How to Select Semiconductor Strain Gauges (SG)

Overview

The semiconductor SG from BCM SENSOR are made from P-type monocrystalline silicon wafers doped with Boron. The silicon wafers are diced to form silicon bars of tiny width (about 220μm), and processed to very thin thickness (about 30μm). To utilize the piezoresistive effect, the longitudinal dimension of silicon bars is diced along the [111] crystallographic axis.

By means of silicon surface finishing technique, the flatness and quality of the lower surface of the silicon bars are adapted to the requirements for bonding the semiconductor SG onto the surface of the sensor body. There are metallization contact pads at the two ends of the silicon bars, from which two golden leads are welded as two electrical terminals. The diameter of the golden leads is 50μm and their length is standardized to 10mm.

All the semiconductor SG from BCM SENSOR are classified into two categories: one is the naked gauge without the backing-layer (N-series) and the other is the gauge with the backing-layer (B-series).

Naked Gauges versus Backed Gauges of Backing Layer

The advantage of the naked gauges is that, they have no creep-, hysteresis- and nonrepeatability-errors which are mostly introduced by the backing layer. In addition, the response time of the naked gauges is faster than that of the backed gauges. As there is no backing layer, one has to take more care when handling the naked gauges in the bonding process, compared to the gauges with the backing layer.

As the naked gauges have no backing-layer, it is necessary to first create an insulation layer on the surface of the sensor body where the naked gauges are to be bonded. This can be done by curing a proper amount of SG adhesive on the sensor body surface. One can refer to Section 4. of *Installation of Strain Gauges* for more details.

The backed gauges have the advantage of easier handling in the gauge bonding process. Nevertheless, as the backing layer introduces creep-, hysteresis- and nonrepeatability-errors, it is not recommended to use the B-series gauges for high precision sensor applications.

Gauge Length

The gauge lengths available from BCM SENSOR are 1.3mm, 2.6mm, 3.8mm and 5mm. The shorter gauge length is suitable for a limited bonding area. If the strain in question is distributed over a large area, it is suggested to select the semiconductor SG of longer gauge length in order to sense the measurable strain as much as possible.

Measurable Strain

The minimum strain is in a level of about 1 με (microstrain), which is measurable by the naked gauges (N-series). In practice the minimum probed strain will depend on the working conditions of the specific application on site such as measuring devices, signal conditioning electronics and working environment.

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To keep reasonable linearity, the maximum strain to measure is limited to ±1000με for all semiconductor SG from BCM SENSOR. The higher the strain level beyond the strain limit of ±1000με, the larger the nonlinearity will be observed.

Bonding on Curved Surface

In general, it is not recommended to bond the semiconductor SG onto a curved surface because silicon can easily be broken due to the curvature of the surface.

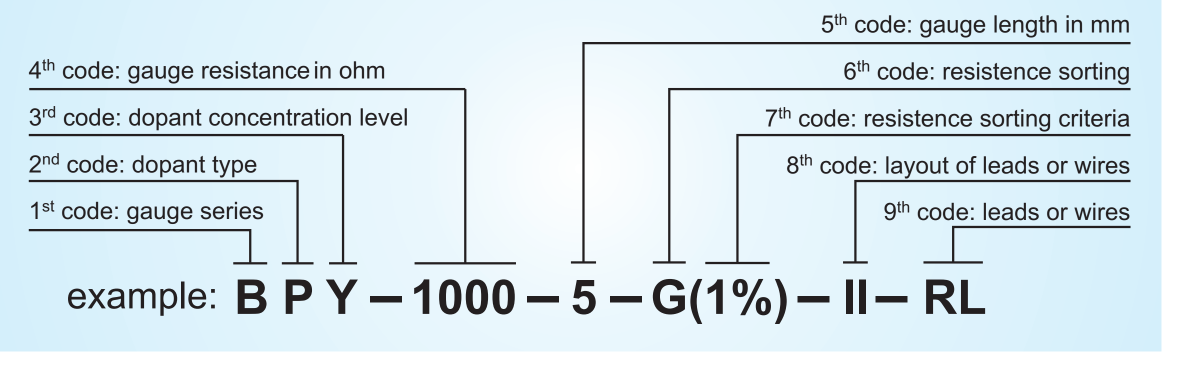
Nevertheless, in case a very small strain in a spring element of a curved surface has to be measured, the radius of curvature is limited to 10mm.

One can also try with the semiconductor SG of the shortest gauge length (i.e., 1.3mm or 2.6mm from BCM SENSOR) as long as it cannot be broken during bonding process.

For detailed engineering advice on utilizing the semiconductor SG, one can contact BCM SENSOR.

1. Guidance of Ordering Code System of Semiconductor Strain Gauges

The ordering code system shown below is to help users to purchase the semiconductor strain gauges (SG) from BCM SENSOR. More advice is given in the explanation of each code below the chart.



<u>1st code: gauge series</u> – whether the gauge is with or without the backing layer.

Two available series are:
- B: gauge with backing;
- N: naked gauge.

<u>2nd code: dopant type</u> – all semiconductor SG from BCM SENSOR take use of the P-type silicon which features a positive gauge factor.

Therefore, only one dopant type is available:
P: P-type.

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3rd code: dopant concentration level – one of the factors to determine the gauge factor.

Listed below are the 5 available dopant concentration levels and the corresponding gauge factor:

level	gauge factor
V	80
W	100
X	130
Y	150
Z	200

4th code: gauge resistance – the resistance which is measured from the two leads of the gauge at 20°C.

The gauge resistance is influenced by the dopant concentration level and the dimensions of the silicon-bar. The available gauge resistances for the specific dopant concentration level can be found in the datasheet of semiconductor SG.

5th code: gauge length – the length of the silicon-bar.

Please refer to the datasheet for the available gauge lengths for each dopant concentration level.

6th code: resistance sorting – whether the gauges will be sorted further or not.

Two available options are:

- G: grouped gauges, i.e., the gauges will be sorted further by grouping every 4 gauges together according to the maximum difference of resistance which is specified by the 7th code. In this way the difference of resistance over these 4 grouped gauges can be lower than the ±2% tolerance of nominal resistance per package.

- U: ungrouped gauges, i.e., the gauges will not be specially sorted and grouped. In this case the 7th code can be omitted.

7th code: resistance sorting criteria – the maximum difference of average resistance over the 4 grouped gauges.

The available sorting criteria is: 1%.

For other sorting criteria, please consult BCM SENSOR.

As mentioned above at the 6th code, this code is only applicable to the grouped gauges (G).

8th code: layout of leads or wires – the orientation in respect of the gauge's longitudinal dimension.

For the N-series, only one type of layout is available:

I: gold leads extending axially along the two ends of the silicon bar, as demonstrated in the datasheet.

For the B-series, 3 types of layout are available:

I: silver-plated copper leads parallelly to the silicon bar and extending out of the backing layer from two sides, as demonstrated in the datasheet.

II: silver-plated copper leads perpendicularly to the silicon bar and extending out of the backing layer at one side, as demonstrated in the datasheet.

III: silver-plated copper leads parallelly to the silicon bar and extending out of the backing layer from one side, as demonstrated in the datasheet.

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9th code: leads or wires – the electrical interface of the gauge.

Four types of leads or wires are available to select as listed below:
- RL(1): silver-plated round copper leads if one prefers to bonding the SG with round leads;
- EW(2): enamel insulated round copper wires if the SG has to be bonded with enameled wires;
- PW(3): PVC (Polyvinyl chloride) insulated wires, which is rare for sensor applications;
- HW(4): PTFE (polytetrafluoroethylene) insulated wires, not often for sensor applications.

Notes:

(1) Dimensions of RL:
- diameter of its cross section: Ø0.15 mm;
- length: standardized to 13±1.5 mm; other lengths available on request.

(2) Specifications and dimensions of EW:
- operating temperature range: -40 ~ +150 °C;
- diameter of its cross section: Ø0.15 mm;
- length: standardized to 30±1 mm; other lengths available on request, but with a limit of 1m.

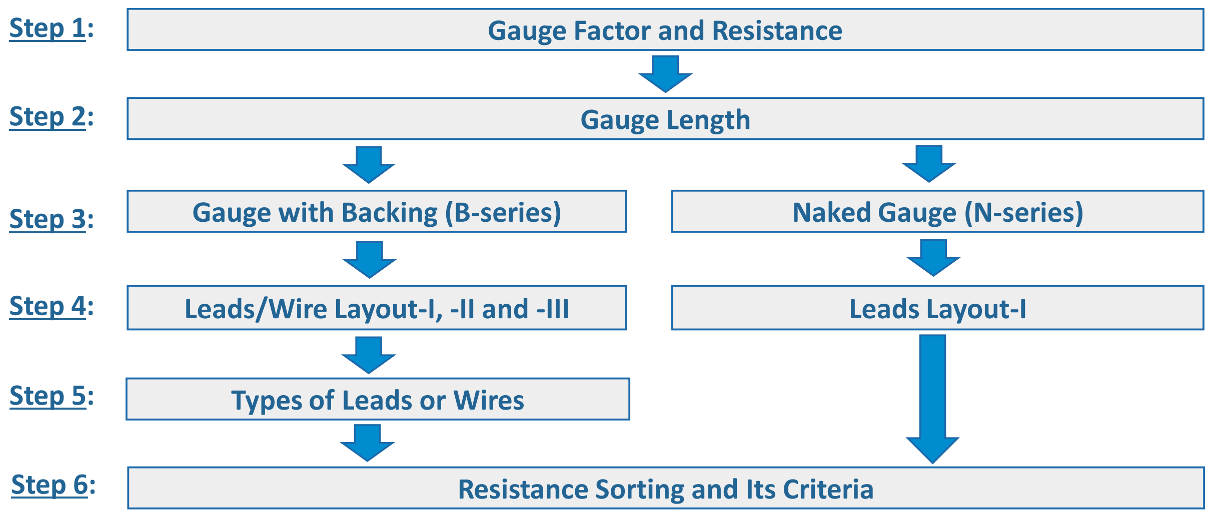
(3) Specifications and dimensions of PW:
- operating temperature range: -40 ~ +105 °C;
- outer-diameter of wire: Ø0.6 mm;
- number of conductors: 7;
- diameter of cross section of the single conductor: Ø0.08 mm;
- length: standardized to 30±1 mm; other lengths available on request, but with a limit of 1m.

(4) Specifications and dimensions of HW:
- operating temperature range: -60 ~ +180°C;
- outer-diameter of wire: Ø0.3mm;
- number of conductors: 1, i.e., solid conductor;
- diameter of cross section of the single conductor: Ø0.15mm;
- length: standardized to 30±1mm; other lengths available on request, but with a limit of 1m.

2. Selection Procedure of Semiconductor Strain Gauges

The selection procedure of semiconductor strain gauges (SG) are less complex, compared to the selection procedures of metal foil SG. Anyhow a right selection of SG is still crucial in the beginning of the application.

The following chart can assist you with your selection according to the application. Below the chart is the further explanation of each step.



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Step 1: Decide the gauge factor and resistance by considering the electronics of the data acquisition circuitry or system.

The level of dopant concentration is one of the main factors to determine the gauge factor. For the standard semiconductor SG from BCM SENSOR, each doping-level code refers to one specific gauge factor.

With the same gauge factor, there are different gauge resistances available for selection.

When sensors are powered by batteries, it is recommended to use SG with higher resistance to lower the power consumption.

Step 2: Decide the gauge length by considering the beam length of the designed sensor body, as well as the available bonding area.

For applications of non-linearity correction of the column load cells, the bonding area is normally not a concern.

Generally, the semiconductor SG with a longer gauge length needs more care when handling during its installation process as the SG is fragile. On the other hand, one can benefit from a better heat dissipation due to the longer gauge length.

Step 3: Decide between the semiconductor SG with or without the backing layer (in short, called backing) by considering the handling and creep error.

The pros and cons of the semiconductor SG with or without the backing are as follows:

The naked gauges (i.e., N-series) have the advantage of eliminating the creep error introduced by the backing and of occupying less bonding area. However, without the backing, more care is needed when handling the N-series during the gauge bonding process. Furthermore, an insulation layer must be formed prior to bonding the N-series onto the sensor body surface.

The gauges with backing (i.e., B-series) have the advantage of easier handling in their bonding process. But, compared to the N-series naked gauges, the B-series gauges with backing will result in a longer response-time, and the backing layer will also introduce creep-, hysteresis- and repeatability-errors into the output signal of the sensors.

Step 4: Select the layout of leads or wires according to the gauge type and the convenience of wiring the gauges to the designed electrical circuit in the application.

The B-series has three available layouts of leads or wires, while the N-series has only one layout.

Step 5: Select the type of leads or wires according to the working conditions in the applications.

This step is only applicable if the B-series is selected. If the N-series is selected, one can skip this step to the next step.

The mostly used leads type is RL (silver-plated round copper leads) in sensor applications.

The wire type of EW (enamel insulated copper wires), PW (PVC insulated copper wires) and HW (PTFE insulated copper wires) are rarely used in sensor applications. They are more often selected for application of stress analysis. As this data book focuses on the sensor application, there will be no further explanation about these wires.

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Step 6: Decide resistance sorting and its criteria according to the applications.

The grouped gauges are required if the nominal tolerance of gauge resistance of four gauges is too high to guarantee the zero offset of Wheatstone bridge circuit in sensor applications.

For non-linearity correction of column load cells or stress analysis, it is normally not necessary to require the grouped gauges.

The remaining code which was not discussed here is the dopant type. Now all the semiconductor SG from BCM SENSOR are made from the P-type silicon. Therefore, one can already complete the ordering code after following the above-mentioned four steps.

For detailed engineering advice on utilizing the semiconductor strain gauges, one can contact BCM SENSOR.

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