# Exercise 0616 for "Semiconductors"

**Problem setting**:                02/06/2021    出題        2021 年 6 月 2 日
**Solution submission deadline**:   16/06/2021    解答提出期限    2021 年 6 月 16 日

## General notes / 一般的注意

The text part in the answer should be typed in English or Japanese. I hope you could avoid handwriting but if you have no way to do so, the handwriting should be as clear as possible. The scoring does not depend on the language. It doesn't matter if you are good at grammar, vocabulary, or sentences, but if I cannot catch the meaning, the scoring will get deducted regardless of English or Japanese. The answer sheet should be in small-sized (hopefully less than 1 MB) PDF format, which can be appropriately displayed by Adobe Reader. The file of the answer should be submitted through ITC-LSM.

解答のテキスト部分は極力手書きでないようにお願いします．英語，日本語のどちらでも良く，採点は言語に依存しません．文法や語法，文章の上手下手は問題にしませんが，意味が取れない場合は，英語日本語にかかわらず，減点します．解答は，ファイルサイズのできるだけ小さな (1 MB 以下が目安)，Adobe Reader できちんと表示できる PDF ファイルにまとめ，ITC-LSM を通して提出してください．

## For exercise 6016/ 今回の問題について

Choose two of the three problems. Please avoid answering all the problems since I do not have time to check all of them.

今回は，３問のうち２問を選択してお答えください．講師に時間的余裕がなく，3 問の全答は避けてください．

## 0616-1 Capacitance in reverse bias region

A $p^+$n-junction ($N_A$ in the p-layer is much higher than $N_D$ in the n-layer) of GaAs (relattve dielectric constatnt 13) was grown by MBE. The dopings in n-region and p-retion are spatially uniform. The $p^+$n-junction wafer was cut into a device with 1 mm$^2$ cross section. The differential capacitance of the device was measured under the reverse bias voltage $V_b$, and the following results were obtained.

| $V_b$ (V) | $C$ (pF) |
|---|---|
| 0.0 | 408 |
| −0.2 | 380 |
| −0.4 | 350 |
| −0.6 | 334 |
| −0.8 | 313 |
| −1.0 | 296 |
| −1.2 | 283 |
| −1.4 | 273 |

1. Find the built-in potential in the unit of Volt. The above values of $C$ contain measurement errors. But this is not a problem for experimental analysis and the fitting can be done by using a ruler to draw a straight line on the data points. Of course, for your exercise, you are free to do that with numerical fitting and estimate the measurement error.

2. By assuming that the capacitance is determined by the n-side, obtain the donor concentration in the n-region in the unit $cm^{-3}$.

## 0616-2 Reverse-biased Schottky diode

1. Consider an ideal Schottky diode in which the barrier height is written as $e(\phi_M - \phi_S)$. Obain the expression of the differential electrostatic capacitance for the reverse bias $V$.

2. Consider an n-channel MESFET in which the Schottky barrier height is 0.5 eV. The relative dielectric constant of the material for conduction channel is 16, and the donor concentration is $2\times10^{16}$ $cm^{-3}$. The thickness of the conduction channel is 0.5 $mu$m. How high is the reverse-bias voltage required to pinch-off the conduction channel?

## 0616-3 Built-in potential of pn junctions

1. Can we measure the built-in potential of a pn-junction diode as the voltage between the two terminals?

2. Explain how you derive your answer for the above question.

3. Are there any methods to measure the built-in potential of a pn-junction from outside? If yes, give an example.