

Contents

Resumen	i
Resum	iii
Abstract	v
Contents.....	vii
1. Introduction	1
1.1. Silicon photonics	1
1.2. Electro-optic modulation in silicon	5
1.2.1. Optical modulators	5
1.2.2. Different mechanisms for electro-optic modulation in silicon.....	6
1.2.3. Structures for modulation.....	7
1.2.3.1. MZIs.....	8
1.2.3.2. Ring resonators	9
1.2.3.3. Amplitude modulation principle	9
1.3. Barium titanate	11
1.3.1. Ferroelectricity and domain structure	11
1.3.2. Anisotropy	13
1.3.3. Pockels effect	14
1.3.4. Barium titanate on SOI.....	15
1.3.5. State-of-the-art of BTO based modulators	16
1.4. Objectives and outline of the thesis.....	18
2. Design of electro-optic modulators based on BTO in silicon.....	21
2.1. Introduction	21
2.2. Optical design.....	21
2.2.1. Slot waveguide structure	22
2.2.2. Design of the slot waveguide.....	22
2.2.2.1. Fully etched waveguide	24
2.2.2.2. Half etched waveguide	27
2.2.2.3. Final waveguide structure	29
2.3. Electro-optical design.....	29
2.3.1. Electrode design in DC regime.....	30
2.3.2. Influence of BaTiO₃ ferroelectric orientation.....	30
2.3.2.1. EO performance for a-axis oriented BaTiO₃.....	31
2.3.2.2. EO performance for c-axis oriented BaTiO₃.....	34

2.3.3. Influence of multi-domain BaTiO ₃ structure	38
2.4. RF design.....	42
3. Fabrication and characterization of electro-optic modulators based on BTO in silicon.....	45
3.1. General approach to develop photonics structures.....	45
3.2. BTO fabrication techniques.....	46
3.2.1. RF sputtering	47
3.2.2. Molecular Beam Epitaxy	47
3.3. Low loss amorphous silicon	48
3.4. Fabrication of BTO based modulators	53
3.5. Electrode fabrication process	55
3.6. Optical characterization.....	56
3.6.1. Fabricated devices	57
3.6.2. Experimental set-up	57
3.6.3. Samples with RF sputtered BTO	58
3.6.4. Sample with MBE BTO	69
3.7. Electro-optical characterization.....	71
3.7.1. DC regime	71
3.7.1.1. Experimental set-up	71
3.7.1.2. DC electro-optic results	72
3.7.2. RF regime	82
3.7.2.1. Experimental set-ups	83
3.7.2.2. RF electro-optic analogic results.....	85
3.7.2.3. RF electro-optic digital results	89
4. Conclusions and future outlook.....	91
List of publications	95
Bibliography.....	99