J.Phy.Ast.
Print-ISSN: 2320-6756
Online-ISSN: 2320-6764

Journal of
Physics &
Astronomy
WWW.MEHTAPRESS.COM

Full Paper

Calibration of cryogenic Si diode for temperatures between 30-210 K

S.B.Ota

Institute of Physics, Bhubaneswar 751005, (INDIA)
E-mail: snehadri@hotmail.com
PACS: 07.20.Dt; 07.20.Mc; 85.30.-z; 06.70.Dn

Received: July 05, 2013
Accepted: August 20, 2013

*Corresponding author's Name & Address

S.B.Ota
Institute of Physics, Bhubaneswar 751005, (INDIA)
E-mail: snehadri@hotmail.com

Abstract

The variation of forward voltage with temperature of a cryogenic silicon diode of CRYO Industries of America Inc. Model No. DT-470-SD-13 is measured in the temperature range 30-210 K and for current values between 10 nA and 200 μA. The characteristic is least squres fitten by a 1st order polynomial and the coefficients are given. The least squares fitting has high temperature root between 420 K and 625 K.

Key Words

Forward characteristic; Silicon; Temperature sensors.

The forward voltage of a semiconductor diode is known to increase by decreasing the temperature[1-4]. The characteristic has therefore found application in the measurement of low temperature[4,5]. Semiconductor diodes exclusively made for sensing low temperature are nowadays available commercially which can provide accuracy of 50 mK. Recently, the calibration of GaAlAs diode[6-8] and Si1N4007 diode[9] have been communicated. In this article the forward voltage variation with temperature of cryogenic silicon diode[10] of CRYO Industries of America, Inc., Model No. DT-470-SD-13 for a range of current values in the temperature range 30-210 K has been presented.

The measurements were carried out using a computer-controlled four-probe setup built around a Leybold closed cycle helium refrigerator. A Keithley model 224/2243 programmable current source provided a stable constant current to the experimental diode. The forward voltage was measured using a Keithley model 182 digital voltmeter. The temperature of the sample site was controlled using a calibrated silicon diode in connection with a Leybold model LTC-60 temperature controller. Each data point was obtained by averaging 500 voltage readings.

The relation between the forward current I_f and forward voltage V_f is given by:

$$V_f=(nk_BT/e)\ln(I_f/I_S+1) \quad (1)$$

where I_S is the saturation current, e is the electronic charge, k_B is the Boltzmann constant and n is a parameter depending on the material, temperature and current level. The sensitivity $S=|dV_f/dT|$ is linear in $\ln(I_f)$ and is given by:

$$S=(nk_B/|e|)\ln(I_f/I_S+1) \quad (2)$$

Figure 1 shows the temperature dependence of V_f for currents between 10 nA to 200 μA. The measured voltage as a function of temperature, for various current values, was least-squares fitted to a 1st order polynomial.

$$V_f=a_0+a_1T \quad (3)$$

For the 1st order least-squares fitting there are two coefficients, a_0 and a_1, which are given in TABLE 1 for various values of current. The coefficients a_0 and a_1 are found to be positive and negative respectively. The R^2 of the least squares fitting was nearly 1.0. There is high temperature root T_0 for the least squares fitting which is found to increase as the corresponding values of the current is increased from 10 nA to 200 μA. The T_0 is 420 K and 625 K, for I_f of 10 nA to 200 μA, respectively. In case of 1st order least squares fitting the coefficient a_1 represents the average sensitivity of the diode which is found to increase with decrease in current which is given in Eq.2.

$$S = 1.26 - 7.45 \times 10^{-2} \ln(I) \quad (4)$$

where I is in A and S is in mV/K. Therefore, S is found to reduce linearly with ln(I).

The coefficient a_0 represents the extrapolated voltage at zero temperature. Although it agrees approximately with the band gap of Si which has a value of 1.2 eV, there is noticeable increase from 1.08 V for 10 nA to 1.20V at 200 μA unlike Si1N4007 diode[9].

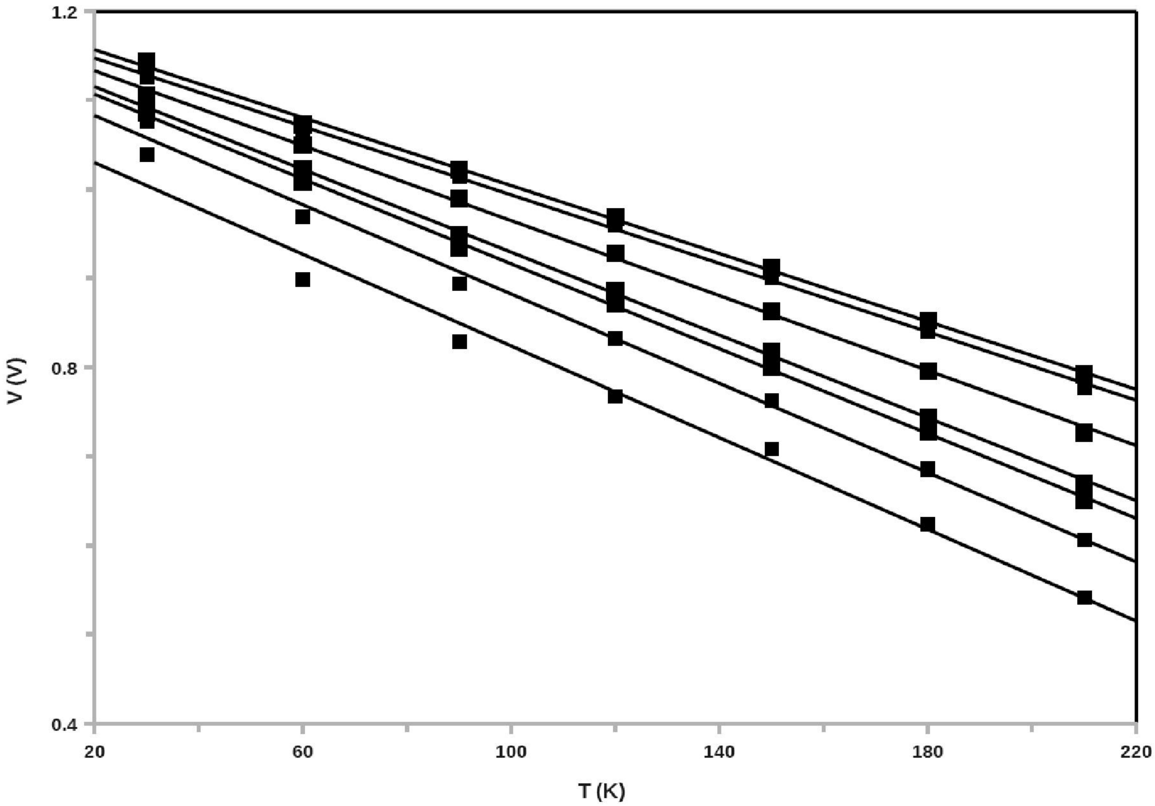

Figure 1 : The temperature dependence of the forward voltage of the cryogenic Si diode temperature sensor for various current values: 10 nA (lowest curve); 100 nA; 500 nA; 1 μA; 10 μA; 100 μA and 200 μA (topmost curve). The solid line through the data are 1st order least-squares fits.

TABLE 1 : The 1st order least squares fitting of cryogenic Si diode

Current	a_0	a_1	R^2	T_0 (K)
10 nA	1.08166	-0.00258	0.98	420
100 nA	1.13319	-0.00251	1.00	450
500 nA	1.15438	-0.00238	1.00	485
1 μA	1.16175	-0.00232	1.00	500
10 μA	1.17522	-0.00210	1.00	560
100 μA	1.18602	-0.00192	1.00	620
200 μA	1.19516	-0.00191	1.00	625

In conclusion the forward voltage of a cryogenic Si diode is measured at low temperaures. The data is obtained for current values between 10 nA and 200 μA and in the temperature range 30 K 210 K. The voltage as function of temperature is least-squares fitted to a 1st order polynomial. Flicker 1/f noise has also been observed in the cryogenic diode.

REFERENCES

[1] H.Harris; Scientific American, **204**, 192 **(1961)**.
[2] A.G.McNamara; Rev.Sci.Instrum., **33**, 330 **(1962)**.
[3] B.G.Cohen, W.B.Snow, A.R.Tretola; Rev.Sci.Instrum., **34**, 1091 **(1963)**.
[4] J.Unsworth, A.C.Rose-Innes; Cryogenics, **6**, 239 **(1966)**.
[5] G.K.White; Experimental techniques in low-temperature physics, Clarendon Press, Oxford, 115 **(1979)**.
[6] S.B.Ota, S.Ota; J.Mod.Phys., **3**, 1490 **(2012)**.
[7] S.B.Ota, S.Ota; J.Phy.Ast., **2**, 7 **(2013)**.
[8] S.B.Ota, S.Ota; J.Phy.Ast., **2**, 33 **(2013)**.
[9] S.B.Ota; J.Phy.Ast., **2**, 50 **(2013)**.
[10] M.Bose, S.B.Ota; Rev.Sci.Instrum., **67**, 4176-4178 **(1996)**.