured resistance of the chip resistor approaches a target resistance, but at a smaller pitch in said final stage of laser trimming.

In practice, the chip substrate and the laser beam are moved intermittently relative to each other at a pitch of $7-15\mu\text{m}$ before said final stage of laser trimming, but at a pitch of $3-6\mu\text{m}$ in said final stage of laser trimming.

Preferably, the laser beam may have a collected beam diameter of $10-40\mu\text{m}$ to provide a groove width of $15-45\mu\text{m}$. Further, the laser beam may have an output of $0.15 \times 10^{-3} - 0.5 \times 10^{-3}\text{W}$ per shot.

The laser beam may be moved relative to the chip substrate which is held stationary. Alternatively, the chip substrate may be moved relative to the laser beam which is held stationary.

Other objects, features and advantages of the present invention will be apparent from the detailed description of a preferred embodiment given below with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a perspective view showing a chip resistor embodying the present invention;

Fig. 2 is an enlarged sectional view taken along lines II-II in Fig. 1; and

Figs. 3 through 10 are views illustrating the successive steps of making the same.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment of the present invention will be described below with reference to the accompanying drawings.

Figs. 1 and 2 of the accompanying drawings illustrate a chip embodying the present invention. The chip resistor of this embodiment comprises a chip substrate 1 made of an insulating material such as alumina or ceramic. The substrate 1 has a top surface 1a formed with a spaced pair of main top electrodes 2 located adjacent to an opposite pair of end faces 1b of the chip substrate 1, and a resistor film 3 in electrical conduction with the main top electrodes 2.

The resistor film 3 is covered by a protective coating. This protective coating includes an undercoat layer 4 of glass formed directly on the resistor film 3, a middle coat layer 5 of glass or resin formed on the undercoat layer 4, and an overcoat layer 6 of glass or resin formed on the middle coat. The resistor film 3 is subjected to laser trimming for resistance adjustment together with the undercoat layer 4, as described hereinafter.

An auxiliary top electrode 7 is formed on each main top electrode 2 in electrical conduction therewith, and a side electrode 7 is formed on each of the end faces 1b in electrical conduction with the corresponding main top electrode 2 and the corresponding auxiliary top electrode 7. Further, the auxiliary top electrode 7 and the side electrode 8 at or adjacent to each end face 1b of the chip substrate 1 are covered by a plated metal layer (see Fig. 2) which includes a plated nickel layer and a plated solder layer.

The chip resistor having the above-described structure may be advantageously produced in the following manner.

First, as shown in Fig. 3, each of the main top electrodes 2 is formed on the top surface 1a of the insulating chip substrate 1 adjacent a respective end face 1b thereof by printing a silver-palladium paste which is thereafter dried and baked for fixation.

Then, as shown in Fig. 4, the resistor film 3 is formed on the top surface 1a of the chip substrate 1 in partially overlapping relation to the respective main top electrode 2 by printing a resistor material paste which is thereafter dried and baked for fixation. The thickness of the resistor film 3 may be 5-15 μm for example.

Then, as shown in Fig. 5, the undercoat layer 4 is formed on the resistor film 3 by printing a glass paste which is thereafter dried and baked for fixation. The thickness of the undercoat layer 4 may be 7-10 μm for example.

Then, as shown in Figs. 6-8, while probes (not shown) are held in contact with the two main top electrodes 2 for resistance measurement, a trimming groove 10 is formed in the resistor film 3 and the undercoat layer 4 by irradiating a laser beam until the measured resistance of the resistor film 3 falls in a predetermined tolerable range. Such laser trimming is performed by using a laser beam generator 11 which incorporates a lens system (not shown) for collecting the laser beam to have a predetermined diameter D (see Fig. 7), thereby forming a trimming groove 10 of a predetermined width W which is slightly greater than the collected laser beam diameter D. In the course of the

laser beam trimming, the chip substrate 1 may be held stationary while the laser beam generator 11 is moved intermittently at a predetermined pitch P along an L-shaped path for example (see Fig. 6), the laser beam projection taking place every time the laser beam generator 11 stops. Alternatively, the laser beam generator 11 may be held stationary while the chip substrate 1 is moved intermittently at the pitch P.

Then, as shown in Fig. 8, the middle coat layer 5 is formed over the undercoat layer 4 by printing a glass paste which is later dried and baked for fixation. Alternatively, the middle coat layer 5 may be formed by applying a fluid resin and thereafter allowing the applied resin to cure.

Then, as shown in Fig. 9, the overcoat layer 6 is formed over the middle coat layer 5 by printing a glass paste which is later dried and baked for fixation. Alternatively, the overcoat layer 6 may be formed by applying a fluid resin and thereafter allowing the applied resin to cure.

Then, as shown in Fig. 10, each of the auxiliary top electrodes 7 is formed on a respective one of the main top electrodes 2 by printing a silver-palladium paste which is thereafter dried and baked for fixation.

Then, each of the side electrodes 8 is formed on a respective end face 1b of the chip substrate 1 (see Fig. 1) by applying a silver-palladium paste which is later dried and baked for fixation.

Finally, each of the plated metal layers 9 is formed on the auxiliary top electrode 7 and the side electrode 8 (see Fig 2) by

first plating with nickel followed by plating with solder (or tin).

Conventionally, the laser beam trimming is performed with a laser beam which has a collected beam diameter D of $45-55\mu\text{m}$ for realizing a trimming groove width W of $50-60\mu\text{m}$, whereas the pitch P for relative intermittent movement between the chip substrate 1 and the laser beam generator 11 is set in the range of $3-6\mu\text{m}$. Further, the output of the laser beam for the conventional laser beam trimming is $0.6 \times 10^{-3} - 1.5 \times 10^{-3}W$ per shot.

According to the present invention, by contrast, the laser beam trimming is performed with a laser beam which has a collected beam diameter D of $10-40\mu\text{m}$ for realizing a trimming groove width W of $15-45\mu\text{m}$, whereas the pitch P for relative intermittent movement between the chip substrate 1 and the laser beam generator 11 is set in the range of $7-15\mu\text{m}$. In this way, the laser beam diameter D is reduced in comparison with the conventional laser trimming while the intermittent movement pitch P is increased in comparison with the conventional laser trimming. Further, the output of the laser beam is decreased to $0.15 \times 10^{-3} - 0.5 \times 10^{-3}W$ per shot.

Due to the decrease of the trimming groove width W to $15-45\mu\text{m}$ (namely, due to the decrease of the laser beam diameter D to $20-40\mu\text{m}$), the amount of materials of the resistor film 3 and the undercoat layer 4 vaporized for trimming is reduced, the amount of vaporized substances scattered and deposited will be reduced. Further, due to the increase of the relative movement pitch P between the chip substrate 1 and the laser beam generator 11, it

is possible to reduce the number of laser beam shots, thereby reducing the total energy and time required for trimming. Moreover, the consumption of energy is additionally reduced by the fact that the output of each laser beam shot is reduced to $0.15 \times 10^{-3} - 0.5 \times 10^{-3} \text{W}$.

According to the experiments performed by the inventor, it has been found that, due to scattering and deposition of vaporized substance in the conventional laser trimming method, the product chip resistors suffered a high degree of deviations from the adjusted resistance beyond tolerable limits. Thus, for avoiding such a problem, it was necessary to perform washing with an acid or pure water after laser trimming.

By contrast, due to the reduction of the trimming groove width W and the relative movement pitch P , the product chip resistors suffered only a small degree of deviations from the adjusted resistance without washing with an acid or pure water after laser trimming. Actually, the number of rejectable products was reduced to 1/10 in comparison with the products made by the conventional laser trimming.

As previously described, the trimming groove width W lies in the range of $15-45 \mu\text{m}$, whereas the pitch P for relative intermittent movement between the chip substrate 1 and the laser beam generator 11 is set in the range of $7-15 \mu\text{m}$. If the trimming groove width W is smaller than $15 \mu\text{m}$, the chip resistor may suffer a malfunction due to passage of a current across the trimming groove 10 upon application of an excessive voltage while increasing noises. Further, if the trimming groove width W is

smaller than $15\mu\text{m}$, air may be unexpectedly trapped in the trimming groove 10 when forming the middle coat layer 5, which air may expand to form pin holes in the protective coating layers 4-6 at the time of subsequent baking. Moreover, if the relative movement pitch P is larger than $15\mu\text{m}$, the trimming groove 10 may become discontinuous or incomplete.

According to the embodiment described above, the pitch P for relative intermittent movement between the chip substrate 1 and the laser beam generator 11 is set in the range of $7\text{--}15\mu\text{m}$. However, the relative movement pitch P may be reduced to $3\text{--}6\mu\text{m}$ only in the final stage of the laser trimming when the measured resistance approaches the target value. Such a change of the pitch P in the final stage of the laser trimming provides a fine adjustment of the resistance while maintaining the advantages obtainable by an increase of the pitch P .

The preferred embodiment being thus described, it is obvious that the present invention may be varied in many ways. Such variations should not be regarded as a departure from the spirit and scope of the present invention, and all such variations as would be obvious to those skilled in the art are intended to be included within the scope of the following claims.



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CLAIMS

1. A process for adjusting the resistance of a chip resistor which comprises an insulating chip substrate (1), a resistor film (3) formed on the chip substrate (1), and an undercoat layer (4) formed on the resistor film (3), the process comprising the steps of forming a trimming groove (10) in the resistor film (3) and the undercoat layer (4) by irradiating these with a laser beam while causing the chip substrate (1) and the laser beam to move intermittently relative to each other,

characterised that the laser beam is collected so that the trimming groove (10) has a width of 15-45 μ m, and

that the chip substrate (1) and the laser beam are moved intermittently relative to each other at a pitch of 7-15 μ m.

2. The process according to claim 1, wherein the laser beam has a collected beam diameter of 10-40 μ m.

3. The process according to claim 1 or 2, wherein the laser beam has an output of 0.15×10^{-3} - 0.5×10^{-3} W per shot.

4. The process according to any one of claims 1 to 3, wherein the laser beam is moved relative to the chip substrate (1) which is held stationary.

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5. The process according to any one of claims 1 to 3, wherein the chip substrate (1) is moved relative to the laser beam which is held stationary.

6. A process for adjusting the resistance of a chip resistor which comprises an insulating chip substrate (1), a resistor film (3) formed on the chip substrate (1), and an undercoat layer (4) formed on the resistor film (3), the process comprising the steps of forming a trimming groove (10) in the resistor film (3) and the undercoat layer (4) by irradiating these with a laser beam while causing the chip substrate (1) and the laser beam to move intermittently relative to each other,

characterised the chip substrate (1) and the laser beam are intermittently relative to each other at a larger pitch before a final stage of laser trimming wherein a measured resistance of the chip resistor approaches a target resistance, but at a smaller pitch in said final stage of laser trimming.

7. The process according to claim 6, wherein the laser beam has a collected beam diameter of 10-40 μm to provide a groove width of 15-45 μm .

8. The process according to claim 6 or 7, wherein the chip substrate (1) and the laser beam are moved intermittently relative to each other at a pitch of 7-15 μm before said final stage of laser trimming.

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9. The process according to any one of claims 6 to 8, wherein the chip substrate (1) and the laser beam are moved intermittently relative to each other at a pitch of $3-6\mu\text{m}$ in said final stage of laser trimming.

10. The process according to any one of claims 6 to 9, wherein the laser beam has an output of $0.15 \times 10^{-3} - 0.5 \times 10^{-3} \text{W}$ per shot.

11. The process according to any one of claims 6 to 10, wherein the laser beam is moved relative to the chip substrate (1) which is held stationary.

12. The process according to any one of claims 6 to 10, wherein the chip substrate (1) is moved relative to the laser beam which is held stationary.

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