4.5. Determination of the band gap from V–T *data*

For the evaluation of the energy band-gap it is more frequently followed a different experimental procedure (and also data analysis), consisting on the recording of V at different temperatures at fixed current I. It is possible to extract from our set of I–V curves the $V\,vs.\,T$ pairs at fixed diode current $\overline{I}$. The data processing consist in a linear interpolation of the value of V between adjacent experimental pairs (V_i, I_i) and (V_{i+1}, I_{i+1}) with $I_i < \overline{I} < I_{i+1}$.

It is customary to choose $\overline{I}$ in a region where the Shockley characteristic curve can be approximated by

$$\overline{I} = I_A \exp \frac{V - eE_G}{nkT}$$

Taking the logarithm of both sides, a linear relation $T(V)$ is obtained:

$$T = -aV + b \tag{9}$$

with

$$a = \frac{1}{nk \log \frac{I_A}{\overline{I}}}$$

and

$$b = \frac{eE_G}{nk \log \frac{I_A}{\overline{I}}}$$

so that with a simple linear fit the best values of a and b are calculated and:

$$E_G(eV) = -\frac{b}{a}$$

where the possible dependencies of n and I_A cancel out. The final result of this analysis is shown in Fig.(10) where the linearity of $T(V)$ is corroborated and the best fit values give $E_G = 1.161 \pm 0.002$ eV for $\overline{I} = 20\mu A$. The values does not depend significantly on the choice of $\overline{I}$ in the region of moderate currents.

The overestimation of the expected value of E_G is quite common in experiments driven at constant current and based on the analysis of the $T - V$ dependence. For example, [24] reports a value of 1.18 ± 0.02 eV at 300 K for the 1N4007 Si diode and [25] a value of 1.23 eV for the 1N4181. A good agreement with the accepted values of E_G extrapolated at 0 K is reported by [10] which reports 1.19 ± 0.02 eV for the base emitter junction in a 2N2222 transistor and [26] (1.165 ± 0.002 eV) in a 2N930 transistor. Finally, in [27] the authors analyze the (T, V) data of a diode 1N4148, taken at different values of I with a reciprocal procedure that extracts the temperature dependence of the saturation current. Assuming a pure exponential model for I_S they find a value $E_G = 1.04 \pm 0.02$ eV in very good agreement with the result found with our first method.

5. Conclusion

We have presented a detailed analysis of the direct current-voltage characteristic of a silicon diode 1N4148. A simple numerical method, based on the standard non linear fitting algorithms used by MatLab or Octave languages, is used with models of increasing complexity. The entire procedure of measurement and modelling can be easily automated integrating the data collection performed in a LabVIEW