Fabrication of Photonic LPCVD Silicon-Nitride Waveguides

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Overview

- Project Goals
- Photonics Overview
- Photomask Design
- Process Flow
- Results
- Acknowledgements
Project Goals

- Fabricate TE mode Nitride Waveguides using the tools available in the RIT SMFL Cleanroom
  - Amorphous silicon waveguides have already been made
- Demonstrate loopback waveguides with ring resonators
- Qualify Nitride Waveguides against similar designs
- Lay the groundwork for research to come:
  - Get test results showing similar transmission as Eigenmode Solution Simulation of 450nm thick and 1000nm wide
Photonics Overview

- Photonics is the study of transmission and detection of light
- Instead of wires, we have waveguides
- Integrated photonic circuits uses photons and electricity to transmit data
- Integrated photonic circuits branch optical physics and microelectronics
Why Photonics is Needed

- Electrical interconnects limited in voltage and frequency, driving power consumption up
- Hard to scale due to bandwidth being limited by size
- Photonics allows for high bandwidth and low power consumption
- Data transmission is much faster
Mask Design

Design Variations:

- Loopback Waveguide
  - Varied Grating Coupler Taper
  - Varied Grating Coupler Pitch
  - Varied Waveguide Length
- Ring Resonator Waveguide
  - Varied Grating Coupler Taper
  - Varied Grating Coupler Pitch
  - Varied Resonator Gap
Mask Design

Design Variations:
• **Loopback Waveguide** □
  • Varied Grating Coupler Taper
  • Varied Grating Coupler Pitch
  • Varied Waveguide Length □
• **Ring Resonator Waveguide** □
  • Varied Grating Coupler Taper
  • Varied Grating Coupler Pitch
  • Varied Resonator Gap □
1000nm Width Loopback Waveguides

Varied Grating Parameters:
Pitch: 700nm – 1500nm
Taper: 100µm – 1000µm

Coupler Separation = 381µm
Taper = 400µm
Test Head Setup

Coupler Separation = 381µm

[1] Sanjna Lakshminarayanamurthy, 2017
500nm Width Resonator Waveguides

Varied Grating Parameters:
Pitch: 700nm – 1500nm
Taper: 100µm – 1000µm

Radius = 100µm
Resonator Gap = 300nm
Process Flow

Nitride Critical Dimensions of: 500nm, 1000nm, and 1500nm

1. RCA Clean
2. Oxide Deposition
3. Nitride Deposition
4. Waveguide Pattern
5. Etch
6. Cladding Deposition
7. Test
Focus Exposure Matrix

- New film stack being used requires different dose exposure
- New Photoresist being used in the lab: MiR 701
- Typical exposure dose: 275mJ/cm²

- FEM Exposure variation from 175mJ/cm² to 375mJ/cm²
  - Best exposure dose: 185mJ/cm²
  - Resolved 0.375µm lines and spaces
Photoresist Problems

- First photoresist exposure showed poor resolution
- Small photoresist lines not sticking to surface
- Used PRS2000 to chemically strip photoresist and attempted again
- Concluded: Nitride left surface rough
- Chemical strip and rinse did surface preparation that allowed good adhesion
Fabrication Results

Fabricated Loopback Waveguide with 1.5µm width, 1µm coupler pitch, and 400µm coupler taper

Close up of Grating Coupler showing 0.5µm line and space resolution
Fabrication Results

Fabricated Resonator Waveguide with 0.5µm width, 1µm coupler pitch, and 300µm coupler taper

Close up of resonator gap showing 0.3µm space between waveguide and ring
Simulation Results

- Test Head Angle Variation to optimize transmission through Grating Coupler
- Varied from 20 degrees to 30 degrees with best result of 24 degrees
Simulation Results

- Grating Coupler Pitch Variation to optimize transmission
- Varied from 700nm to 1500nm with best result of 1300nm
What’s Next

❖ **Next Step:** *Physical testing of the fabricated waveguides*

❖ Improve process to get smaller features

❖ Project focused more on the fabrication than simulation and optimization

❖ Simulations for each waveguide to compare the “ideal” to actual

❖ More simulations to redesign mask and get better transmission and lower loss

❖ Create a tunable thermo-optic waveguides or CMOS photonic structures
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