ICS 27.120
CCS F 88

NATIONAL STANDARD OF THE PEOPLE'S REPUBLIC OF CHINA

GB/T 5201-2012

Replacing GB/T 5201-1994

Test procedures for semiconductor charged particle detectors

带电粒子半导体探测器测量方法

Issued on: June 29, 2012 **Implemented on: November 1, 2012**

Issued by: State Administration for Market Regulation;
Standardization Administration of the PRC

Table of Contents

1 Scope

The standard lays down methods for measuring the electrical characteristics and the nuclear radiation performance of semiconductor charged particle detectors, together with test methods for certain special environments.

It applies to semiconductor detectors for charged particles with a partially depleted layer.

The measurement of fully depleted semiconductor detectors may be carried out by reference to this standard.

2 Normative references

Three documents are cited: GB/T 4960.6-2008 Terminology of nuclear science and technology, Part 6: Nuclear instruments; GB/T 10263-2006 Environmental conditions and test methods for nuclear radiation detectors; and GB/T 13178-2008 Gold-silicon surface barrier detectors.

For dated references only the edition cited applies; for undated references the latest edition, including all amendments, applies.

3 Terms and definitions

The terms and definitions given in GB/T 4960.6-2008 apply to this document; the standard defines no terms of its own.

4 General requirements

4.1 Measurement shall be carried out under the reference conditions or the standard test conditions given in Table 1. That table has three columns, for the item, the reference condition and the standard test condition, and covers thirteen items: ambient temperature, relative humidity, atmospheric pressure, ac supply voltage, ac supply frequency, ac supply waveform, dc supply voltage, ambient gamma radiation as air absorbed dose rate, external magnetic field interference, external magnetic induction and radioactive contamination. The reference ambient temperature is 20 °C and the standard test range 18 °C to 22 °C; the reference relative humidity is 65 % and the standard range 50 % to 75 %; the reference atmospheric pressure is 101.3 kPa and the standard range 86 kPa to 106 kPa. Two footnotes state that the single phase supply is 220 V or the three phase supply 380 V, that when a battery supply is used its voltage variation is plus or minus 1 % of the rated value and ripple is not taken into account, and that in special cases the ac supply frequency is dealt with as the product standard provides.

4.2 Every measurement of the performance of a detector shall be carried out in complete darkness.

4.3 During measurement the limiting conditions of the detector, such as the permitted working bias and the maximum particle fluence rate, shall not be exceeded, and the technical specification of the instruments used shall have no marked influence on the result of the measurement of the detector parameters.

4.4 The reproducibility of the performance parameters measured shall lie within the measurement uncertainty.

4.5 The voltage drop that the leakage current of the detector produces across the bias resistor shall be less than 15 % of the bias applied to the detector.

4.6 For detectors working under low vacuum, the relevant performance may be measured at 0.1 Pa to 5 Pa. For detectors working under high vacuum, the relevant performance shall be measured at a pressure below 0.0001 Pa.

5.1 Voltage-current characteristic (V-I characteristic)

When the reverse V-I characteristic is measured, the circuit shall be connected as in Figure 1; for each value of reverse bias the corresponding reverse current shall be recorded, and the ambient temperature at the time of measurement shall be recorded as well.

When the forward V-I characteristic is measured, the circuit shall be connected as in Figure 2; the result is expressed as the forward voltage drop at a fixed forward current, for instance 5 mA.

Both block diagrams show the detector with an ammeter in series and a voltmeter in parallel, a resistor R, and a bias supply.

5.2 Capacitance-voltage characteristic

The block diagram of the measurement is Figure 3. The working frequency of the bridge shall lie between 1000 Hz and 100 000 Hz. The peak to peak value of the ac signal that the bridge applies to the detector shall be less than one tenth of the detector bias. The value of the dc blocking capacitor, in picofarads, shall be at least ten times the maximum junction capacitance of the detector under test, and its voltage rating shall be twice the maximum bias applied to that detector. The inductor may also be replaced by a high value resistor; the resistance shall be chosen so that the voltage drop across it is negligible compared with the detector bias and so that the output capacitance of the supply does not affect the result.

The steps are: measure the capacitance of the system at a given bias with the detector disconnected; connect the detector and measure, at the same bias, the sum of the detector capacitance and the system capacitance, the detector capacitance in picofarads being the difference of the two, as given by equation 1; then change the bias and repeat, so obtaining the variation of the detector capacitance with bias.

5.3 Noise measurement

5.3.1 Detector noise is measured by the pulse height method, the measuring system being connected as in Figure 4: bias supply, load resistor R, detector, charge sensitive amplifier, amplifier and multichannel pulse height analyser, with a test capacitor and a matching impedance Z fed from a precision pulse generator. If the multichannel pulse height analyser used is of the digital type, it may be connected directly to the charge sensitive amplifier and no amplifier is needed.

5.3.2.1 The amplifier shall have a quasi-Gaussian shaping function with adjustable shaping time. The shaped pulse shape is that of Figure 5, settled by the performance of the shaper and by the time constant. Figure 5 gives the parameters that fix the shape, the rise time to the peak, the tail time and the width at half the peak amplitude; noise shall be measured with the half amplitude width at 1 microsecond.

5.3.2.2 The pulse signal delivered by the precision pulse amplitude generator shall be an exponentially decaying signal whose rise time is not greater than 5 % of the shaping time constant of the amplifier. The decay time of the pulse signal shall be such that, over an interval equal to the shaping time constant of the amplifier, the pulse amplitude falls by less than 2 %. The integral non-linearity of the generator shall be less than 0.1 %.

5.3.2.3 The test coupling capacitor shall in general be less than 10 pF.

5.3.2.4 The gain of the measuring system and the signal amplitude shall work in the linear range, and the width at half height of the peak measured on the multichannel pulse height analyser shall be greater than 12 channels.

5.3.3 For the calibration of the input signal, the detector is given its normal working bias and irradiated with a charged particle source of known energy, an alpha source requiring vacuum conditions, so that a corresponding spectrum is obtained on the multichannel pulse height analyser. The source is then removed, the precision amplitude pulse generator is switched on and its output is adjusted until its peak position on the multichannel analyser coincides with the peak position of the source.

5.3.4 To measure the amplifier noise, the detector is taken off and the input of the preamplifier is closed with a screening cap; the spectral lines corresponding to the generator signals of energy E1 and E2 are recorded separately. With the generator signal set to E1, when the count in the peak channel of the spectrum is greater than 4000, the points on the spectral line whose count is more than half the peak count are taken and the peak channel is calculated by the weighted mean of equation 2. The amplifier noise expressed as the width at half height is settled by interpolation. If a computer curve fitting method is used, a lower count may be used provided the deviation of the width at half height is within plus or minus 5 % at 90 % confidence. The generator signal is then changed to E2 and the peak position determined in the same way. The amplifier noise with zero external capacitance is calculated by equation 3, and the difference between the chosen E1 and E2 shall be greater than three times the width at half height of the spectral line. Capacitors of different values are then connected at the input of the preamplifier and the measurement repeated, so that the curve of amplifier noise against external capacitance is obtained and from it the slope of the preamplifier noise against capacitance.

5.3.5 To measure detector noise, the detector is given the intended bias and the spectral lines corresponding to the generator signals of energy E1 and E2 are obtained, as shown in Figure 6. Again with a count in the peak channel greater than 4000, the peak positions and the width at half height are recorded, and the total noise of the detector and amplifier system is calculated by equation 4. If the pulse spectral line is Gaussian or quasi-Gaussian, the detector noise may be obtained as follows: the detector capacitance at the intended bias is read from the capacitance-voltage curve measured in 5.2, and the amplifier noise corresponding to that capacitance is read from the curve of amplifier noise against external capacitance measured in 5.3.4; this noise value represents the electrical noise other than