Háskóli Íslands
Rafmagns- og tölvuverkfræði

Rafeindatækni fastra efna
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Haynes - Shockley Experiment

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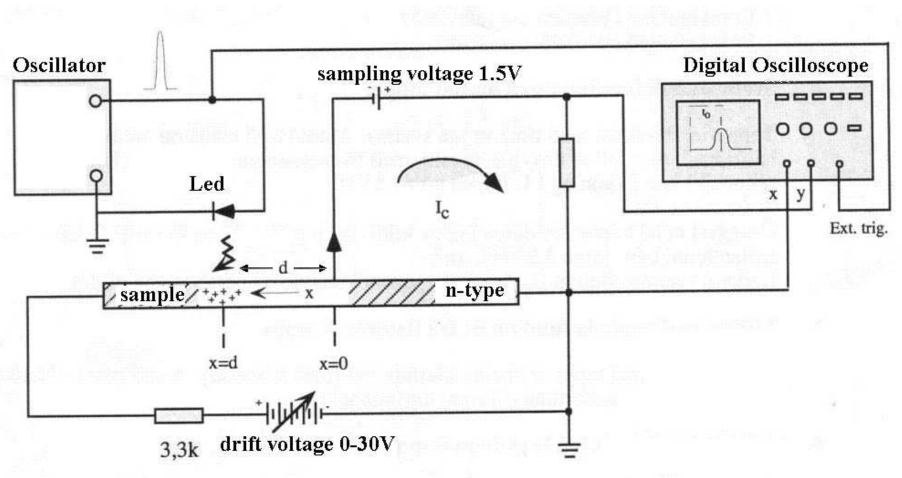
1 Measurements on drift velocity

The voltage over the specimen is set to its maximum, 15 V, and the drift time, t_d, is measured as a function of displacement, d. It is possible to calculate the drift velocity with the equation:

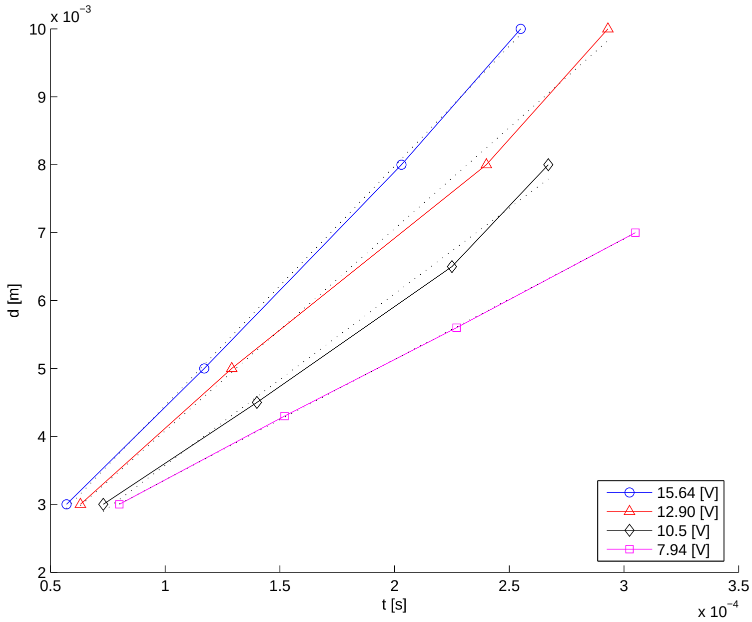
$$v_d = \frac{d}{t_d}. \tag{1}$$

We take measures of drift time by sending light pulse from the LED to the specimen and measure the time it takes for the pulse to reach the end of the specimen where we measure the light pulse with an oscilloscope. Values for pulse width at half maximum , Δt, and values for the pulse height, v_p, are also included for next sections.



1.1 Drift velocity

We plot displacement as a function of drift time and find the drift velocity from the slope of the graph.



The results of the measurements and calculations can be seen in table 1.

Table 1

Voltage $[V]$	$v_d[m/s]$	$\varepsilon[V/m]$
15,6	35,3	680
12,9	29,8	561
10,5	25,2	457
7,9	17,7	354

The electric field, ε, is found from:

$$\varepsilon = \frac{V}{L} \tag{2}$$

where $L = 23\ mm$.

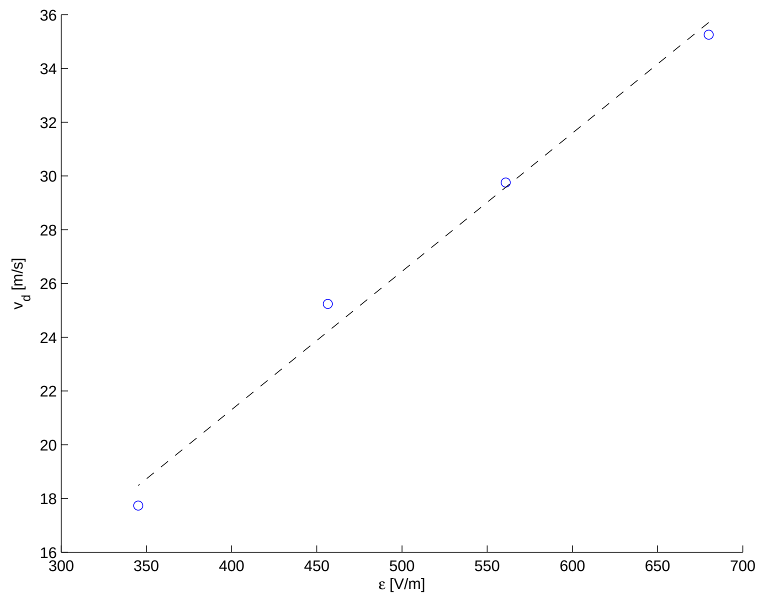
From table 1 we see that the drift velocity increases by nearly the same factor as the electric field increases. We draw the conclusion that the drift velocity is proportional to the electric field.

1.2 Hole Mobility

Equation for hole mobility is:

$$\mu_p = \frac{v_d}{\varepsilon} \tag{3}$$

and a plot of v_d as a function of ε should give straight line with slope μ_p



The hole mobility appears to be:

$$\mu_p \approx 500 cm^2/Vs \tag{4}$$

which is very close to the hole mobility of silicon, $\mu_p = 480\ cm^2/Vs$. From the graph we see that the hole mobility does not depend on the electric field.

2 Diffusion coefficient calculated from pulse width

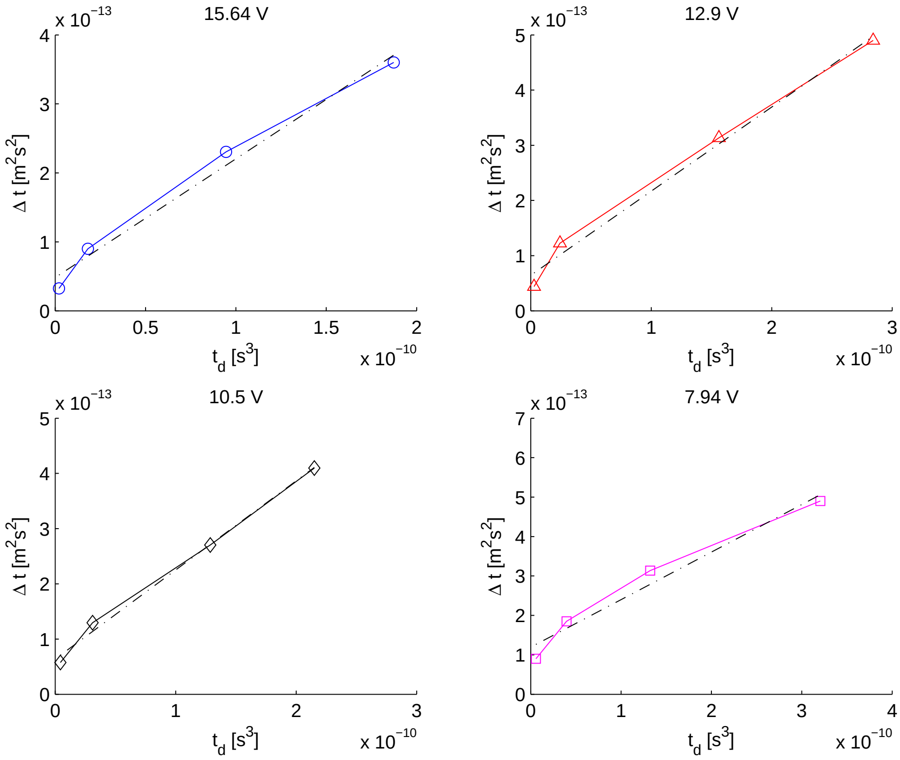
From the handover the diffusion coefficient, D_p, is denoted as:

$$D_p = \frac{(d\Delta t)^2}{16 \ln 2 \cdot t_d^3} = \frac{(d\Delta t)^2}{11,1 t_d^3} \tag{5}$$

A simple rewrite gives us:

$$(d\Delta t)^2 = 11.1 t_d^3 \cdot D_p \tag{6}$$

We see that this equation represents a straight line with slope D_p.



We plot our data using equation (6) for all voltages and the results are presented in table 2.

Table 2

Voltage $[V]$	ε $[V/m]$	D$_p$ $[cm^2/s]$
15,6	680	17,2
12,9	561	15,2
10,5	457	16,1
7,9	345	12,1

The values for D_p are very much alike and we draw the conclusion that the diffusion coefficient does not depend on the electric field, ε.

2.1 Einstein's relation

Einstein's relation gives us that

$$\frac{D}{\mu} = \frac{k_B T}{q} \approx 0,0259\ [V] \tag{7}$$

at $T = 300K$. We can check if our values are correct by dividing the diffusion constant with the hole mobility.

Table 3

Voltage $[V]$	$\frac{D_p}{\mu_p}$ $[V]$
15,6	0,0332
12,9	0,0287
10,5	0,0292
7,9	0,0235

We see that our values are close to the value found from Einstein's relation.

3 Excess hole lifetime found from pulse area

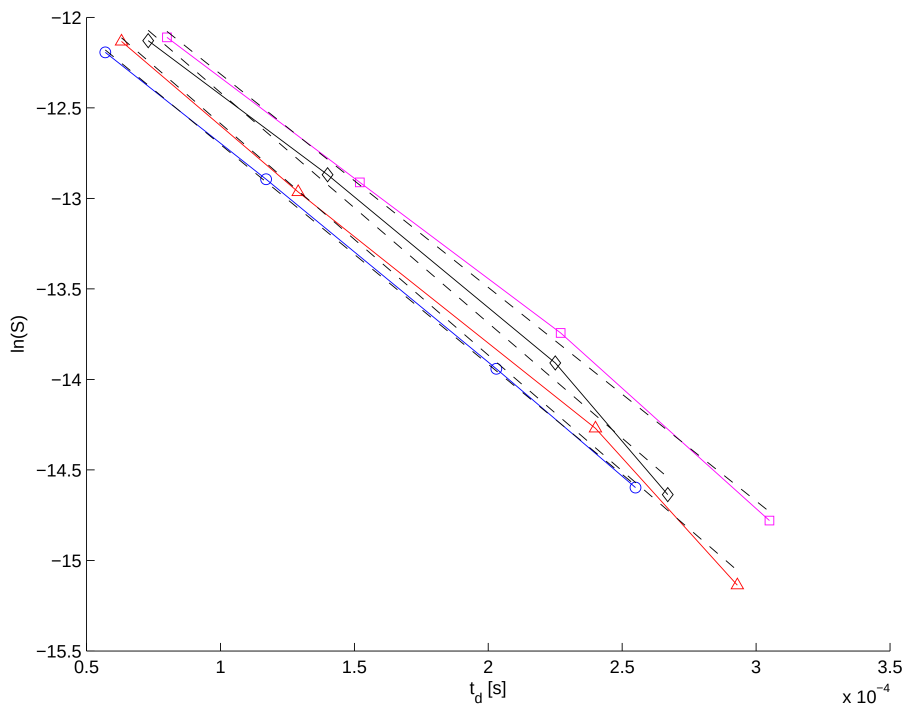
The area of the pulse is denoted by:

$$S = \hat{P}_0 e^{-\frac{t_d}{\tau_p}}. \tag{8}$$

Which is equivalent to:

$$\ln S = \ln \hat{P}_0 - \frac{t_d}{\tau_p}. \tag{9}$$

We approximate the area as $S = v_p \cdot \Delta t$ and then plot $\ln(S)$ as a function of t_d and get a line with slope $-\frac{1}{\tau_p}$



We calculate the lifetime for each voltage and find the average lifetime

$$\tau_p = 80,3 \mu s. \tag{10}$$

4 Conclusion

In the first section we saw that the drift velocity was proportional to the electric field, but the hole mobility did not depend on the electric field. Our hole mobility was close to the hole mobility of Si.

In the second section we found the diffusion coefficient for different electric fields and by observation it seemed that the diffusion coefficient did not depend on the electric field.

In the last section we calculated the excess hole lifetime by examining the pulse area.