

Project Assignment

EE 5340 - Semiconductor Device Theory

[draft]

Due November 17, 2009

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All project solutions should be submitted on 8.5" x 11" paper with a cover sheet attached. The project report should be stapled only in the upper left-hand corner and no other cover or binder or folder should be used. The cover sheet should include (1) your name, (2) the project title, (3) the course name and number, and (4) your e-mail address. The report should include clearly marked sections on (a) purpose of the project and the theoretical background, (b) a narrative explaining how you did the project, (c) answers to all questions asked in the project assignment, and (d) a list of references used in the order cited in the report (the reference number should appear in the report each time the reference is used). All figures and tables should be clearly marked with a figure or table number and caption. The caption and labels on the figures should make the information in the figure comprehensible without reading further in the text of the report. Auxiliary information (such as SPICE data outputs, etc.) should be included in appropriate Appendices at the end of the report. Be sure to describe exactly how all results were obtained, giving enough information for anyone who understands EE 5340 to repeat your work. All work submitted must be original. If derived from another source, a full bibliographical citation must be given. (See all of Notes 5 and 6 in the syllabus.) Click [solution.pdf](#) to download a pdf file copy.

Minority Carrier Lifetime, Diffusion Length and Mobility Models in Silicon

- A. [40%] Write a review of the model equations for minority carrier (both electrons in p-type and holes in n-type material) lifetime, mobility and diffusion length in silicon. Any references may be used. At a minimum the material given in the following references should be used.
1. *Device Electronics for Integrated Circuits*, 3rd ed., by Richard S. Muller, Theodore I. Kamins, and Mansun Chan, John Wiley and Sons, New York, 2003.
 2. Mark E. Law, E. Solley, M. Liang, and Dorothea E. Burk, "Self-Consistent Model of Minority-Carrier Lifetime, Diffusion Length, and Mobility, IEEE ELECTRON DEVICE LETTERS, VOL. 12, NO. 8, AUGUST 1991.
 3. ~~Note: This article is removed from the list and items 6 and 7 are added. D.B.M. Klaassen; "A UNIFIED MOBILITY MODEL FOR DEVICE SIMULATION", Electron Devices Meeting, 1990. Technical Digest., International 9-12 Dec. 1990 Page(s):357-360.~~
 4. David Roulston, Narain D. Arora, and Savvas G. Chamberlain "Modeling and Measurement of Minority-Carrier Lifetime versus Doping in Diffused Layers of n⁺-p Silicon Diodes", IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL. ED-29, NO. 2, FEBRUARY 1982, pages 284-291.
 5. M. S. Tyagi and R. Van Overstraeten, "Minority Carrier Recombination in Heavily Doped Silicon", Solid-State Electr. Vol. 26, pp. 577-597, 1983. Download a copy at [Tyagi.pdf](#).
 6. D.B.M. Klaassen, "A Unified Mobility Model for Device Simulation – I. Model Equations and Concentration Dependence", Solid-State Electr. Vol. 35, pp. 953-959, 1992. See below.
 7. D.B.M. Klaassen, "A Unified Mobility Model for Device Simulation – II. Temperature Dependence of Carrier Mobility and Lifetime", Solid-State Electr. Vol. 35, pp. 961-967, 1992. Download at [DbmK.pdf](#).

Based on the information in these resources, decide which model formulae and parameters are the most accurate for D_n and L_n for electrons in p-type material, and D_p and L_p holes in n-type material.

B. [60%] Part of a SPICE model for the Motorola 1N5233 Zener diode is shown in Table 1.

Table 1. A SPICE model for the Motorola 1N5233 diode

```
.model D1N5233
Is=629E-18
Rs=1.176
N=1
Xti=3
Eg=1.11
Cjo=140p
M=.5369
Vj=.75
Isr=1.707n
Nr=2
BV = 6
```

For purposes of this assignment, this means that

1. IS may be interpreted as the multiplier of the $(\exp(v_D/NV_t) - 1)$ term in the diffusion current.
2. The multiplier of the $\exp(v_D/(NRV_t))$ term in the recombination current may be interpreted as ISR.
3. The M value implies that this is essentially a step diode.

Use the information given to make the best estimate of the following:

1. Diode area.
2. Concentration of donors or acceptors on the lightly doped side. Support your conclusion as to the type of Si on the lightly doped side.
3. Concentration and type of the heavily doped side.
4. Estimate the value IKF might have. The multiplier of the $\exp(v_D/(2NV_t))$ term in the high level injection current may be interpreted as $\sqrt{IS \times IKF}$.
5. Length of the charge neutral region on the lightly doped side.
6. Show that the estimates are self-consistent for all regions of diode operation – especially capacitance, BV, recombination, and diffusion ranges.