Finding the IV curve of a Power Diode

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1 Theory

One can calculate the resistance of a any ohmic device using Ohm's law:

$$V = IR, R = \frac{V}{I}$$

if the relationship between V and I is linear in the range of interest. Components, such as semiconductors, filaments, inductors and capacitors, for which the relationship between V and I is not linear($V \not\propto I$) exhibit interesting and useful properties. This investigation will look at the IV curve of a power diode and interpret the curve in terms of the useful properties it imbues the device.

A diode is a silicon PN junction, a negative voltage across it increases the width of the depletion region between two doped regions by decreasing the number of carriers in the doped regions, between 0 and $0.65V$ the depletion region become thinner but still limits the flow of charge (effectively a high resistance), after $0.65V$ the deletion region is gone and the effective resistance drops to that of normal doped silicon which is very low. Theory predicts two other phenonmena that are unlikely to be measurable with the appartus used:

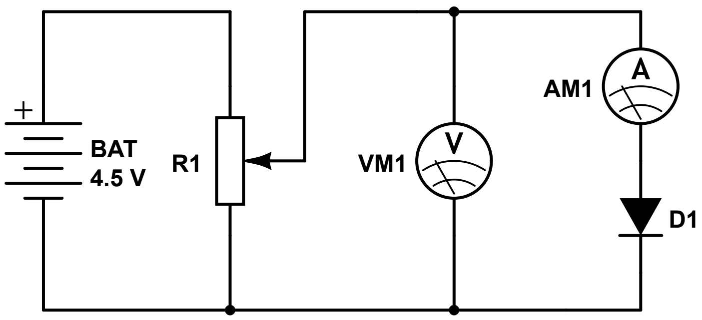
- A very low leakage current in the negative voltage range caused by thermal carries, this current is likely to be below the range of the ammeter used.
- A breakdown at a high negative voltage caused when the electrons have enough energy to break down the PN junction, this typically occurs at 100s of Volts for power diodes and is thus impractical to measure in this instance.

2 Method

The voltage across the diode (independent variable) will be varied over an appropriate range, each measurement will consist of a voltage (*independant*) and current (*dependant*) pair representing a point on the diode's IV curve.

The measurement apparatus was constructed as follows:

- In order to avoid noise in the measurements, a stable voltage source was constructed using chemical batteries and a potentiometer. This avoids the low frequency noise observed from a comparable AC to DC style voltage source.
- Both the voltage and current were measured using multi-meters to an accuracy of $\pm 0.005V$ and $\pm 0.005mA$, respectively.

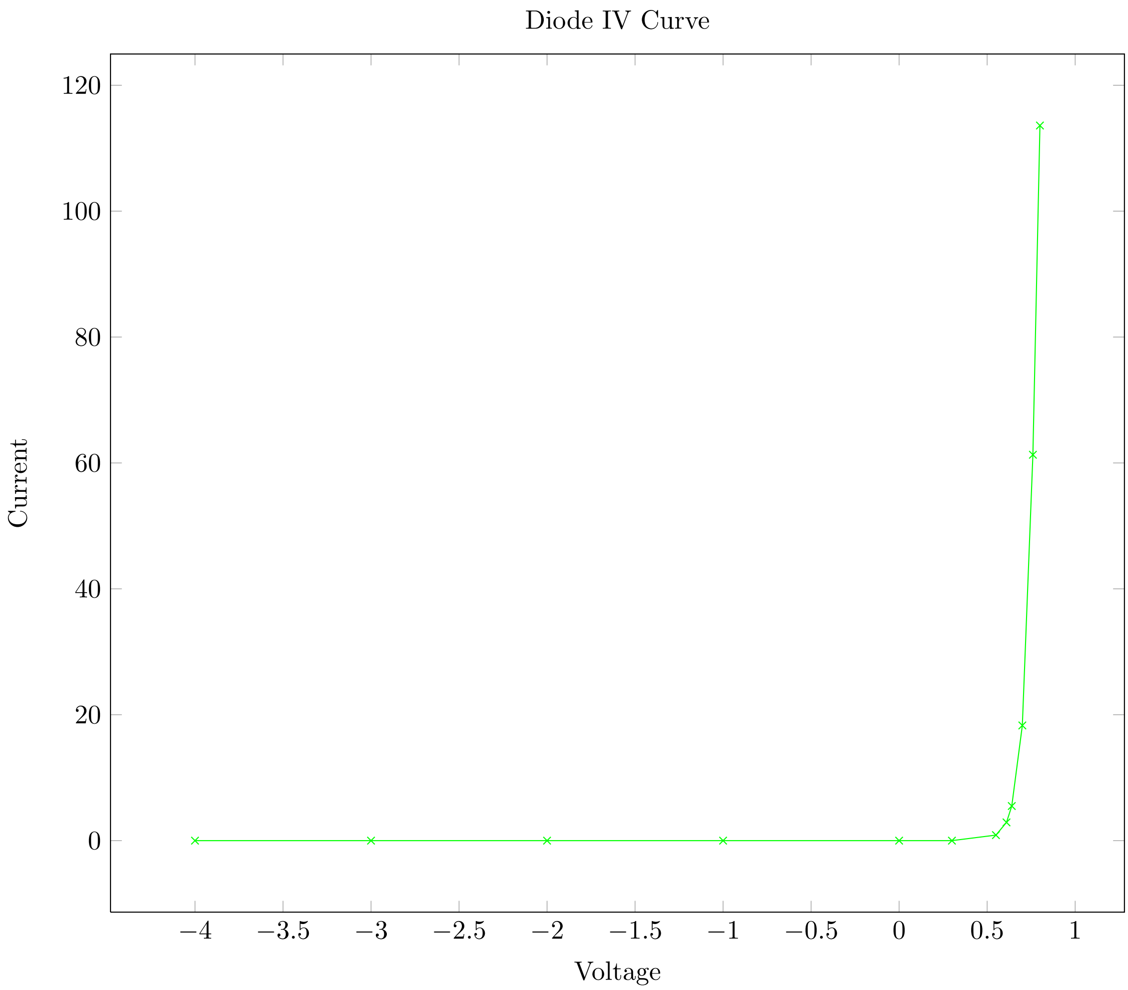


- The connections in the measurement apparatus were disturbed as little as possible during the experiment to minimise any change in the resistance of the connections.
- Some attempt was made to ensure that the component's temperature was steady before each measurement but due to time constants this variable was not controlled to any degree of accuracy.
- A negative voltage can be attained using this apparatus by simply flipping the component being tested around.

3 Results

Voltage (V, $\pm 0.005V$)	Current (mA, $\pm 0.005mA$)
-4.00	0.00
-3.00	0.00
-2.00	0.00
-1.00	0.00
0.00	0.00
0.30	0.00
0.55	0.88
0.61	2.90
0.64	5.50
0.70	18.30
0.76	61.30
0.80	113.60

4 Analysis



The graph shows 3 interesting regions:

$V < 0$	There is no measurable current ($I < 0.005mA$). Resistance is high.
$0 < V < 0.65$	The current is again negligible. Resistance is high.
$0.65 < V$	The current increases at a rate that appears to be exponential with voltage. Resistance is low.

The existence of a region of very high resistance and a region of very low resistance means that this component can be used as a one way gate for current and that it will not waste too much of the power through it as heat. This makes it useful for converting from AC to DC (rectifying).

The sharp $0.65V$ cut-off point also makes this diode usable as a voltage reference point that does not change much when the supply voltage changes (although there are other more suitable diodes for this purpose). A cursory internet search yields many results agreeing that the forward voltage of a silicon diode is around $0.65V$.

4.1 Uncertainty

The uncertainties in the Current and Voltage measurements are known to be $\pm 0.005V$ and $\pm 0.005mA$. Should one want to calculate the approximate differential resistance ($\frac{dV}{dI}$) between two points (V_1, I_1) and (V_2, I_2):

$$R_d = \frac{dV}{dI} \approx \frac{I_2 - I_1}{V_2 - V_1}$$

Taking the last two measurements $(0.76V, 61.30mA), (0.80V, 113.60mA)$ as an example:

$$R_d = \frac{0.80 \pm 0.005V - 0.76 \pm 0.005V}{113.60 \pm 0.005mA - 61.30 \pm 0.005mA}$$

$$= \frac{0.04 \pm 0.01V}{52.3 \pm 0.01V}$$

$$= \frac{0.04 \pm 25\%}{52.3 \pm 2\%}$$

$$= 7.6 \times 10^{-4}\Omega \pm 27\%$$

5 Conclusion

The relationship between voltage across and current through a power diode is non-linear and can be measured and subsequently used to explain its usefulness as an electronic component.

6 Evaluation

Originally the IV curve of a filament bulb was also going to be measured but due to failures in the method of measurement these results were disrupted and then found to not be reproducible. The exact cause was unknown but it could be that a loose connection was introducing a significant resistance into the measurement circuit. This could be removed by either correcting for the changing resistance numerically after the measurents are taken or by using a voltage source with a lower internal resitance.

6.1 Improvements

- While it was disregarded here, the setup used to supply voltage to the component had a significant and changing internal resistance that could have affected the results.
- A useful control would have been a known linear component such as a high precision resistor that would have allowed sanity checking of the results and quantifying of errors caused by the resistance of the potentiometer.
- Initially, a mains powered variable power supply was used as the voltage source. The filtered DC output still contains low amplitude noise from the original AC, this noise although small in absolute magnitude was amplified in the current measurement by the extreme non-linearity of the diode. This caused the reading from the ammeter to jitter in a way that made it very difficult to judge a fair average of the readings by eye.