



UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

Trabajo de Tesis

Design and Sizing of an Energy Storage System for a Hybrid Tugboat

Tesis para optar al título de
Magister en Ciencias de la Ingeniería Electrónico

Alumno
Leonardo Solis Zamora

Profesor Guía
Dr. Marcelo Pérez Leiva

Comisión evaluadora
Nombre del primer correferente, Correferente, UTFSM
Nombre del segundo correferente, Correferente, CODELCO

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Agradecimientos

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Resumen

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Abstract

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Capítulo 1

Introducción

1.1. Motivation and Background

1.2. Challenges and Research Opportunities

1.3. Thesis Objectives and Outline

[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23],

Capítulo 2

Remolcador: Descripción y Requerimientos

2.1. section one

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Capítulo 3

Hibridación de Remolcadores

Capítulo 4

Metodología para diseño de Banco de Baterías

Capítulo 5

Resultados de Simulación

5.1. Celda de Batería

5.2. Banco de Batería

5.3. Motor diesel

5.4. Motor eléctrico

5.5. Tren de Potencia

Capítulo 6

Conclusiones

Apéndice A

Sample Code for Appendix

This appendix provides an example of code used in the project. The code is displayed using the verbatim environment to preserve formatting and indentation.

A.1. Example Code: Bandgap Calculation in Python

```
# Python code to calculate the bandgap of a semiconductor
def calculate_bandgap(Ec, Ev):
    """
    Function to calculate the bandgap energy.
    Ec: Conduction band energy (in eV)
    Ev: Valence band energy (in eV)
    Returns: Bandgap energy (in eV)
    """
    bandgap = Ec - Ev
    return bandgap

# Example usage
Ec = 3.4 # Conduction band energy for GaN (eV)
Ev = 0.0 # Valence band energy (reference, eV)

bandgap = calculate_bandgap(Ec, Ev)
print(f"The bandgap energy is {bandgap} eV.")
```

Apéndice B

Supplementary Tables

This appendix contains supplementary tables that provide additional data and detailed information used in this study.

B.1. Material Properties of GaN and Related Semiconductors

Tabla B.1: Material Properties of GaN and Related Semiconductors.

Property	GaN	SiC	Si
Bandgap Energy (eV)	3.4	3.3	1.1
Thermal Conductivity (W/m·K)	130	490	150
Breakdown Electric Field (MV/cm)	3.3	2.8	0.3
Electron Mobility (cm ² /V·s)	1200	900	1400
Lattice Constant (Å)	3.189	4.358	5.431

B.2. Experimental Parameters for Epitaxial Growth

Tabla B.2: Experimental Parameters for MOCVD Growth of GaN.

Parameter	Value	Unit
Growth Temperature	1050	°C
Reactor Pressure	200	mbar
Precursor Flow Rate (TMA/Ga)	50	sccm
NH ₃ Flow Rate	5000	sccm
Growth Rate	2.5	µm/hr
Buffer Layer Thickness	25	nm

Tabla B.3: Performance Metrics of Fabricated GaN HEMTs.

Metric	Measured Value	Unit	Device ID
Threshold Voltage (V_{th})	-2.5	V	D1
Maximum Current Density	800	mA/mm	D1
Peak Transconductance (g_m)	200	mS/mm	D1
Breakdown Voltage	1200	V	D1

B.3. Device Performance Metrics

B.4. Comparison of Simulation and Experimental Results

Tabla B.4: Comparison of Simulation and Experimental Results.

Parameter	Simulation	Experiment
Electron Mobility ($\text{cm}^2/\text{V}\cdot\text{s}$)	1350	1200
2DEG Density (cm^{-2})	$1,5 \times 10^{13}$	$1,2 \times 10^{13}$
Threshold Voltage (V_{th})	-2.2	-2.5
Breakdown Voltage (V)	1300	1200

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