Fabrication of interdigital transducers and growth of ZnO films for the generation of surface acoustic waves

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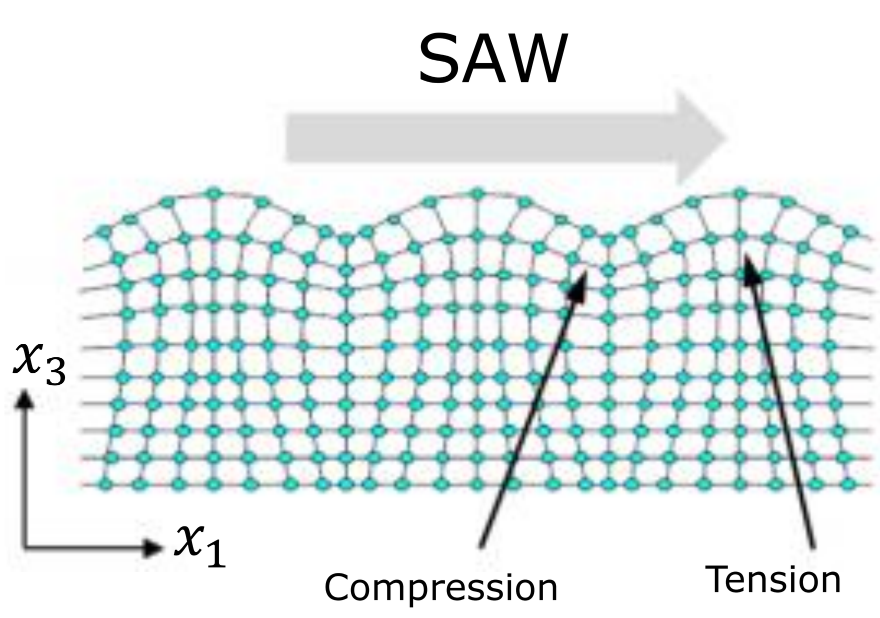
Motivation

Surface acoustic waves (SAWs)

- ✓ High strain and piezoelectric fields
- ✓ Non-destructive tool
  - ✓ Probing of interactions in semiconductor nanostructures
- ✓ High acousto-optical modulation
- ✓ Industry applications
  - ✓ Filtering, sensing, signal processing

ZnO Films

- ✓ High piezoelectric material
  - ✓ Generation of SAWs in non-piezoelectric substrates



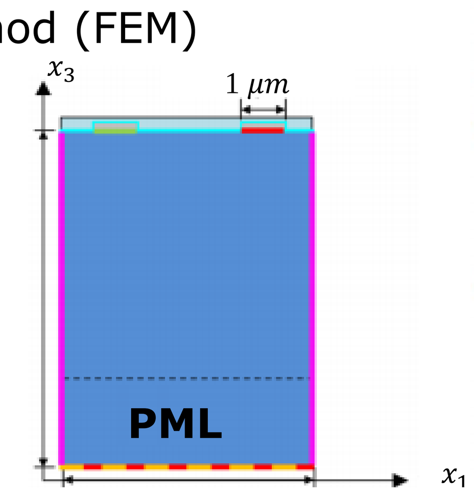
Simulation

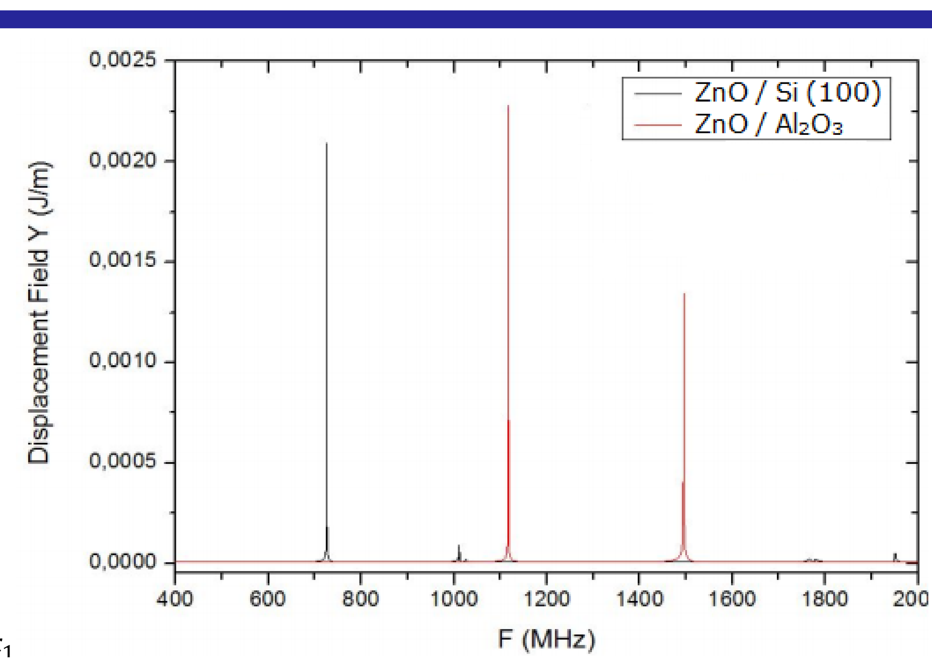
SAW generation

- ✓ Finite Element Method (FEM)

Material	Geometry	Thickness (µm)
Air	Top cover	0.3
Aluminium	IDTs	0.2
ZnO	Substrate	14.0

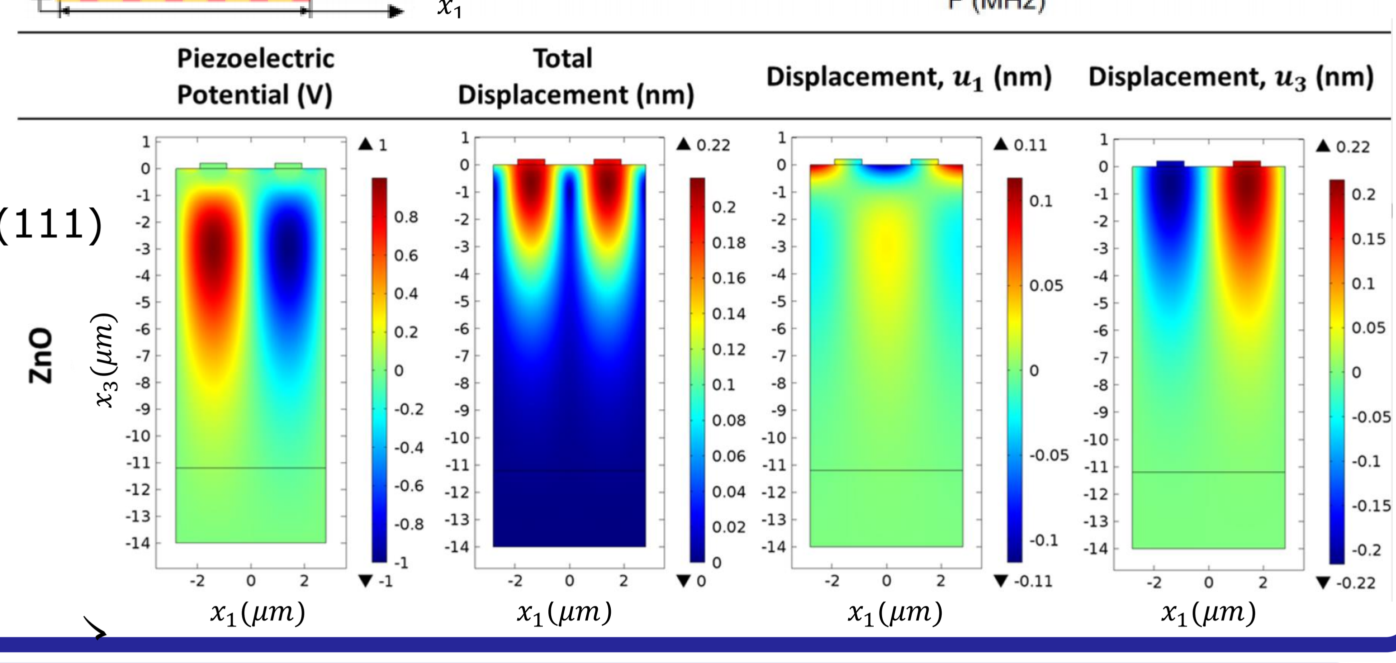
Boundary Conditions	
Electric Potential	$V = V_{RF}$
Ground	$V = 0$
Fixed Constraint	$\lvert\vec{u}\rvert = 0$
Periodic Condition (*continuity*)	$\phi_L = \phi_R$, $\vec{u}_L = \vec{u}_R$
Free	$T = 0$





Substrate:

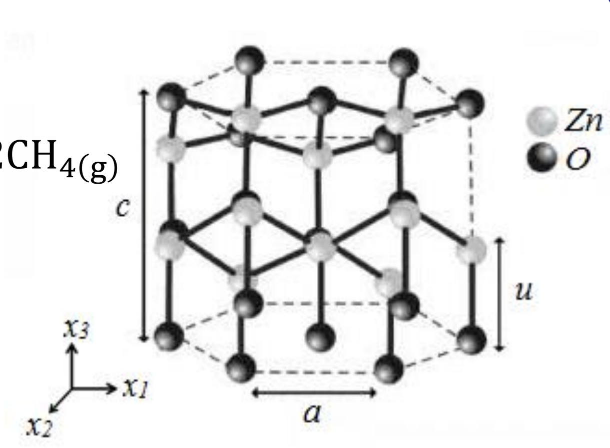
- ✓ Sapphire (Al_2O_3) and Si (111)
- ✓ 500 nm ZnO thin film
- ✓ c-oriented
- ✓ Calculation of SAW resonances
- ✓ $\lambda_{SAW} = 5.6\ \mu m$
- ✓ Mode visualization



Growth of ZnO thin films

Process

- ✓ Atomic Layer Deposition (ALD): $Zn(CH_3)_2 + H_2O \rightarrow ZnO + 2CH_{4(g)}$
- ✓ Substrates: sapphire (Al_2O_3), Si (111) and Si (100)



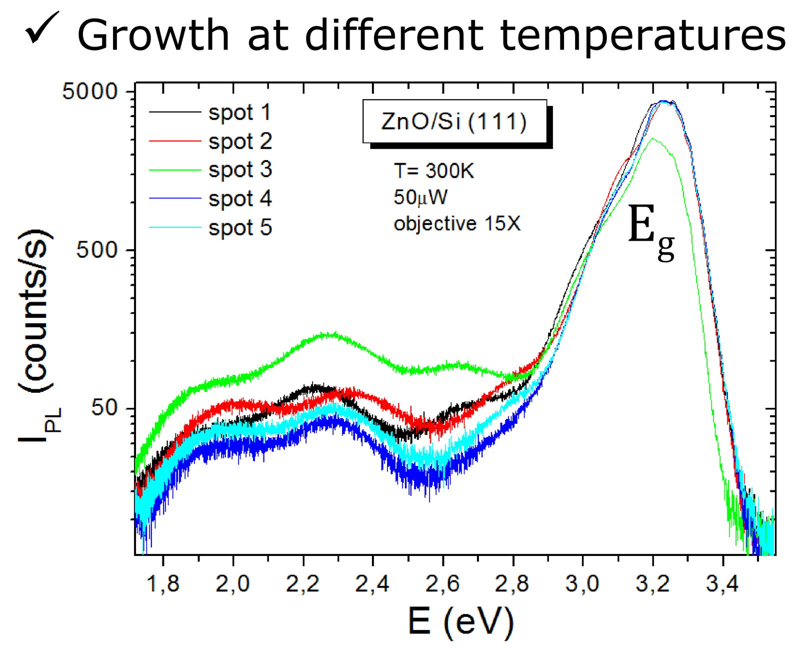
Photoluminescence (PL)

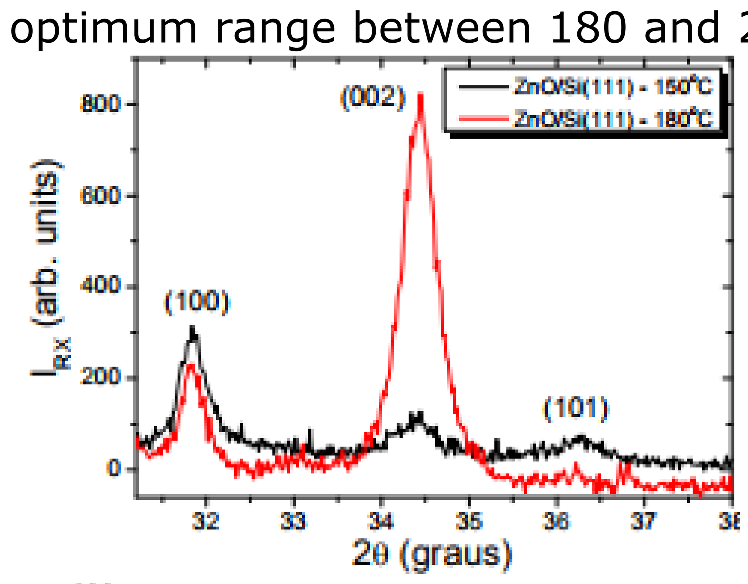
- ✓ ZnO on Si (111) at RT
  - ✓ PL homogeneously along film's directions
  - ✓ E_g in good agreement with literature reports [1]
  - ✓ Relatively low defect density
  - ✓ Same results obtained for Si (100) and (111)

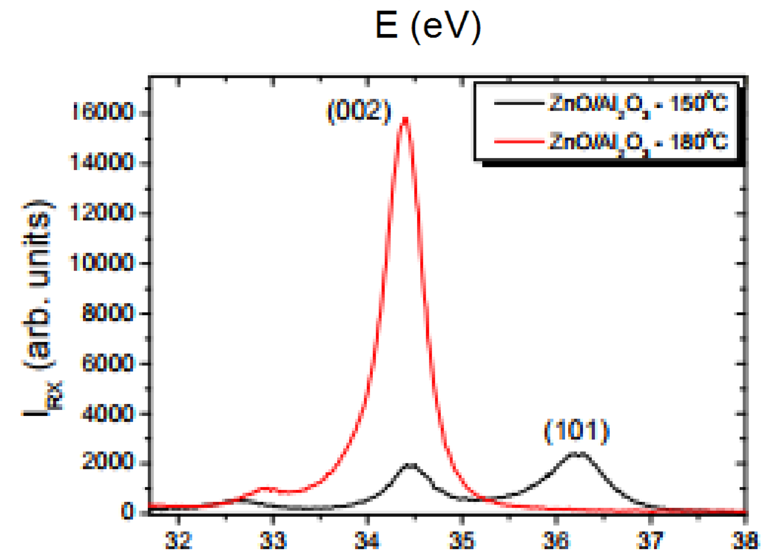
Substrate	Temp [°C]	T_1 [s]	T_2 [s]	T_3 [s]	T_4 [s]
Si (100)	150	0,15	0,15	0,50	0,75
Si (111)	150	0,15	0,15	0,50	0,75
Al_2O_3	150	0,15	0,15	10,00	20,00
Si (111)	150	0,15	0,15	10,00	20,00
Al_2O_3	180	0,15	0,15	10,00	20,00
Si (111)	180	0,15	0,15	10,00	20,00
Al_2O_3	210	0,15	0,15	10,00	20,00
Si (111)	210	0,15	0,15	10,00	20,00
Al_2O_3	240	0,15	0,15	10,00	20,00
Si (111)	240	0,15	0,15	10,00	20,00

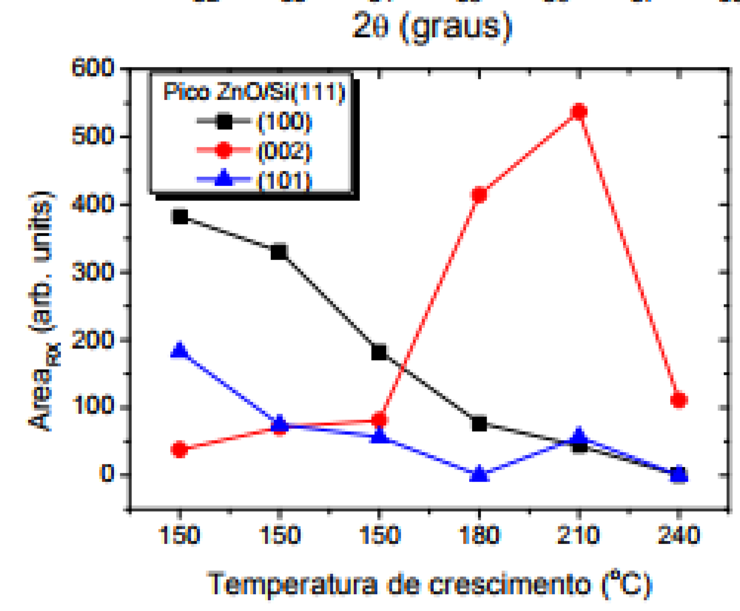
X-Ray Diffraction (XRD)

- ✓ Optimized for c-oriented films (piezoelectricity)
  - ✓ 150°C
    - ✓ (100), (002) and (101) diffraction peaks detected
    - ✓ (002) peak weak in comparison with (100) and (101)
  - ✓ 180°C
    - ✓ (002) peak dominates (100) and (101)
    - ✓ Growth at different temperatures shows optimum range between 180 and 210°C





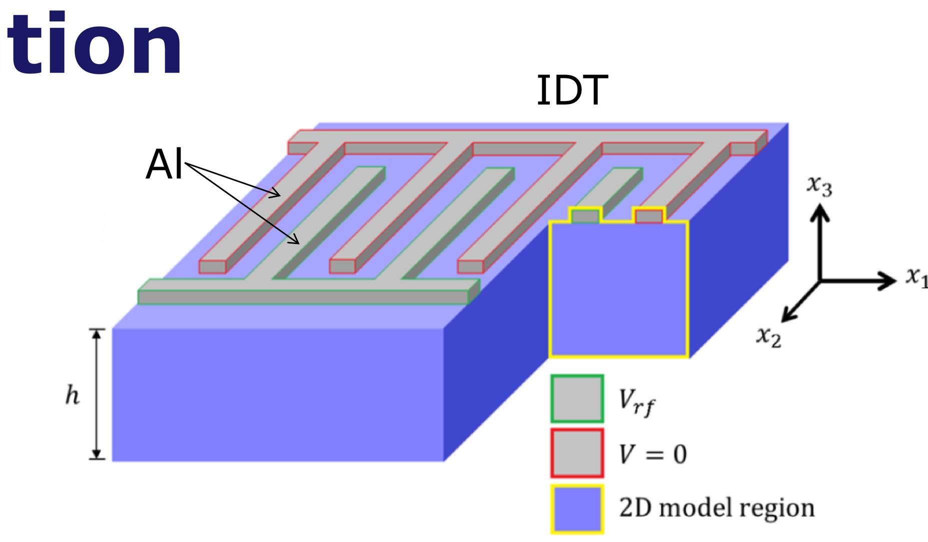




[1] V. Srikant and D. R. Clarke , J. Appl. Phys. 83, 5447 (1998).

Transducer fabrication

Interdigital transducers (IDTs)



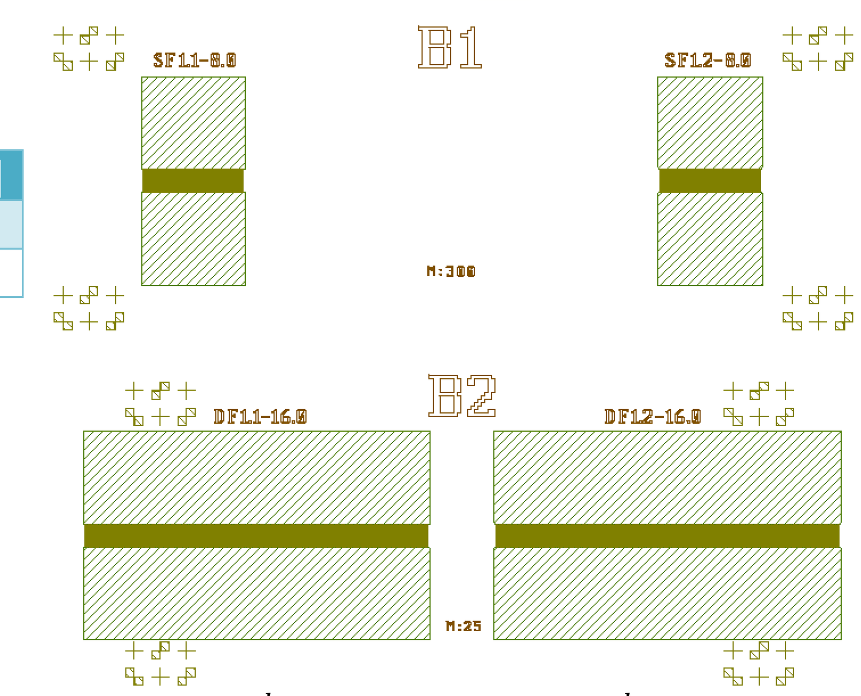
Mask Generation

- ✓ Mask: 96 IDTs (48 pairs)
  - ✓ Geometry
    - ✓ Single Finger (SF)
    - ✓ Double Finger (DF)

Parameters

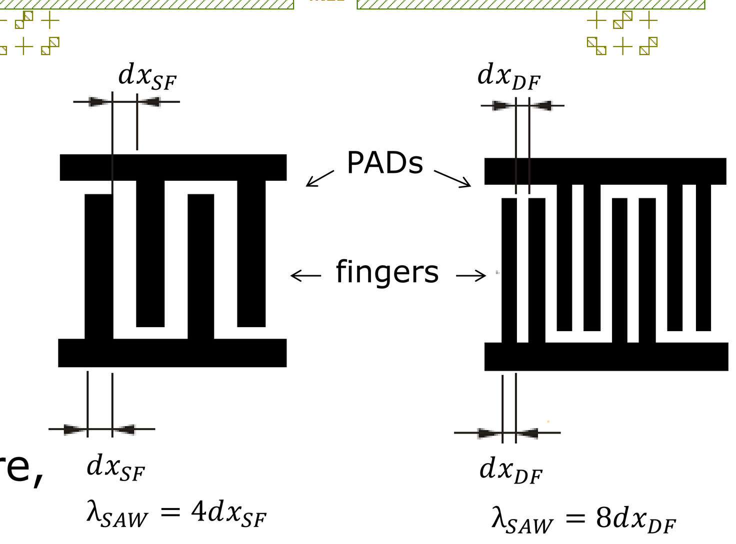
- ✓ $\lambda_{SAW} = 8\ \mu m$ and $16\ \mu m$
- ✓ $v_{SAW} = \lambda_{SAW} f_{SAW}$

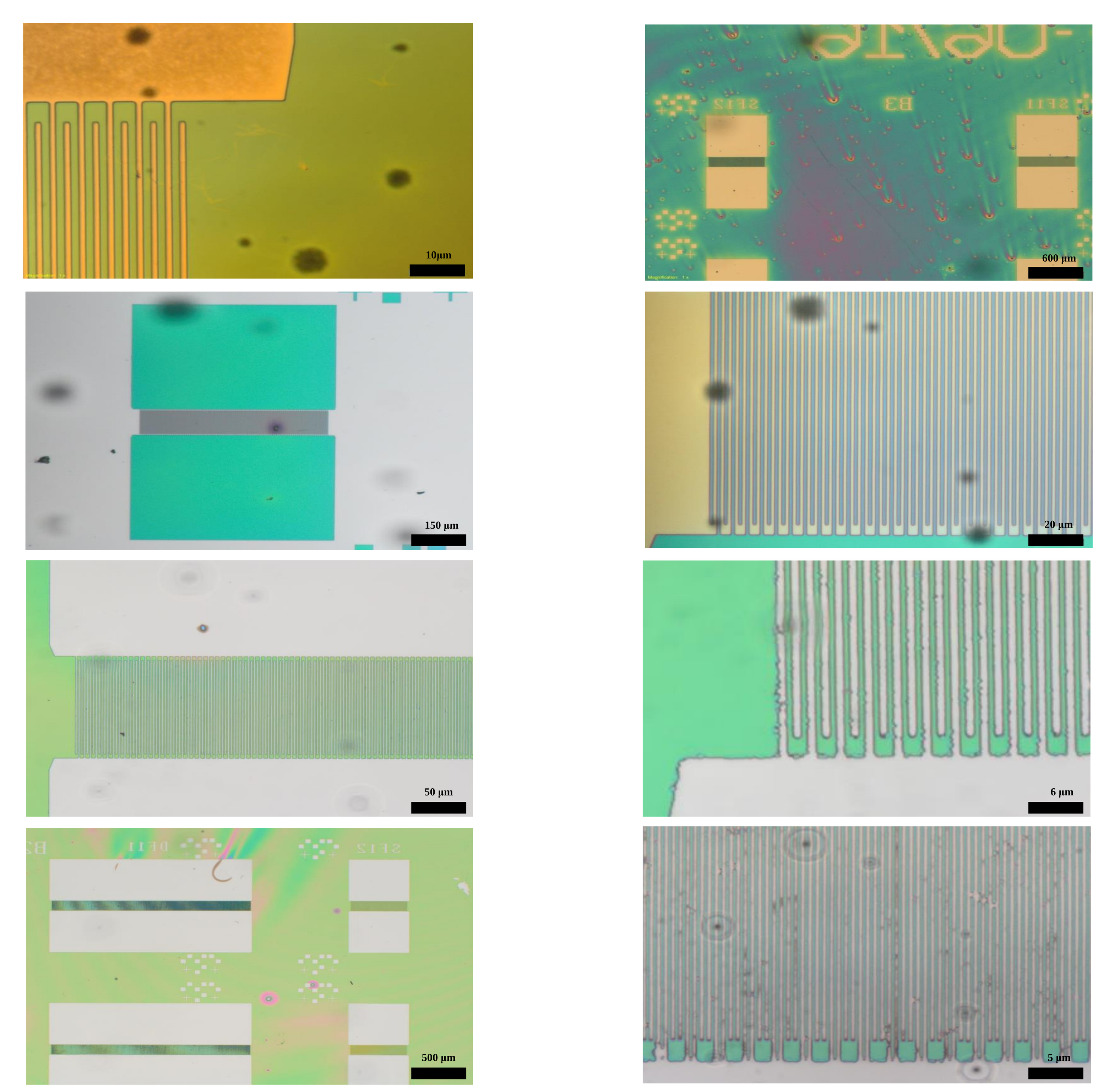
Material	v [m·s⁻¹]	f_1 [MHz]	f_2 [MHz]
ZnO	2694	336.8	168.4
$LiNbO_3$	3843	480.4	240.2



Process

- ✓ Optical Lithography
- ✓ Aluminum metallization
- ✓ Lift-off
- ✓ Tests
- ✓ Substrate: Si
- ✓ E-beam resist: 200 nm thickness
  - ✓ Particles due to resist aging
- ✓ Photo resist: AZ-5206
  - ✓ Conditions:
  - ✓ Inversion photolithography
  - ✓ Parameters to be optimized
    - ✓ exposition time, hard bake temperature, revelation time





Conclusions

ZnO Growth

- ✓ Atomic layer deposition
- ✓ c-oriented films
  - ✓ Optimum temperature range: 180 – 200°C
- ✓ Long growth times
  - ✓ Reduction needed more complex layered structures

Fabrication

- ✓ Metal fingers
- ✓ Well defined, better on single finger geometry
- ✓ Double finger width larger than system resolution
- ✓ Inversion Photolithography: functional process
- ✓ New tests needed for optimization and reproducibility

Acknowledgments FAPESP CNPq CAPES FAEPEX

Grupo de Propriedades Ópticas