Table 1. Experimental parameters of the models for the I–V data at $T = 47.8\,°C$

	G (μS)	$R_s(\Omega)$	I_S (nA)	B (V^{-1})	n
Minimal model	-	-	14.63 (0.16)	19.48 (0.03)	1.856
Low I (eq. (5))	2.75 (0.01)	-	9.72 (0.17)	20.30 (0.05)	1.783
High I (eq. (7))	-	2.32 (0.03)	13.4 (0.12)	19.78 (0.02)	1.830
Full curve (eq. (4))	2.80 (0.05)	2.75 (0.05)	10.5 (0.2)	20.2 (0.1)	1.790

of eq. 4, an equation $I = f(I, V)$ could be written as the objective function of a fitting procedure suitable for models expressed in implicit form. Nevertheless this kind of algorithms are very complex and frequently suffer of numerical instabilities.

Here we describe an alternative method, based on an iterative fitting procedure for models expressed in explicit form, leading to simultaneous determination of four parameters necessary to reproduce the DC diode characteristic in a large region of currents. This method can be summarized in few steps, including the iteration described in the loop section, where i is the flowing index, I, I^i and I^i_J are respectively the experiment values, computed values and computed junction values of current:

1 The first few data at very low currents are used to compute a first guess G^i $(i = 0)$ of the parallel conductance with a linear fit of the model $I = GV$.

2 **BEGIN LOOP** Computing $I^i_J = I - G^iV$ gives the estimate of the junction current.

3 The explicit model $V = V(I_J)$ of eq. (7) is fitted with the data calculated at step 2 and the estimate of I^i_s, B^i and R^i_s is found.

4 Updated values of the junction current I^{i+1}_J are found solving numerically eq. (7) with the measured V and assuming the estimate of the three parameters I^i_S, B^i and R^i_s.

5 Updated values of total current I^{i+1} are computed as $I^{i+1} = G^iV + I^{i+1}_J$.

6 The first few data of I^{i+1} are compared to I to obtain the new value G^{i+1}: $I - I^{i+1} = \delta GV$, $G^{i+1} = G^i + \delta G$.

8 **END LOOP** The four parameters with index $i+1$ are compared to previous values: if the change is much less than the estimate of their errors the loop ends, otherwise it continues, returning to step 2.

After few iterations the four parameters converge toward stable values and the procedure may be stopped. The final result is shown in the Fig. (8) where the agreement of the model with the experimental data is very good over the entire range.

Table 1 shows the extracted parameters with the different models presented, using data of a specific current region when needed. The last set is obtained by using the iterative fitting procedure.

4.4. Determination of energy band gap from temperature dependence of parameters

In this section we extract energy band gap from temperature dependence of I_S parameter, fitting I–V data taken at temperature between 10 and 100 °C. E_G is not explicitly present in the Shockley equation as it is enclosed only in the saturation current I_S; a more detailed expression of eq. (3) is given by:

$$I_S = AT^2 \exp\left(-\frac{E_G}{nkT}\right) \tag{8}$$