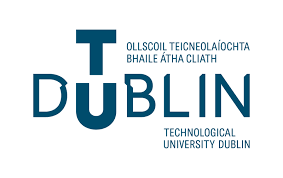
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**TU Dublin – Grangegorman**

**Lab 2: Concept of Diffusion – Making an IC Resistor**

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# Laboratory Objectives

The objective of this lab was to gain an understanding of the process of diffusion and to study a basic technological process of manufacturing an IC resistor based on the interactive Mathlab Animations for “Understanding Semiconductor Devices” (Oxford University Press, New York 2002, S. Dimitriev.

## Introduction to Diffusion

The essence of diffusion is the random thermal motion of the diffusing particles (electrons, holes, doping atoms such as boron of phosphorous, molecules in the air, or smoke particles.

The diffusion of particles creates an effective particle current towards the points of lower particle concentration. There is no effective particle current when the concentration of particles is uniform, as in this case equal numbers of particles move either way. The current of particles (charged or uncharged) produced by a difference in the particle concentration is called diffusion current.

# Laboratory Tasks

## 2.1. Part 1 – Diffusion

1. Launch the “Mathlab Animations” on your PC:
2. Run “Section 1.3.1: The Concept of Diffusion”. Observe the simulation. Comment on the changes in particles concentration in the semiconductor with time; answer the question at the end of Section 1.3.1.

## 2.2. Part 2 – Making an IC Resistor

1. Run “Section 1.3.3: Making an IC Resistor”.
2. Observe the animated demonstration.

5. Create a table (technological map) of the process of making an IC resistor. In the table record the number/name of each step of the technological process, corresponding sketch (you can copy the image corresponding to each step from the screen), description of the step and any additional information, such as substrate/dopant type, dose, carrier concentrations, conditions (diffusion, exposure time, temperature etc.).

6. Answer the following questions:

* 1. What is the main function of silicon dioxide in the fabrication of semiconductor ICs?

What additional function can it perform?

b. What are the two main properties that a photoresist must possess?

c. Name two steps of the diffusion process

# 3. Results

## 3.1. Section 1.3.1: The concept of Diffusion

The animation in this figure 1 is created by generating a random set of particles above the semiconductor substrate and allowing every particle to move in a Purely Random Direction at every animation step.

Although individual particles move with equal chances in any direction, overall, the particles move into the semiconductor.

A picture containing text, vector graphics

Description automatically generated

Figure 1 - Individual particles move with equal chances in any direction

Chart

Description automatically generated

Figure 2 - Simulation of diffusion

## 3.1.1. Analysis of Diffusion

Diffusion is that the process whereby particles flow from a region of high concentration toward a region of low concentration. If the particles are electrically charged, the net flow of charge would end in a diffusion current. [1]

Diffusion current Density is a current within a semiconductor caused by the diffusion of charge carriers. This is the current which is thanks to the transport of charges occurring thanks to the non-uniform concentration of charged particles in a semiconductor.

The electron diffusion current density is given by  , where  is called the electron diffusion coefficient, has units of .

The hole diffusion current density is given by , where  is called the hole diffusion coefficient, has units of .  
The total current density is composed of the drift and the diffusion current density.

There are four possible independent current mechanisms in a semiconductor. These components are electron drift and diffusion currents and hole drift and diffusion currents. The total current density is the sum of these four components [1]

**1-D:**



**3-D:**



## 3.2. Section 1.3.3: Making an IC Resistor

Demonstrating photolithography and diffusion processing steps, by the example of making an integrated-circuit resistor.

Table 1 – Technological Process of making an IC Resistor

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **No.** | **Step Name** | **Sketch** | **Description** | **substrate/**  **dopant type** | **dose** | **carrier** |  |
| 1 | SUBSTRATE |  | Nsub = 1e+16 cm^-3  Silicon base material | N-Type |  |  |  |
| 2 | INITIAL OXIDATION |  | Silicon wafer into silicon di-Oxide |  | SiO2 |  |  |
| 3 | Photoresist application |  | Spinning  Soft-Baking  After oxidation and disposition of negative photoresist | Photoresist  SiO2 |  |  |  |
| 4 | Exposure |  | UV-light  Patterned optical mask  Exposed resist [2] |  |  |  |  |
| 5 | Developing |  | Followed by hard baking |  |  |  |  |
| 6 | OXIDE ETCHING |  | After development and etching of resisting chemical or plasma stretch of SiO2 |  |  |  |  |
| 7 | FIRST PHOTOLITHOGRAPHY COMPLETE |  | After resist stripping |  |  |  |  |
| 8 | P-TYPE DIFFUSION (Boron deposition) |  | Temperature=900 °C  Time = 2min |  |  |  |  |
| 9 | DRIVE-IN |  | Temperature=1100 °C  Time = 120min |  |  |  |  |
| 10 | ETCH MASKING OXIDE |  |  |  |  |  |  |
| 11 | DEPOSIT NEW MASKING OXIDE |  |  |  |  |  |  |
| 12 | SECOND PHOTOLITHOGRAPHY |  | To open window for N-type diffusion |  |  |  |  |
| 13 | N-TYPE DIFFUSION (Phosphorus deposition) |  | Temperature=900 °C  Time = 5min |  |  |  |  |
| 14 | DRIVE-IN |  | Temperature=1100 °C  Time = 5min |  |  |  |  |
| 15 | ETCH MASKING OXIDE |  |  |  |  |  |  |
| 16 | DEPOSIT ISOLATING OXIDE |  |  |  |  |  |  |
| 17 | THIRD PHOTOLITHOGRAPHY |  | To open contact windows |  |  |  |  |
| 18 | METALLIZATION |  |  |  |  |  |  |
| 19 | FOURTH PHOTOLITHOGRAPHY |  | Metal patterning |  |  |  |  |

## 3.3. Question 6

3.3.1. Functions of silicon dioxide in the fabrication of semiconductor ICs

There are multiple functions of silicon dioxide () which plays an important role in IC because it’s the only semiconductor material that has native oxide capable of achieving all the properties of . The important roles of are as follows:

* Used for surface passivation which is creating protection layer in the wafer surface and protects the junction from atmospheric contamination and moisture.
* Acts as a diffusion mask permitting selective diffusions into silicon wafer through the window etched into oxide. [3]
* It works as an insulator on the water surface. It's the high relative dielectric constant, which enables the metal line to pass over the active silicon regions. [3]
* Acts as the active gate electrode in MOS device structure.
* Used to isolate one device from another.
* Provides electrical isolation of multilevel metallization used in VLSI.

3.3.2. Two properties photoresists possess

Photoresist layers have two main functions as follows:

* Precise pattern formation
* Protection of the substrate from chemical attack during the etch process

A photoresist is a material changing its characteristics upon exposure to light. Softening or hardening depends on the type of photoresist. That is what is stated by calling them photoresists.

There are different materials like PMMA, SU8, AZ etc, all photoresists. In Lithography we need a material that is affected by light exposure and accordingly shaped; photoresists will be indispensable.

3.3.3. Name two steps of a diffusion process

The diffusion process consists of two stages:

* Adoption
* Implementation

# 4. References

**[1]** "chapter 6: Carrier Motion", *http://osp.mans.edu.eg/*, 2021. [Online]. Available: http://osp.mans.edu.eg/rehan/solid\_2004/ch6.htm#1. [Accessed: 23- Oct- 2021]

**[2]** "The manufacturing process", *Bwrcs.eecs.berkeley.edu*, 2021. [Online]. Available: http://bwrcs.eecs.berkeley.edu/Classes/icdesign/ee141\_f01/Notes/chapter2.pdf. [Accessed: 23- Oct- 2021]

**[3]** "Oxidation Process in IC Fabrication", Circuitstoday.com, 2021. [Online]. Available: https://www.circuitstoday.com/oxidation-process-in-ic-fabrication. [Accessed: 26- Oct- 2021]