Installation of Strain Gauges for Sensor Applications

1. Overview

Strain Gauges (SG) installation process consists mainly of gauge bonding and gauge wiring processes. In this chapter, the recommended steps or procedures will be discussed for bonding the SG onto a sensor body and wiring the bonded SG into a Wheatstone bridge circuit, in order to have a complete sensor.

The recommended steps/procedures are tailored to sensor applications with the SG from BCM SENSOR. These steps are proven to be the useful means and necessary techniques for the manufacturing of precision sensors, and can be applied to both the metal foil SG and the semiconductor SG purchased from BCM SENSOR.

To manufacture precision sensors, it is necessary to use so-called heat-curing adhesives to bond the SG onto the surface of the sensor body. Therefore, the instruction described in this chapter will focus on the gauge bonding with an SG adhesive, model B610, which is the heat-curing adhesive and is specially developed by BCM SENSOR for sensor applications. The emphasis of the discussion will be on the proper utilization of the B610 adhesive.

Caution:
- Ensure that the cleaned area is much larger than the size of the SG to be bonded.
- Apply or dry cleaners by movement along one-direction. Never move back and forward.
- Avoid any drying solution on the bonding surface.
- Never touch the cleaned area with the fingers.
- Do not use cotton-tipped applicators with a plastic grip.

2. Installation Steps of Strain Gauges

The installation process of strain gauges (SG) on a sensor body is composed of a number of subprocesses including:

Gauge bonding process, including
- glueing SG with adhesive,
- curing the adhesive

Gauge wiring process, including
- soldering the bonded SG with solder,
- wiring the bonded SG to Whestone bridge circuit

Hereby these processes will be explained in 14 steps.

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Step 1: Surface Preparation of Sensor Body

It is important to make sure that the bonding surface of the sensor body is chemically clean, especially free from any silicone-containing contamination, e.g., the silicone-containing cutting oil or lubricant. Silicone is the worst enemy for the gauge bonding due to its lubricating effect. Therefore, the least amount of silicone contamination can ruin the entire bonding work.

As the sensor body may have had contact with silicone-containing cutting oil during machining, it is necessary to clean the bonding surface by strictly following the instruction in this step. In addition, it is essential to keep the working area free from any silicone-containing product. For instance, cosmetics such as hand cream commonly contain silicone. Therefore, it is recommended that the personnel carrying out the gauge bonding only uses silicone-free hand cream.

1-1 First clean the bonding surface of a metal plate, which is supposed as a sensor body made from either aluminum or steel, with the degreasing solvent such as the degreaser CL1-S1 that contains choloride, or the degreaser CL1-S2 which is IPA (isopropyl alcohol) free of choloride.

In order to avoid contamination of the solvent, the degreaser should be used in the form of an one-way applicator such as the pressurized spray as shown in Fig. 1.

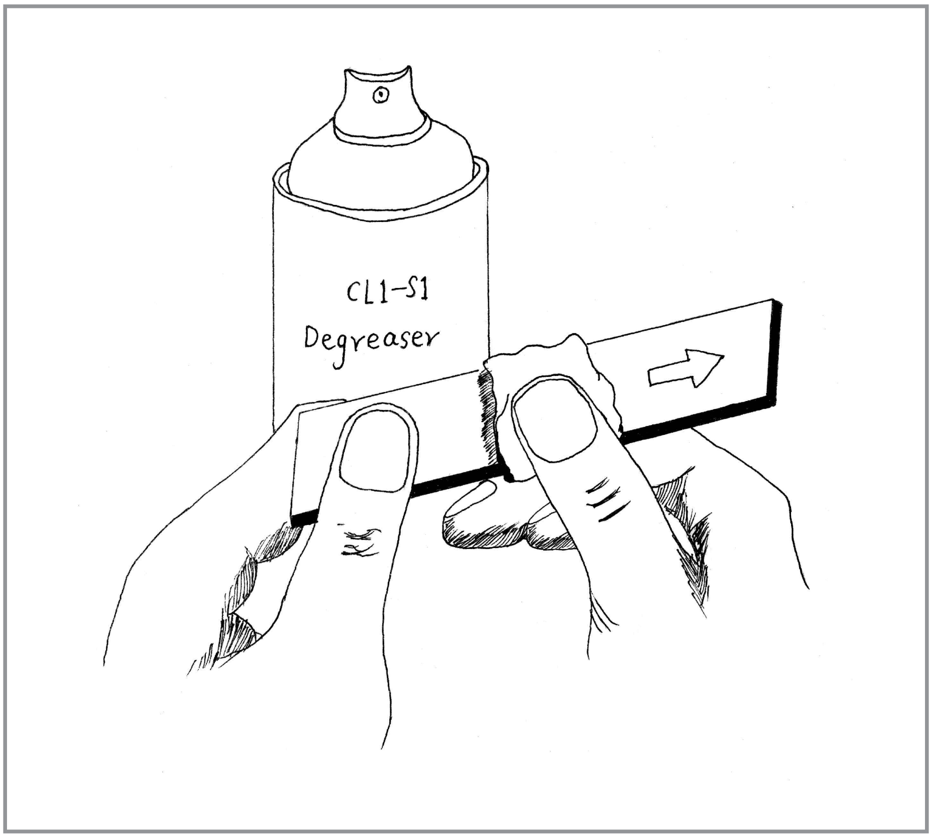

Fig. 1

1-2 Pre-abrade the bonding surface of the metal plate with 220- or 320-grit sandpaper to remove any scale or oxide. Then wet the bonding surface thoroughly with the phosphoric-acid conditioner CL1-W1 and abrade the surface with the 320- or 400-grit sandpaper as shown in Fig. 2. Dry the surface with a gauze sponge after the abrasion as shown in Fig. 3.

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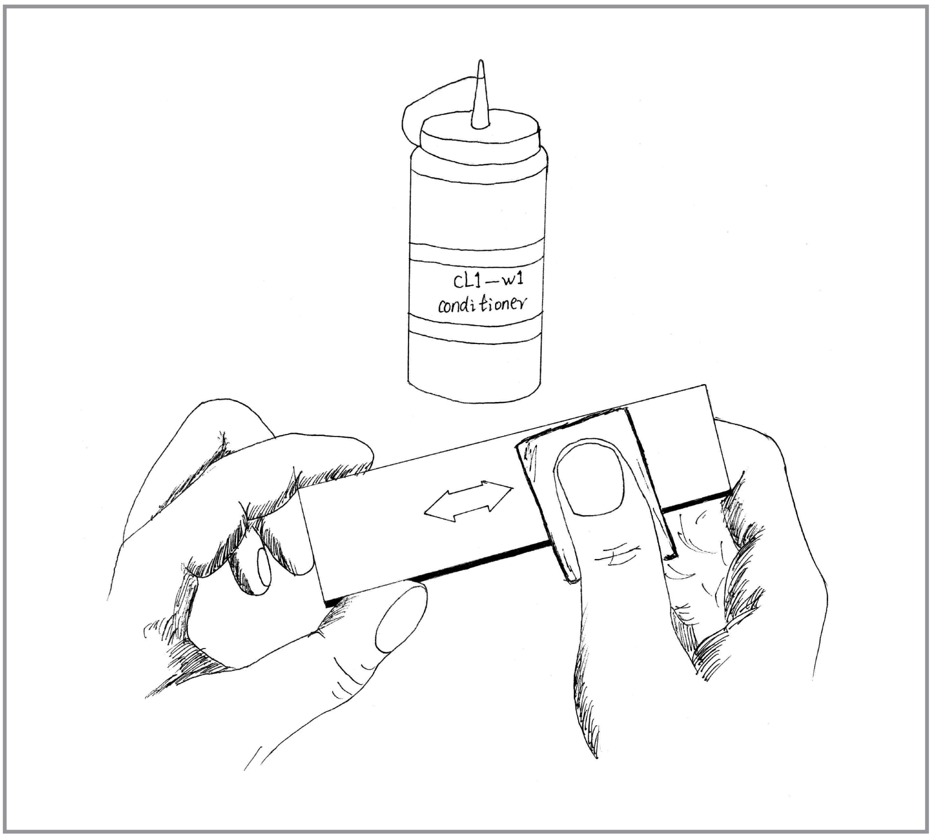

Fig. 2

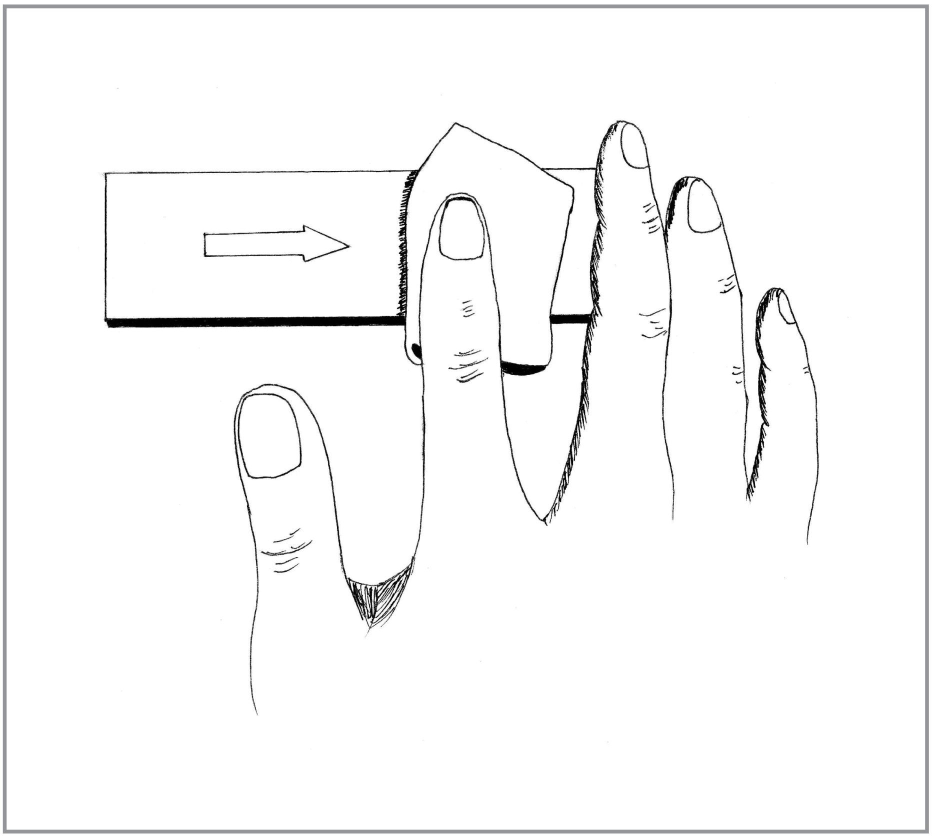

Fig. 3

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1-2' If a sandblast system is employed instead of the sandpapers, it is recommended to use aluminum oxide grits of size 120, …, 400. Moreover, the sandblast system must be operated with oil-free compressed air and used for the surface preparation purpose only in order to avoid any silicone contamination. Finally, the used grits cannot be re-used for surface preparation. Otherwise, there is a risk of contaminating the system with silicone or other chemicals that may cause unqualified bonding.

Remove grinding dust with a gauze sponge wetted with the degreaser CL1-S1 or CL1-S2 IPA, or by brushing with the degreaser CL1-S1 or CL1-S2.

1-3 Mark the critical position to bond the strain gauges on the surface of aluminum plate with a 4H pencil (or with a ballpoint pen if the gauge is to be bonded on the surface of a steel plate). The critical position should be marked as 2 or 3 positioning lines drawn on the metal plate.

1-4 Apply the CL1-W1 conditioner repeatedly with a cotton-tipped applicator on the bonding surface until the color of the applicator tip does not change. Then remove the residual conditioner by slowly wiping with a gauze sponge.

1-5 Apply the CL1-W2 neutralizer with a cotton-tipped applicator, as shown in Fig. 4, to neutralize the pH value of the bonding surface to 7.0~7.5. Then remove the neutralizer and dry the bonding area by slowly and carefully wiping with a gauze sponge.

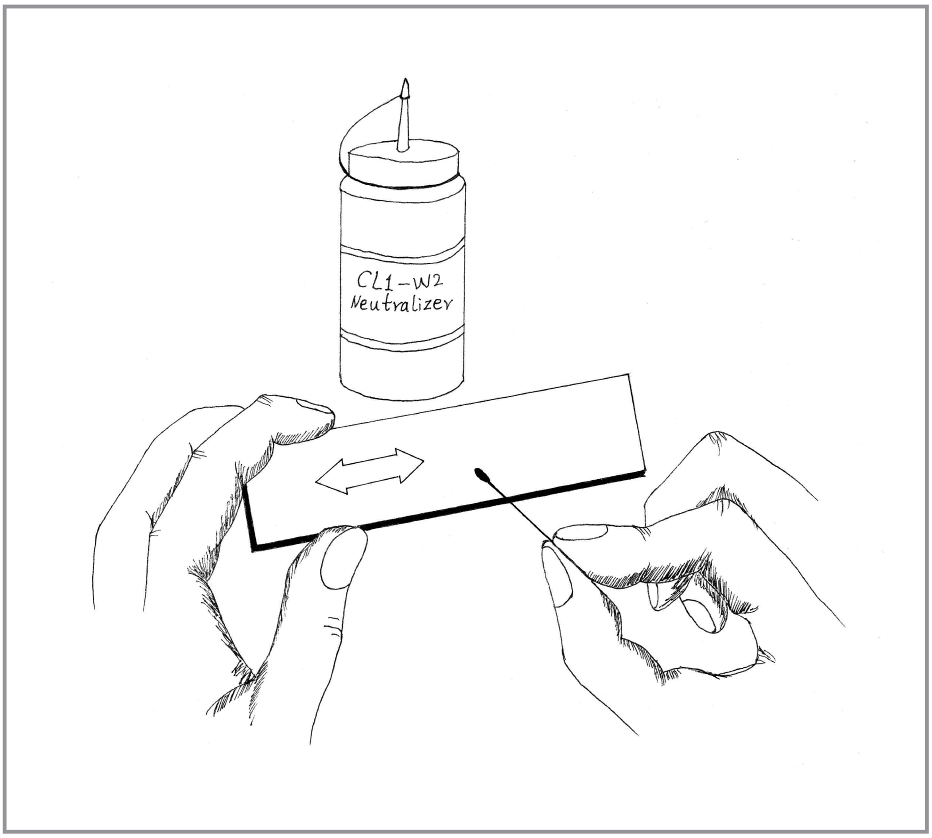

Fig. 4

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Step 2: Positioning Strain Gauges on Sensor Body

Strain gauges (SG) shall be handled only with a blunt-nosed tweezer or a vacuum pen, but can never be touched with the fingers. In case an SG would have been accidentally touched by fingers, clean it immediately with the degreaser CL1-S1 or CL1-S2 IPA, by using cotton-tipped applicators.

Hold the SG at its solder-pad or the edge of its backing layer with the blunt-nosed tweezer or the vacuum pen, but never hold it at its sensing grid area.

Although the SG from BCM SENSOR are cleaned and packaged in a chemically-clean plastic envelope, it is recommended to clean the gauge again immediately before bonding when manufacturing high precision sensors.

2-1 Draw positioning marks on the chemically-clean glass plate. Take the gauge out of its plastic envelope/package with the blunt-nosed tweezer or the vacuum pen, and place the gauge in line with the positioning marks on the chemically-clean glass plate, as shown in Fig. 5, with the gauge bonding side downwards.

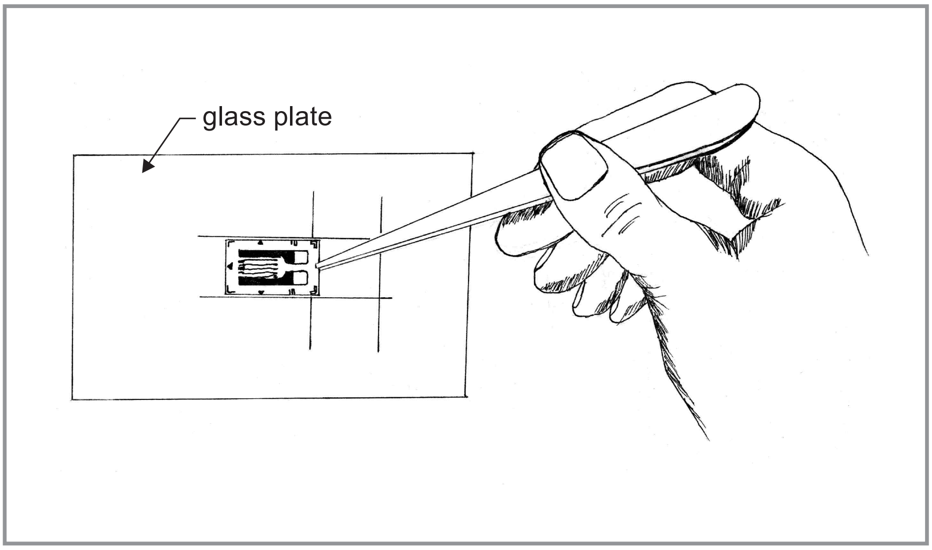

Fig. 5

2-2 Hold the position of the gauge by pressing it with the plastic package, and use a short gauge-anchoring tape (e.g., Mylar tape) to cover half of the gauge's solder pads.

If the bondable terminals are used, peel off the tape at a sharp angle of around 30°, and place the bondable terminals onto the tape at a desired position relative to the gauge. Make sure that the bonding side of the terminals is in the same side as that of the gauge and the terminals are completely covered by the tape. Then stick back the tape, as shown in Fig. 6. One can leave one end of the tape free so as to facilitate the tape removal at the next step.

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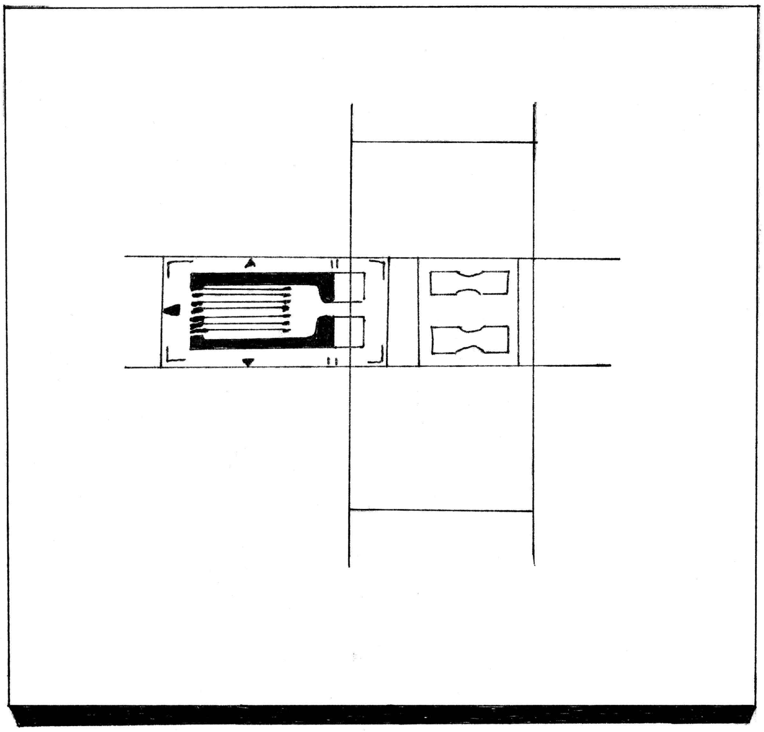

Fig. 6

2-3 Peel off the tape at a sharp angle of around 30°, as shown in Fig. 7, with both the gauge and terminals still sticked on it.

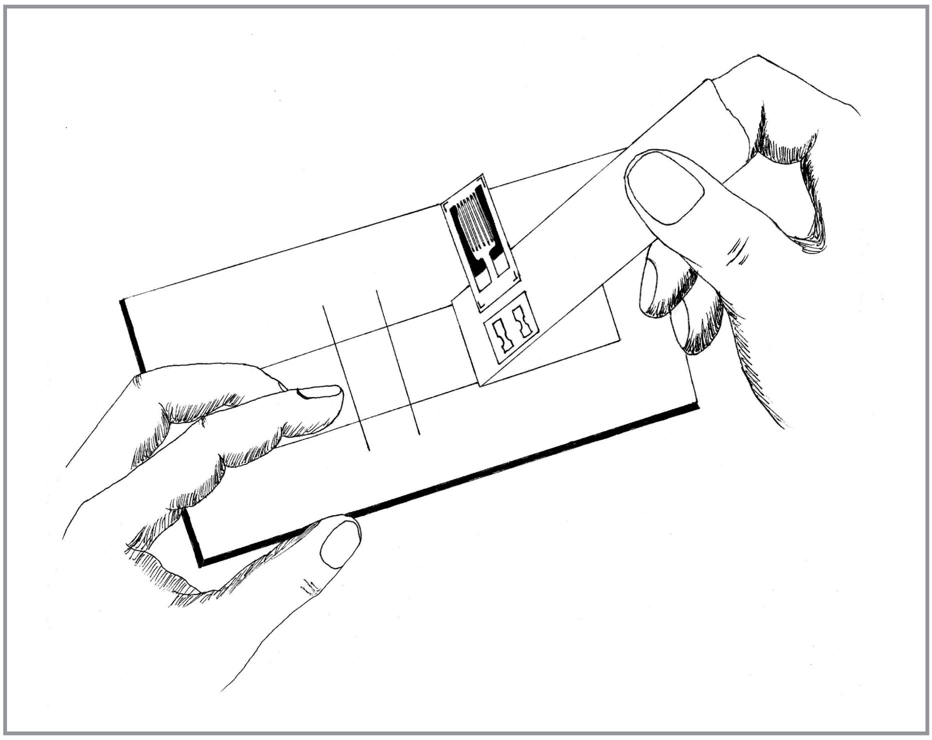

Fig. 7

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2-4 Stick the tape on the bonding surface of the metal plate that has been prepared in Step 1-5 ready for bonding the gauge. It is most important to position the gauge correctly and precisely on the metal plate. This can be done by anchoring the triangle positioning marks on the gauge and the positioning lines drawn on the metal plate, as shown in Fig. 8.

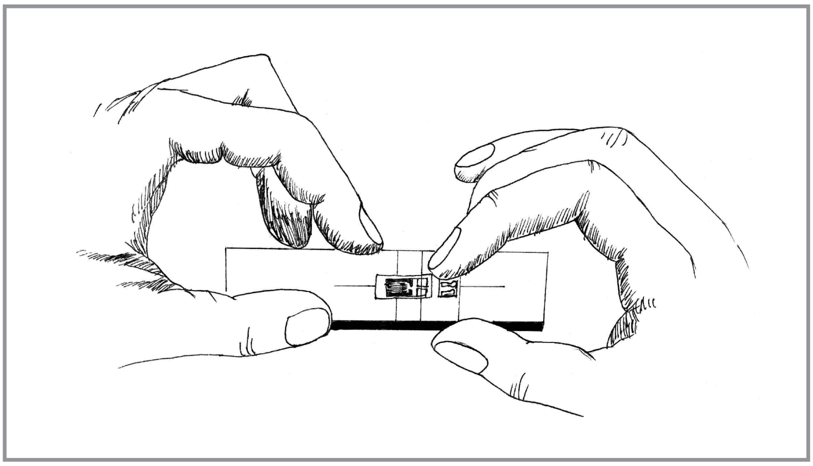

Fig. 8

Step 3: Adhesion of Strain Gauge

To obtain high-quality bonding of the strain gauges (SG), it is essential to keep utmost cleanness. Therefore, the bonding is preferably performed on a dust-free workbench in a clean room with supplied filtered air.

Any surface which is not freshly cleaned (e.g, more than a few minutes after cleaning) shall be considered as a contaminated surface. Therefore, it is recommended to clean this bonding surface again immediately prior to the gauge bonding.

3-1 Peel a part of the gauge-anchoring tape off at a sharp angle of around 30°, to expose the bonding side of the gauge and the terminals for coating of adhesive B610. Nevertheless, the other end of the tape should still be sticked on the metal plate. In this way, the gauge and terminals can easily be placed back at their correct positions when sticking the tape back.

3-2 Clean the bonding surface of the sensor body with cotton tipped applicators wetted with the solvent, e.g., the degrease CL1-S1 or IPA. Renew the cotton tips frequently until the surface is completely clean (cotton tips remain clean).

Caution: The cleaned area should be larger than the bonding area that is required to bond the gauge.

3-3 Coat the bonding area of the sensor body with the B610 adhesive from BCM SENSOR by means of a BDB camel's hair brush, as shown in Fig. 9, and wait a few minutes for the B610 to dry and form a thin layer of the adhesive. In order to have the adhesive layer of a desired thickness, one can refer to Section 3.1. and 3.2..

3-4 Coat the B610 on the bonding side of both the encapsulated SG and the terminals, as shown in Fig. 9. In case one uses the open-face SG or semiconductor SG, one can also coat the B610 on the side of the sensing grid of the open-face SG or the upper side of the semiconductor SG. In this way the B610 can form a thin layer of adhesive to protect the open-face SG or semiconductor SG during the adhesive curing process.

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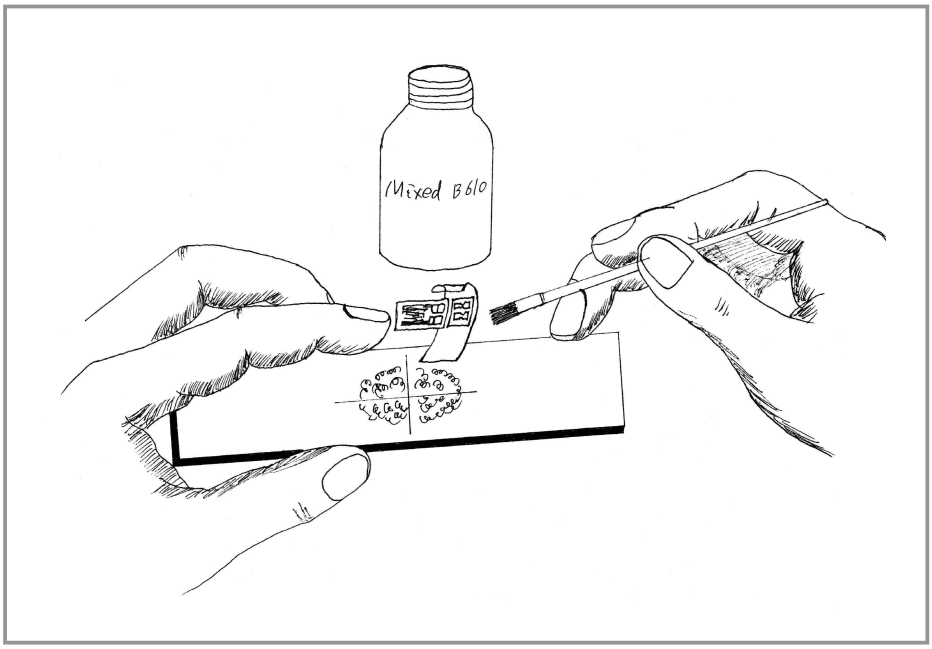

Fig. 9

3-5 Stick back the gauge-anchoring tape to its original position.

3-6 Cover the gauge with a piece of Teflon film of 80μm thick. Slightly press the film with the thumb to smoothly squeeze out the excess amount of the B610. It is very necessary to make sure there is no any possible air bubbles underneath the gauge. Anchor the Teflon film with a piece of the gauge-anchoring tape when it is necessary.

3-7 Cut a 2.5mm thick silicone rubber pad and an aluminum plate with a slightly larger size than the area of the gauge and its terminals. Overlap this silicone rubber pad and the aluminum plate in sequence onto the gauge as shown in Fig. 10. Make sure that the silicone rubber pad does not extend over the Teflon film on at least one side, so that the excess adhesive can easily be pressed and squeezed out by the clamping pressure.

By now, the aluminum plate, silicone rubber pad, Teflon film, strain gauge, and the substrate (i.e., the surface of the sensor body) form a so-called "sandwich" assembly.

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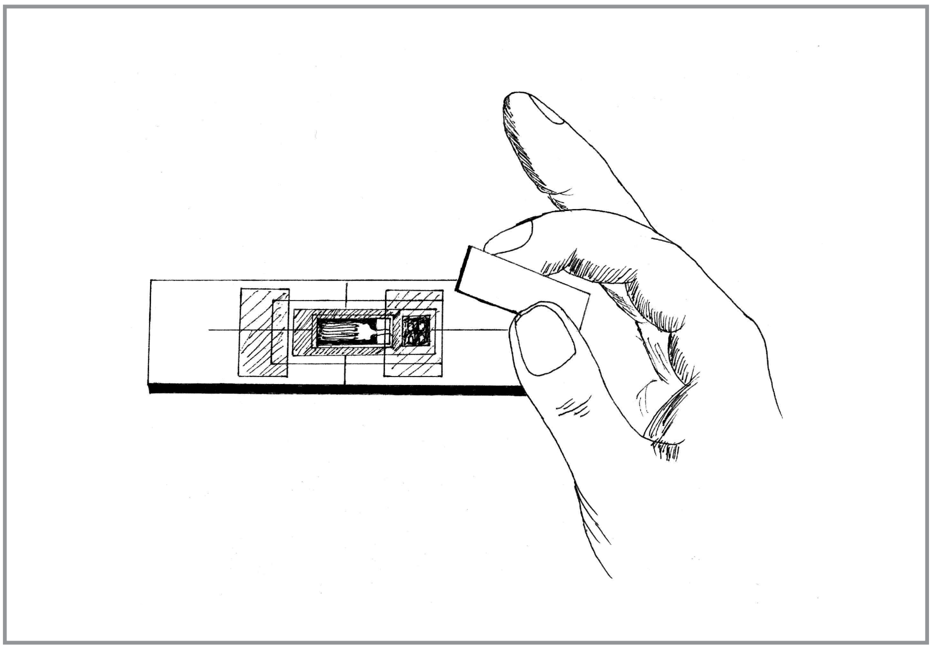

Fig. 10

Step 4: Pressurization of "Sandwich" Assembly with Clamping Tool

The "sandwich" assembly formed at the end of step 3 must be pressurized by means of a spring clamp, as shown in Fig. 11, at a defined and constant pressure during the curing process, in order to have the B610 adhesive form an evenly distributed glue-line of the desired thickness.

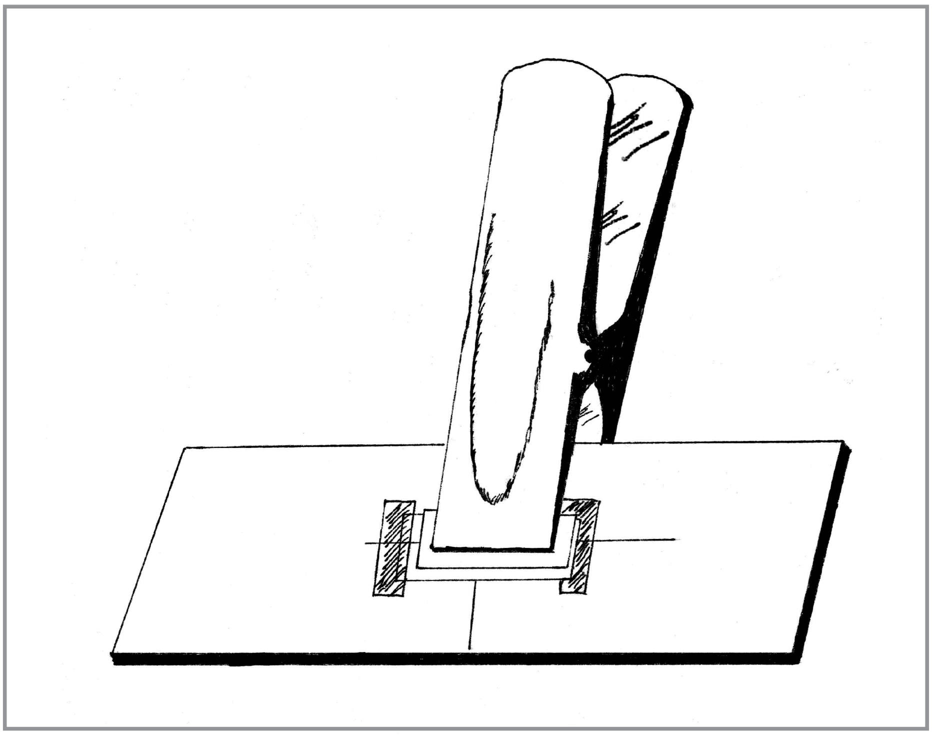

Fig. 11

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The spring clamps or deadweights can be used as a universal clamping tool. To achieve the best quality of gauge bonding, a "tailor-made" clamping tool is highly recommended. This tool must provide a constant and reproducible pressure to the "sandwich" assembly in order to ensure an evenly distributed glue-line of identical thickness.

The aluminum plate, which is the top layer of the "sandwich" assembly, must emulate the shape of the bonding surface. Normally the bonding surface is a plane surface. In case of a cylindrical sensor body, the aluminum plate has to have the same curvature as the cylinder's, so that a homogenous pressure should be guaranteed and applied onto the strain gauges during curing process.

4-1 Put the "sandwich" assembly into the clamping tool and adjust the pressure according to the specified pressure on the adhesive datasheet. How to calculate the optimal clamping pressure will be discussed below in Section 3.1..

4-2 Check whether the Teflon film, the silicone rubber pad and the aluminum plate are in the correct position.

Step 5: Curing of B610 Adhesive

5-1 A correct curing process starts with the clamped "sandwich" assembly placed in a cold oven. The B610 has to be cured at a specified high temperature and the oven temperature must be gradually increased at a rate of 2°C per minute. The various recommended curing temperatures of the B610 are specified and discussed in Section 3..

Starting the curing process in a hot oven often creates air bubbles in the adhesive and often leads to an uneven glue-line and high stress in the adhesive layer.

5-2 After the specified curing temperature is reached, keep the temperature for a certain duration as specified in the datasheet of B610. After the time is over, shut down the power of the oven, keep the clamped "sandwich" assembly inside the oven and let it cool down naturally to the room temperature, in order to remove internal stress in the adhesive layer and toughen it. Then take the clamped "sandwich" assembly out of the oven. Remove the clamping tool, the aluminum plate, the silicone rubber pad, the Teflon film and the gauge-anchoring tapes.

5-3 To finish the curing, clean the entire bonding area with the WBS rosin solvent to remove all residual glue from the tapes and other contamination. Blot dry the solvent with a gauze sponge. The bonded SG should never be touched during this cleaning procedure.

5-4 For high quality sensors, it is necessary to post-cure the SG bonded on the sensor body, in order to completely remove any possible residual stresses in the cured adhesive layer. For the post-curing, the clamping tool has to be removed from the sensor body already. Compared to the curing as mentioned above, the post-curing is conducted with the sensor body heated at a higher temperature for a specified duration, before annealing to the room temperature. One can refer to both the temperature and the duration in the B610 adhesive datasheet.

For the manufacturing of precision sensors, it is always recommended to perform the post-curing process. Nevertheless, one can skip this process if the sensor does not need to have a high accuracy class.

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Step 6: Inspection of Bonding Quality

6-1 After the post-curing, the SG have been bonded on the surface of the sensor body. It is necessary to inspect the bonded SG to ensure the bonding quality. The visual inspection of the bonding quality can be done by using a magnifier or a microscope with 10 times magnification. By means of visual inspection one may find bonding defects as listed in Tab. 1.

Tab. 1

Bonding Defects	Root Cause
Voids, i.e., fairly large un-bonded areas.	Improper adhesiving, or improper clamping.
Bubbles, i.e., similar to voids but always small in a round shape and in a great number.	Improper curing of adhesive, e.g., starting with a hot oven, or improper rate to increase curing temperature.
Uneven glue-line.	Improper clamping pressure, or incorrect shape of clamping tool.

Should bubbles or voids locate under the sensing grid area of the SG, the bonded gauge must be removed and a new SG has to be bonded.

When bubbles are located outside of the sensing grid area, the bonded SG may not be removed which may be suitable for building a qualified sensor.

6-2 The existence of voids or bubbles can be checked by measuring the SG resistance with the SG under excitation. For instance, if voids exist, the measured gauge resistance will be unstable when the SG is excitated with an either constant voltage or constant current source.

6-3 The bonding quality of the bonded SG can be inspected through a creep test too.

Generally speaking, a higher positive creep error (> +0.1%fs/30min) often results from the poor quality of the sensor body material, while a higher negative creep error (> |-0.1%fs/30min|), failure of zero-return, or erratic output reading is mostly due to the poor bonding quality of the SG when it undergoes the gauge bonding process.

Note: In case one of the above-mentioned defects is found, it indicates that a quality problem has happened during the SG bonding process. In such circumstances it is necessary to check the bonded SG thoroughly, in order to figure out and understand the root cause and eventually take necessary corrective and preventative actions in the gauge bonding process.

Step 7: Protect Bonded Strain Gauges (SG) with Protective Coating

The gauge backing is vulnerable to moisture. To prevent the backing layer of the bonded SG from any possible damage at its edge by chemicals or absorbing any moisture during the next steps of gauge installation, it is necessary to apply a protective coating on the bonded SG to form a layer of the protective coating as soon as possible after the curing quality has been ensured.

7-1 Cover the solder pads of the bonded SG with the gauge-anchoring tape.

7-2 Apply the protective coating, e.g., C820 or C821 from BCM SENSOR on the surface of SG and its surrounding area. Cure the coating according to the specified curing conditions as mentioned in the datasheet of protective coating to form a qualified layer of the protective coating.

7-3 After the layer of the protective coating gets properly formed, remove the tape, clean the entire bonding area with the WBS rosin solvent, and blot dry the solvent with a gauze sponge.

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Step 8: Selection of Soldering Tools and Auxilary Products

8-1 Solder station: Select a soldering station which can adjust temperatures of the soldering iron. Typically the temperatures of the soldering iron is from 200ºC to 400ºC. Such temperature range is likely corresponding to the power consumption of the solder station around 20W~50W.

8-2 Solder tip: A correct shape of the solder tip is flat-chisel like instead of a sharp point, as shown in Fig. 12.

Use one solder tip with only one type of solder. If different types of solder are in use, prepare a sufficient number of solder tips so that at least each type of solder is used with a specific solder tip.

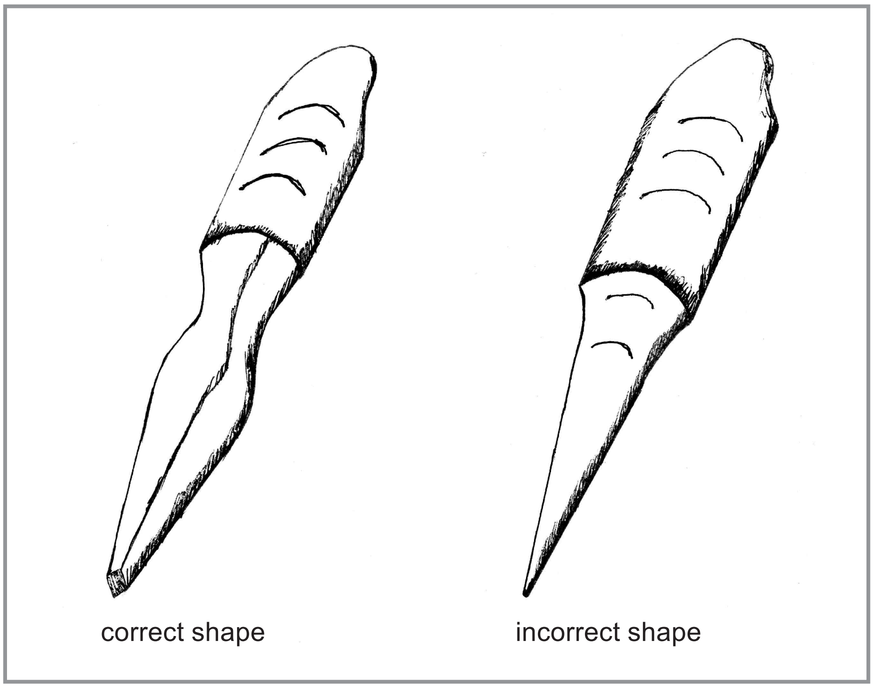

Fig. 12

8-3 Solder: Select the proper type of solders according to the metal foil materials of the bonded SG, the bonded resistors and the bonded terminals.

In sensor applications, the solder of an intermediate melting temperature is commonly used. For instance, a solder of Sn60Pb40 (i.e., 60% tin and 40% lead) or Sn63Pb37 with melting point of 183°C is mostly used. Comparing the lead-free solder with the leaded solder, a lead-free solder normally has a higher melting point. The most commonly used lead-free solder, e.g., SAC 305 (Sn96.5 Ag3 Cu0.5) has a melting point around 217°C ~ 220°C.

For general-purpose of soldering, a widely used solder is the WFS solder which has a core of activated rosin flux. The WFS solder is normally sufficient as it can be used to solder leads/wires onto the constantan SG and the copper foil resistors without need for the external flux. Thanks to this, the WFS solder is especially popular when the liquid rosin flux is not available in the field.

The WFS rosin-core solder can also work with the WLF liquid rosin flux in case the activated rosin flux in the core is insufficient. However, the WFS rosin-core solder can never be used together with the WAF liquid acid flux, because the activated rosin flux in the core is not compatible with the WAF liquid acid flux.

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To solder leads/wires onto the karma SG, the WSS solid-wire solder is recommended to be used together with the WAF liquid acid flux. This is because the WAF liquid acid flux can assist the soldering process of the karma SG.

Caution: Never mix different types of solder during soldering process.

8-4 Flux: Select the flux according to the type of solder as listed in Tab. 2 below.

Tab. 2

Type of Solder	Type of Flux	Application
WFS rosin-core solder	WLF liquid rosin flux	General purpose, e.g., soldering leads/wires onto the constantan gauges and the copper terminals.
WSS solid-wire solder	WAF liquid acid flux	Soldering leads/wires onto the karma gauges.

Caution: Never mix different types of flux.

Step 9: Gauge Soldering

To facilitate the work, it is recommended to conduct the soldering under a magnifier of 2, …, 10 times magnification.

9-1 Prepare the solder pads and the gauge before tinning.

If there is any excess adhesive or protective coating contaminated on the solder pads of the bonded SG, it is necessary to clean the solder pads by removing the adhesive or protective coating away from the pads. This can be done by using an eraser pen or an electrical eraser.

For the karma gauges with the naked solder pads (SP), one may use a sandpaper of 600- or 800-grit to remove the oxidized surface of the SP and clean the SP with ethanol afterwards.

To avoid the SP from being oxidized again, it is recommended to conduct the tinning immediately after the cleaning of the SP.

For the karma gauges with solder dots (SD), if there is any excess adhesive or protective coating contaminated on the SD, one may use a sandpaper of 400-grit to slightly abrade the SD in order to expose the SD for soldering.

If the bonded gauge is the open-face gauge, it is necessary to use the gauge-protective tape (e.g., the paper drafting tape) to completely cover the sensing grid of the gauges so as to protect the sensing grid from any splashed solder or flux.

9-2 Adjust the temperature of the soldering iron.

The temperature of the soldering iron should be high enough to have the solder melted well. But it cannot be too high either, because otherwise the flux would vaporize too quickly and the soldering iron could not remain properly tinned and clean.

The temperature of the soldering iron is normally set to one temperature ranging from 250ºC to 400ºC, depending on the solder and flux materials. The higher the soldering temperature, the shorter the soldering time.

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For the tinning and soldering of thin leads onto the constantan gauges, for instance, the temperature of the soldering iron can be set to 260~300°C and the soldering process should be completed in less than 2 seconds, if one makes use of the WFS rosin-core solder. On the other hand, one can set the temperature of the soldering iron to around 250°C or even lower if one makes use of the solder of Sn60Pb40 together with the flux, which is chloride free and non-corrosive.

For the tinning and soldering of thin leads onto the karma gauges, the temperature of the soldering iron should be set at least at 300ºC and the soldering time should not be longer than 2 seconds. The tinning and soldering should be carried out by using the WSS solid-wire solder together with the WAF liquid acid flux with the solder iron of temperature 330~340°C. In addition the combination of the solder Sn60Pb40 and the 2.5% flux (i.e., the flux with solid content of 2.5% weight ratio) is a good alternative to tin and solder thin leads onto the karma gauges.

9-3 Follow the steps below to tin the solder pads of both strain gauges and bondable terminals.

- Clean the soldering tip and wet it with a small amount of the solder.
- If karma gauges are finished with solder dots (SD), it is not necessary to re-do the tinning on the solder pads of the karma gauges.
- Apply a drop of the WLF liquid rosin flux to the solder pads. If the WFS rosin-core solder is in use, this step may be skipped.

  However, in case tinning on the naked solder pads of karma gauges, apply the WAF liquid acid flux to the solder pads only.

  To help control the amount of flux, one can use a teeth-stick to absorb a little flux and drop a tiny amount onto the soldering pads.
- Tin the solder pads with the WFS rosin-core solder. For the karma gauges, tin the solder pads with the WSS solid-wire solder.
- If the WFS rosin-core solder is used in the tinning, it is not necessary to clean the flux residues at this moment.

  However, if the WAF liquid acid flux is in use, clean the area by brushing the CL1-W1 conditioner and blot dry with the gauze sponge. Then apply the CL1-W2 neutralizer to clean the area again and blot dry with the gauze sponge.

9-4 Follow the steps below to tin and solder the thin leads onto the solder pads.

- Trim the thin leads to the desired length, clean and tin the ends of the leads with the same solder as used in Step 9-3.
- A small amount of flux may be applied to the solder pad. For the karma gauges with solder dots (SD), do not apply any flux.
- Hold the lead flat onto the solder pad in the suitable direction, and apply a drop of the solder at the end of the lead with the soldering tip.
- Keep the position of the end of the lead on the solder pad stable for approximately 1 second until the solder drop becomes solid and form a shinning soldered joint on the solder pad.

  It is usually not necessary to apply additional solder.
- For the leads between the solder pads of the gauge and the terminals, form a strain-relief loop as shown in Fig. 13.

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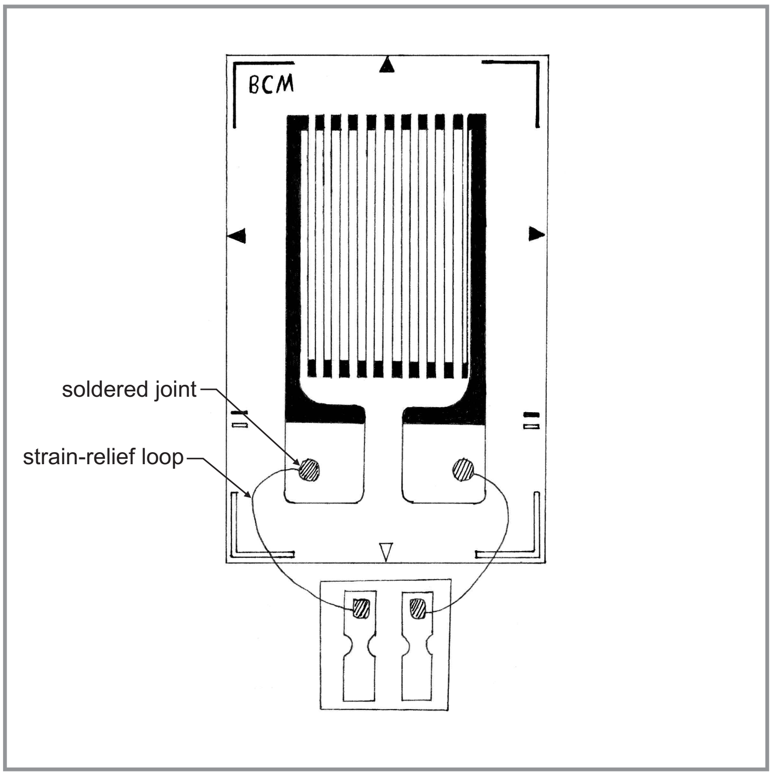

Fig. 13

Step 10: Flux Removal

Flux residues on the strain gauge have to be removed completely after the soldering process is finished. This is because any flux residue can cause instability of the strain gauge and destroy the sealing property of the protective sealant which will be applied on the gauge at Step 12.

10-1 Clean the entire bonding area with the WBS rosin solvent by using a soft middle-sized brush. Other cleaners may be used, e.g., the IPA, or the flux cleaner for printed circuit boards.

10-2 If the gauge-protective tape was used to cover the sensing grid of the open-face gauge, as described at the end of Step 9-1, before removing away this tape, the WBS rosin solvent should be applied continuously to the edge of the tape, so that the glue of the tape can be completely de-adhesive. In this way, the tape can eventually be removed.

Cautions:

(1) Do not pull the tape away from the sensing grid of the open-face gauge prior to the complete de-adhesion of the tape, otherwise the sensing grid may be damaged.
(2) Take care not to break any leads which have been attached to the solder-pads already.

Step 11: Inspection of Soldered Joints

11-1 The soldered joint must be homogeneous, smooth and shiny, without any jagged or burred edges. Any suspected soldered joint shall be re-soldered.

Caution: The quality of the soldered joint cannot be tested by pulling the leads or probing at the joint.

11-2 The leads and wires should lay flat on the solder pad of strain gauges. And the leads between the

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gauge solder pads and the bondable terminals should form the strain-relief loop as shown in Fig. 13.

11-3 No visible flux residues can be observed on the strain gauges.

Step 12: Inspection of Insulation Resistance

Inspect the insulation resistance of the bonded gauge by measuring the resistance between the each soldered lead or wire of the bonded gauge and the sensor body. For instance, an insulation-resistance tester can be employed to execute this inspection.

The insulation should be high at least to 1000MΩ at 50Vdc. A too low insulation resistance is often caused by flux residuals or due to a poor quality of curing of adhesive. When the insulation resistance is too low, the output reading of the sensors will be unstable. Therefore, in such case it is highly recommended to re-do the soldering or the gauge bonding.

Step 13: Gauge Wiring

Refer Step 8 to 12 to wire the bonded SG to form a Wheatstone bridge circuit.

Step 14: Protect Bridge Circuit of Bonded Strain Gauges with Sealant

To protect the bridge circuit against moisture and other chemicals, apply the protective sealant S910 or S911 to cover the complete area of the bridge circuit.

To select the suitable sealant, one can refer to the datasheet of protective sealant.

Check the insulation resistance once again as described in Step 12 after the protective sealant has cured.

3. Curing Conditions of B610 Adhesive

For manufacturing precision sensors, it is recommended to use the B610 heat-curing adhesives from BCM SENSOR. Following the instructions given below is especially important to achieve optimal curing and post-curing results when using the B610 adhesive.

It is always recommended to apply the specified pressure in the curing process. The higher the pressure applied by the clamping tool, the smaller the creep error of sensors.

It is always recommended to apply the specified temperature and time in the curing and in the post-curing processes, respectively, to achieve better curing and annealing results.

3.1. Curing Pressure

The curing pressure may vary in line with the different adhesives or the different sensor body materials. It is recommended to apply the maximum possible curing pressure in the curing process.

The curing pressure is always applied by the clamping tool of clamping forces.

One can calculate the required clamping force by using the following formula:

clamping force = size of aluminum plate x specified curing pressure
For example, if the size of a desired rectangular shape aluminum plate is 10mm x 5mm = 50mm^2, and the

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required curing pressure is 5bar (according to the adhesive specifications and the sensor body material as mentioned above in the section 3.1. and 3.2.), then the required clamping force can be calculated as

$$\text{clamping force} = 5(\text{kgf/cm}^2) \times 50 \times 10^{-2}\ \text{cm}^2 = 2.5\text{kgf} = 24.5\text{N}$$

Caution: The curing pressure cannot be too high, otherwise the glue-line will be too thin to have enough adhesion. For the gauges with tinned solder dots, a too high curing pressure (e.g., 8bar), may result in detached solder dots.

3.2. Curing Pressure versus Glue-Line Thickness and Creep Error

For sensor applications, a higher curing pressure can generate a thinner glue-line which leads to a lower negative creep error. Therefore, it is recommended to apply the maximum allowable curing pressure in order to reduce the creep error.

The optimal thickness of the glue-line ranges from 15μm to 20μm. This thickness can provide not only enough adhesion, but also keep the creep error to remain at a sufficiently low level.

3.3. Curing Pressure versus Sensor Body Materials

For the given SG with the same backing material, the curing pressure may be different if the sensor body is made from different materials. In Tab. 3 an example is shown in which the curing pressure is different for the two different sensor body materials, although the same SG with the modified polyimide (backing code: I) backing layer are bonded on them.

Tab. 3

Backing Material	Sensor Body Material	Curing Pressure
modified polyimide resion (code I)	mild steel or stainless steel	3bar, …, 5bar
modified polyimide resion (code I)	aluminum alloy	1bar, …, 3bar

3.4. Curing Temperature and Duration versus Sensor Body Materials

For the given SG with the same backing material (e.g., the modified polyimide, backing code: I), the curing temperature and duration may vary if the sensor body is made from different material. Listed in Tab. 4 are the curing temperature and duration of the two most commonly used metals, which the sensor body is made from.

Tab. 4

Backing Code	Sensor Body Material	Curing Pressure	Curing Temperature and Duration	Post-Curing Temperature and Duration
I	mild steel or stainless steel	3bar, …, 5bar	170°C for 1.5 hours	200°C for 2 hours
I	aluminum alloy (e.g., 2024)	1bar, …, 3bar	135°C for 2 hours	165°C for 2 hours

Caution: The minimum curing temperature of B610 is 135°C while its maximum curing temperature is 200°C.

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3.5. Curing Temperature and Duration versus SG Backing Materials

The curing temperature and duration are also related to the operating temperature range of the SG backing materials. Listed in Tab. 5 are the curing temperatures and durations according to the SG backing materials.

Tab. 5

Backing Code	Sensor Body Material	Curing Pressure	Curing Temperature and Duration	Post-Curing Temperature and Duration
F	mild steel or stainless steel	3bar, …, 5bar	135°C for 2 hours	165°C for 2 hours
I, B, L	mild steel or stainless steel	3bar, …, 5bar	170°C for 1.5 hours	200°C for 2 hours
A	mild steel or stainless steel	3bar, …, 5bar	200°C for 1.5 hours	230°C for 2 hours

Conclusion: the appropriate curing conditions (pressure, temperature and duration) should be determined by considering both the maximum operating temperature of the SG backing material and the material of the sensor body.

4. Bonding N-series Naked Semiconductor Strain Gauges

The N-series semiconductor strain gauges from BCM SENSOR are the naked gauges without any backing layer beneath the silicon-bar. Compared to the B-series semiconductor gauges that have the backing layer, the N-series is often selected to benefit from both a lower creep error and a faster response time.

Caution: As the silicon-bar of the semiconductor strain gauge is fragile, extra care shall be taken when handling the naked gauges. Take the naked gauge at its leads instead of at its silicone-bar. Do not pull the two leads of the gauge at the same time.

4.1. Insulation Layer of Naked Gauges

Since the N-series are naked gauges, prior to the gauge bonding as described in Step 3 in Section 2., it is necessary to form an insulation layer first for the naked semiconductor gauges. To do so, one can follow the Step 1 and Step 2 as described in Section 2., and apply the B610 adhesive to cover the surface of the gauge bonding area, and cure it completely at the specified temperature to form a proper insulation layer for the naked gauge to be bonded on it.

To reduce the creep error for the naked gauge to be bonded on it, it is better to apply a thinner layer of B610 adhesive on the bonding surface, as long as the layer provides a sufficient insulation to the gauge. It is recommended to form a layer of about 30μm thickness for insulation purpose.

Caution: The insulation layer must have a smooth surface and there should not be any lump, bubble or void in the insulation layer.

4.2. Bonding Process of Naked Gauges

There are two ways to bond the N-series gauges: one is bonding it with pressure and the other is to bond it without pressure (pressure-free bonding process).

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As long as the creep error can meet the required limit of the sensors, it is recommended to apply the pressure-free bonding process. Glue the gauges onto the insulation layer and cure the gauges in an oven at the specified temperature for the specified time.

If the creep is beyond the limit of the sensors, it is recommended to bond the gauge with pressure in the same way as used in bonding of the metal foil gauge. A pressure of 0.5bar, …, 1bar may be applied in the curing process to reduce the creep error.

4.3. Connect Copper Wires to Gold Leads of Naked Gauges

Step-1: Bond the bondable terminals next to the naked gauges.

Step-2: Apply indium instead of tin to solder the gold leads of the naked gauge to the terminal. The maximum soldering temperature is 165 °C.

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