Minority carrier lifetime: Open circuit decay

This experiment is designed to measure the minority carrier lifetime.

Background:

Consider a pn junction. For simplicity we consider aP^+N junction. All the depletion is in the N region which is lightly doped with a dopant concentration N_d. The number of holes (minority carrier) in the N side is P_{n0}. $P_{no} = n_i^2/N_d$. This means there are N_d free electrons/ cc in the N side. P^+ means a heavily doped region- the depletion region in the P^+ region is sufficiently small - we can ignore it as a first approximation.

We shine light illuminating the whole semiconductor. For light energy greater than the band gap, electrons and holes are generated continuously. These also recombine continuously and in the steady state the recombination R = G (generation rate). If there are no traps in the material, the excess carrier density $\delta n = \delta p$. We choose the excitation so that $P_{n0} < \delta n < N_d$. In the steady state, $R= \delta p/\tau$ where τ is the minority carrier lifetime.

Under open circuit conditions, illuminating the pn junction will give rise to a voltage $V_{oc.}$ (V_{oc} - open circuit voltage). On turning off the illumination, G=0. The excess carriers will decay by recombination and V_{oc} will eventually decay to zero. We now quantitatively relate the decay of V_{oc} with the minority carrier lifetime.

We have seen earlier that

$V_{oc} = (kT/q) \ln (J_{sc}/J_0)$..1

where J_{sc} is the short circuit current and J_0 the dark saturation current. The short circuit current in a silicon solar cell can be written as the sum of currents generated in the space charge region and carriers generated in a diffusion length of the edge of the pn junction. Since the diffusion length L is much larger than the width of the space charge region, we can ignore the contribution of the space charge region to the current as a good first approximation. We can then write for $J_{sc} = q\delta pL$ where L is the diffusion length of holes in the N material. Hence

$V_{oc} = kT/q \ln (q\delta pL/J_0)$

$d V_{oc}/ dt = (kT /q) \tau$ (we have used $d\delta p/dt = \delta p/\tau$)

We hence see that $\tau = (kT /q) (1/ d V_{oc}/ dt)$
Hence τ can be obtained from the decay of open circuit decay.

Source of errors: It is important that the cell is not shunted . This can be easily checked by measuring the dark current in reverse bias. Other sources of errors relate to large area cells due to capacitance effects. This can be circumvented by measuring at small decay times.