Department of Electrical Engineering, IIT Bombay

EE 236: Experiment no. 4

Minority carrier lifetime in a semiconductor photodiode

Objective: To measure the minority carrier lifetime in a semiconductor photodiode by 2 independent techniques.

Background: Minority carrier lifetime (τ_0) plays an important role in many semiconductor devices such as diodes and BJTs. In part (A) of this experiment, we shine light on photodiode, which results in an open-circuit voltage V_{OC} across the diode. When the light is turned off, V_{OC} returns to 0V. However this does not happen instantaneously because of the finite time taken by the excess carriers to recombine. Refer to the textbook of Streetman for more details.

In one of the methods, it says that measure the reverse-bias current flowing through the photodiode due to the light pulses. The current displays a RC-like build-up and decay with time constant equal to the minority carrier lifetime τ_0. For this experiment, we are not using this method.

In part (B) of the experiment, we forward bias a diode and then apply a reverse bias to turn it off. The resulting current transient depends on how much "excess charge" was stored in the diode and how fast it is removed. This transient can be related to τ_0.

Pre-session work:

1 a) Derive the open-circuit voltage delay transient for part (A).

2 b) Derive the "storage time" t_s for part (B).

Experiment:

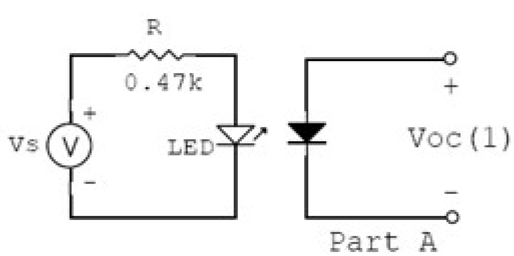

Figure 1

A) In the circuit shown in Fig.1, we generate light pulses by turning LED on or off with positive pulses of 5V amplitude. The light from the LED is made to fall on the open-circuited photodiode. You should adjust the frequency so that the transient is revealed properly on the oscilloscope (use compensated probes if necessary). Copy the transient (V_{OC} versus time during the turning off of the photodiode) in your report and estimate the lifetime τ_0. The open-circuit voltage decay (OCVD) goes approximately as: $V_{OC}(t) = A - (kT/q)(t/\tau_0)$. Make sure you cover the LED and photodiode while taking the measurements. What happens if uncover them? Why?

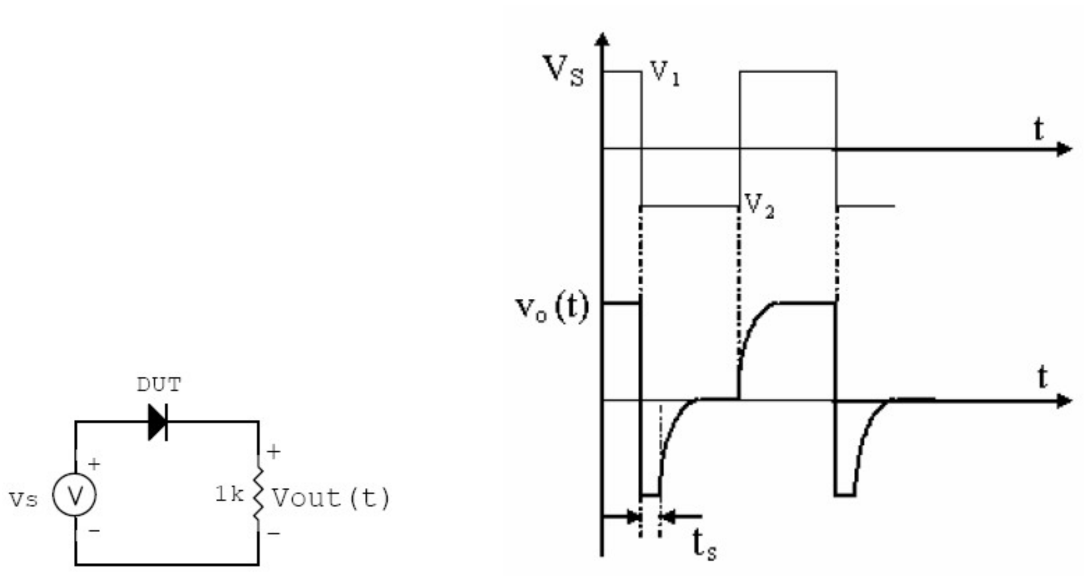

Figure 2

B) In the circuit shown in Fig. 2, adjust the amplitude and DC offset of the function generator to obtain different values of V_1 and V_2. Take the readings for 3 different frequencies i.e., 1 KHz, 40 KHz and 100 KHz. (make sure that the transient can be suitably displayed on the oscilloscope). Record the voltage across the resistor (which is proportional to the diode current) and estimate the storage time t_s. Also record the waveform across the diode (be careful about ground!). Make the measurement for several values of V_1 and V_2 (typical range for V_1 is +2.5V to +6V and for V_2 is -4V to -0.5V) which result in different values of t_s. Comment on the change in storage.

Post-session Work:

a) Estimate τ_0 from parts (A)

b) For part B, plot t_s versus $\ln\{1+(V_1-0.6)/(|V_2|+0.6)\}$. Hence estimate τ_0 from the slope. Alsocomment on the storage time ‘t s ’ for different frequencies.