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AlN/ZnO/Si Structure Combining Surface Acoustic Waves and Waveguiding Layer Acoustic Wave

O. Legrani*, O. Elmazria*, S. Zhgoon +, L. Le Brizoual#, A. Bartasyte*,
* Institut Jean Lamour (IJL), CNRS-Nancy University, 54506 Vandoeuvre lès Nancy, France
+ Moscow Power Engineering Institute, 14, Krasnokazarmennaja, 111250 Moscow, Russia
# Institut des Matériaux Jean Rouxel (IMN), Université Nantes, CNRS, 44322 Nantes, France

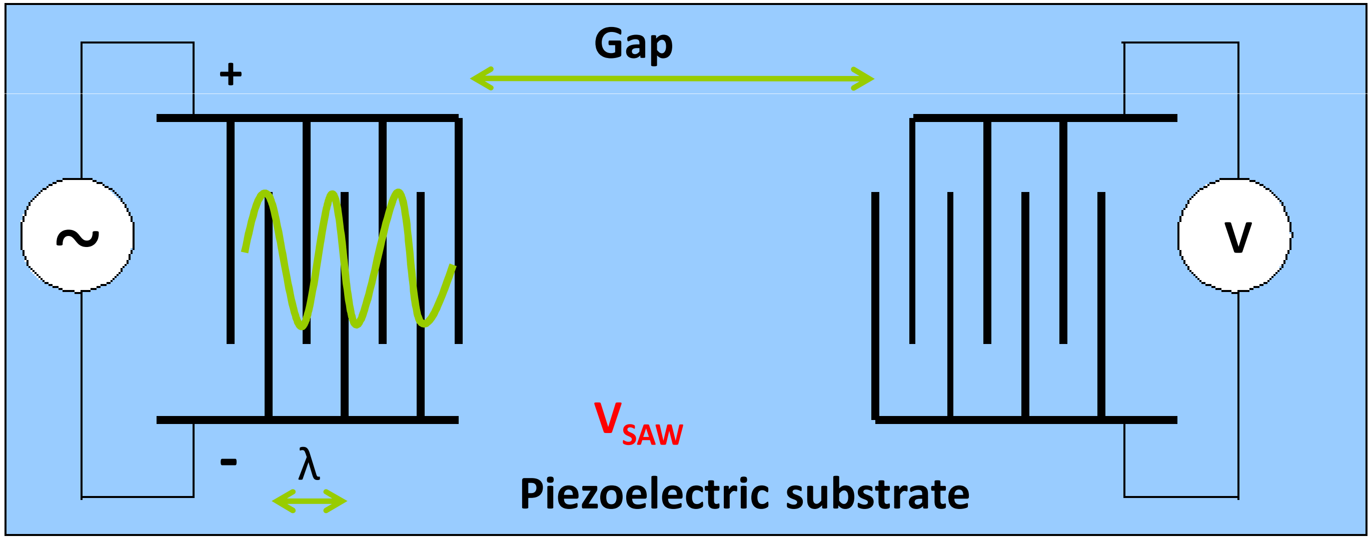
Summary

- Introduction
- Motivation and approach
- Model
- Results
    - > ZnO/Si structure
    - > AlN/ZnO/Si structure: thickness influence
- Conclusion/Outlook

Introduction

- Description and principle:

Surface Acoustic Wave (SAW) = Interdigital Transducer (IDTs) + Piezoelectric layer



$$f\,(Hz) = \frac{V_{SAW}\,(m/s)}{\lambda\,(m)}$$

Introduction

- Advantages of SAW devices:

  > Small size

  > Sensitive to the environments variations (temperature, pressure, atmosphere composition …)

  > Passive → Wireless sensing without embedded electronics

↓

Wireless + harsh environments

Motivation and approach

- What’s wrong?

SAW devices are very sensitive to environmental variations (oxidation, humidity...)

→ Need of protection package

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Packaging limits the extreme miniaturization of devices

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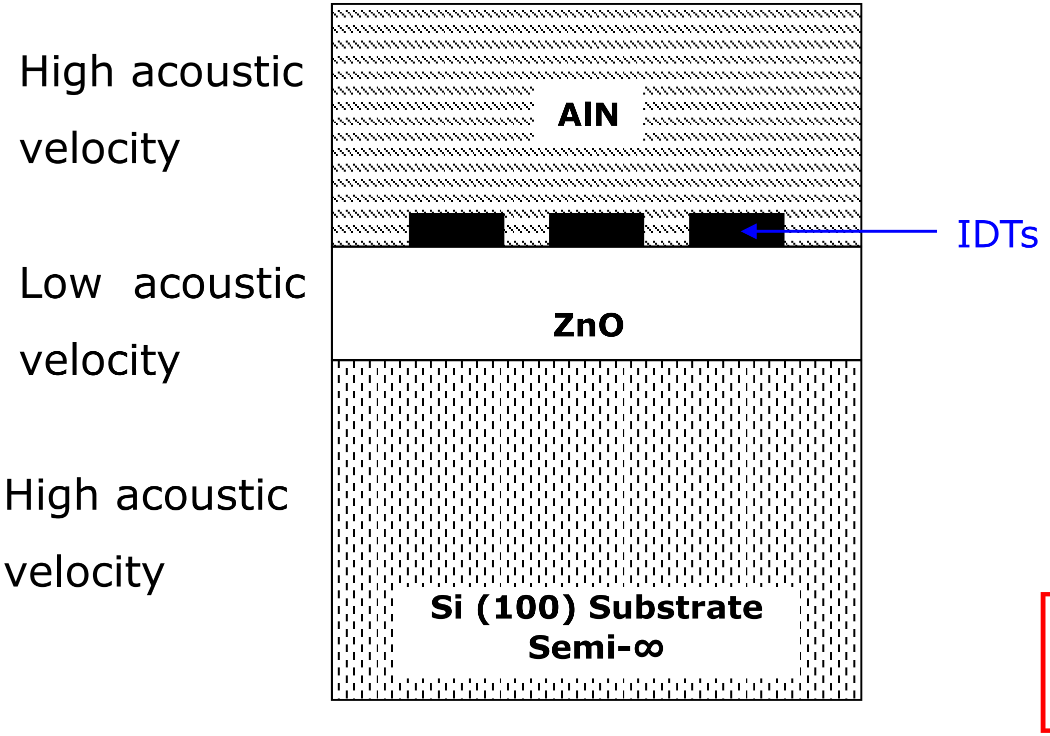
Solution: Realization of Waveguiding Layer Acoustic Wave (WLAW) devices

Motivation and approach

- WLAW device description:



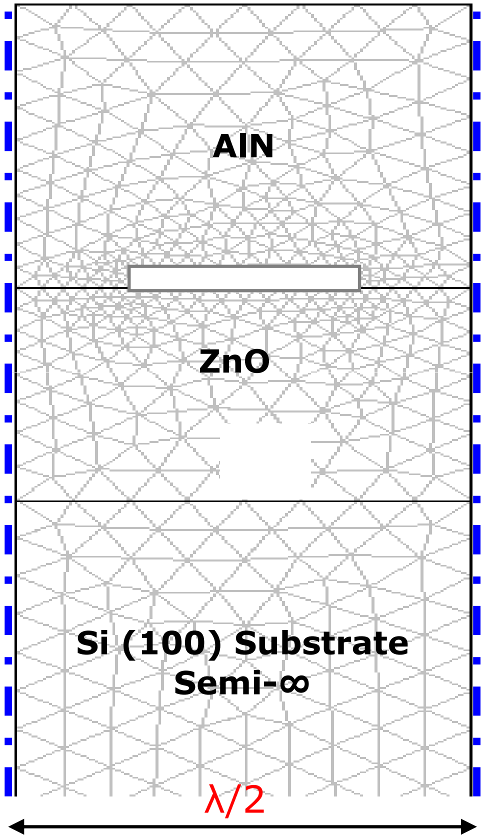
Isolation depends on:

- Choices of Materials
- Film thickness
- Wavelength λ ….

Modeling by software 2D COMSOL Multiphysics

K. Bhattacharjee et *al.*, IEEE, *135* (2007)
L. Le Brizoual et *al., IEEE **57**, 1818 (2010)*

Model



- Built-in 2D Structural Mechanics Module & Piezo plane Stress
- Physical constants of materials given by literature*
- λ = 8 µm -> for the modeling, only need λ/2 (symetric structure, save calculation time)
- Triangle mesh
- Periodic boundary conditions

K. Tsubouchi et *al*., *IEEE Ultrasonics Symposium*, 375 (1981)

G. Carlotti et *al*., *Appl. Phys. Lett* **51**, 1889 (1987)

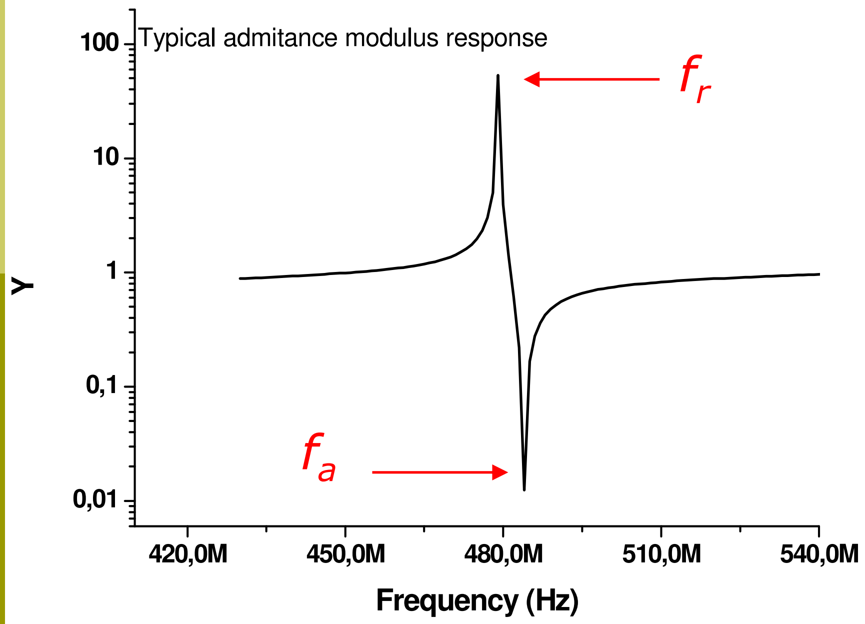
Model

- Important properties of WLAW devices:

> Phase velocity ***V*** => eigenfrequency *f*

$$V = f * \lambda$$

> Electromechanical coupling **K²** => curves of Admittance modulus



$$k^2 = \frac{\pi}{2}\frac{f_r}{f_a} tg\left(\frac{\pi}{2}\frac{f_a - f_r}{f_a}\right)^*$$

f_r: resonance frequency

f_a: anti-resonance frequency

D. ROYER, "*Ondes elastiques dans les solides*", tome 2

Model

- Important properties of WLAW devices:

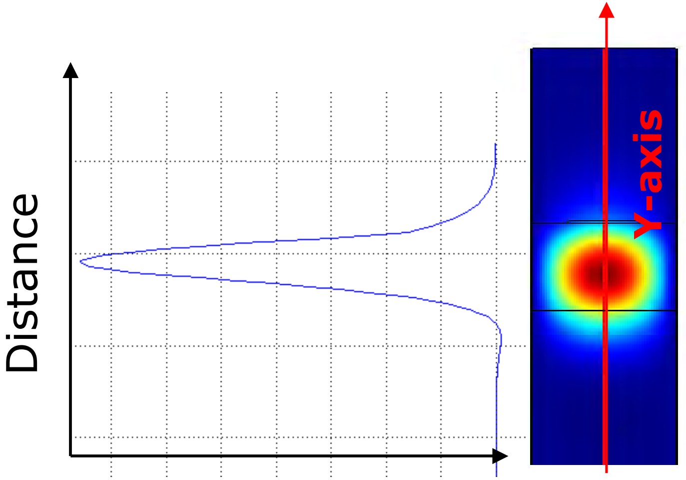
> Phase velocity ***V*** => eigenfrequency *f*

$$V = f * \lambda$$

> Electromechanical coupling **K²** => Curves of admittance modulus

$$k^2 = \frac{\pi}{2}\frac{f_r}{f_a} tg\left(\frac{\pi}{2}\frac{f_a - f_r}{f_a}\right) \quad *$$

> Conditions of wave confinement => cross-section of acoustic field distribution along Y-axis

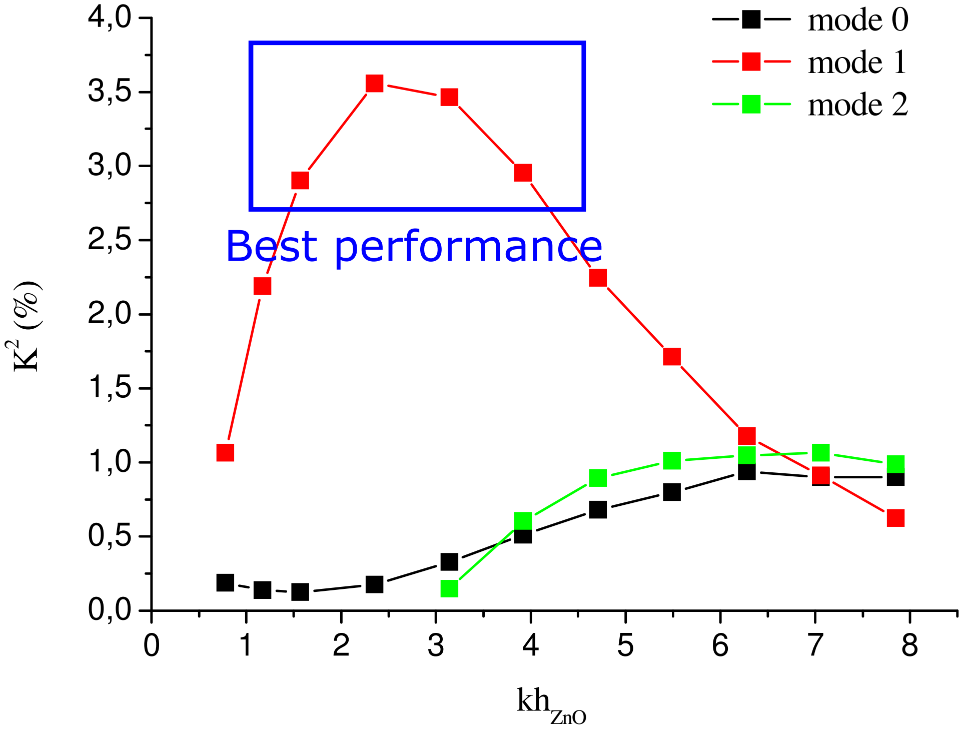


Results

Simple ZnO/Si structure

- Si assumed semi-infinite

- $1\mu m < h_{ZnO} < 10\mu m$



- 1st mode increase up to a maximum value

- 0th and 2nd increase and stabilize at high h_{ZnO}

- Good agreement with previous works*

- Best performance is obtained for $1.5 < kh_{ZnO} < 4.5$

* G. Carlotti et *al.*, *IEEE ultrasonics symposium*, 295 (1987)

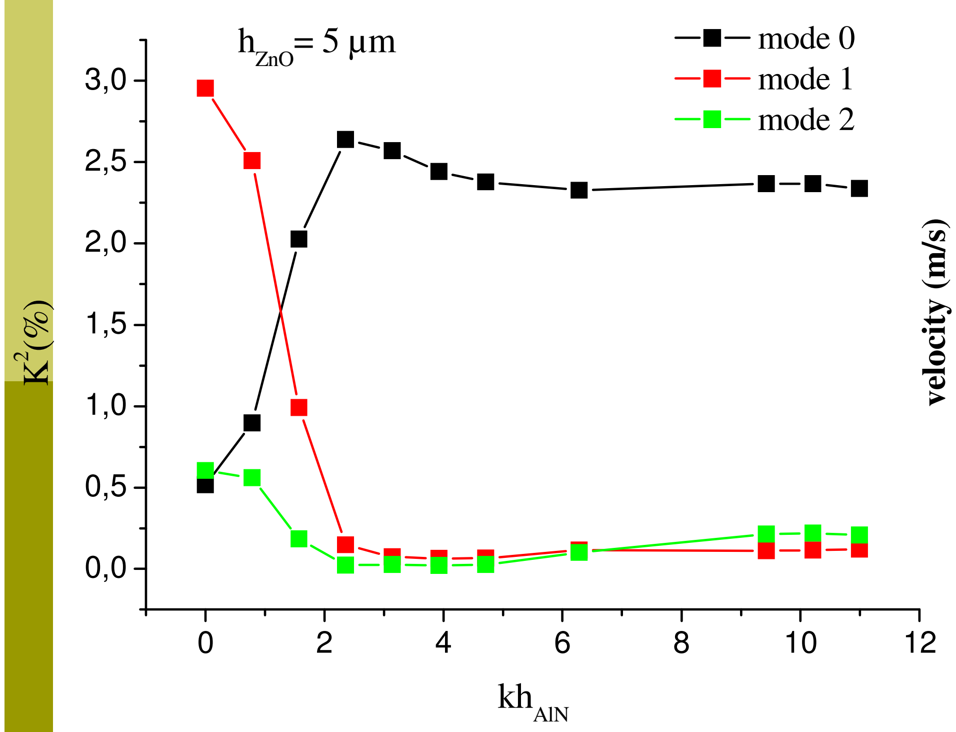
* L. Le Brizoual et *al.*, *Ultrasonics* **45**, 100 (2006)

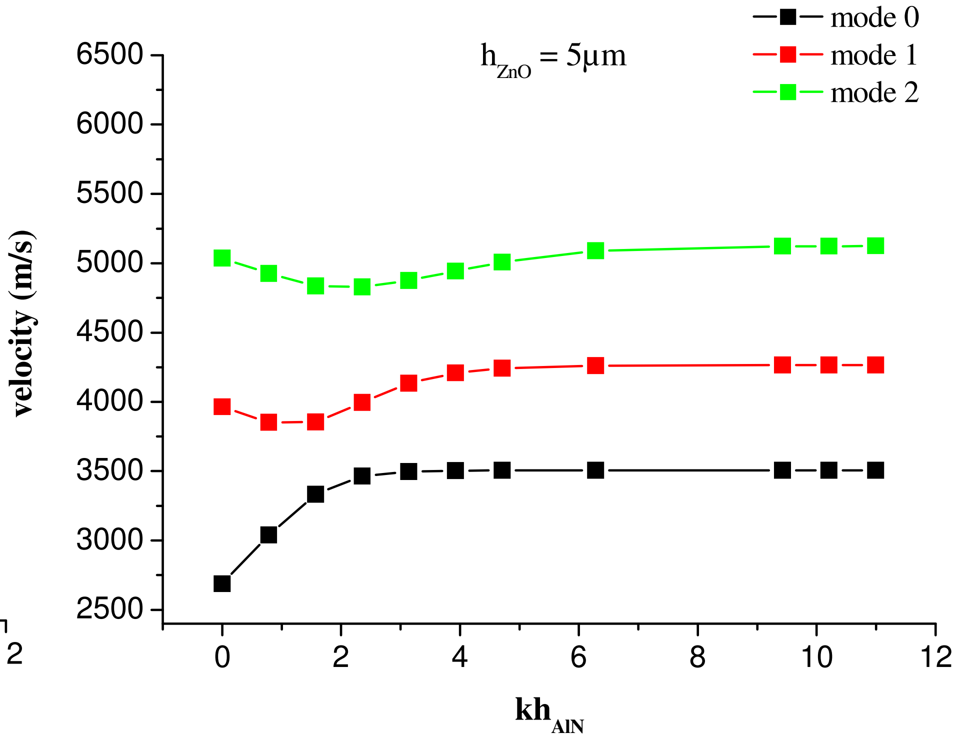
AlN/ZnO/Si structure

Results

AlN thickness

- $1\mu m < h_{AlN} \leq 12\ \mu m$
- ZnO thickness fixed at 5 µm



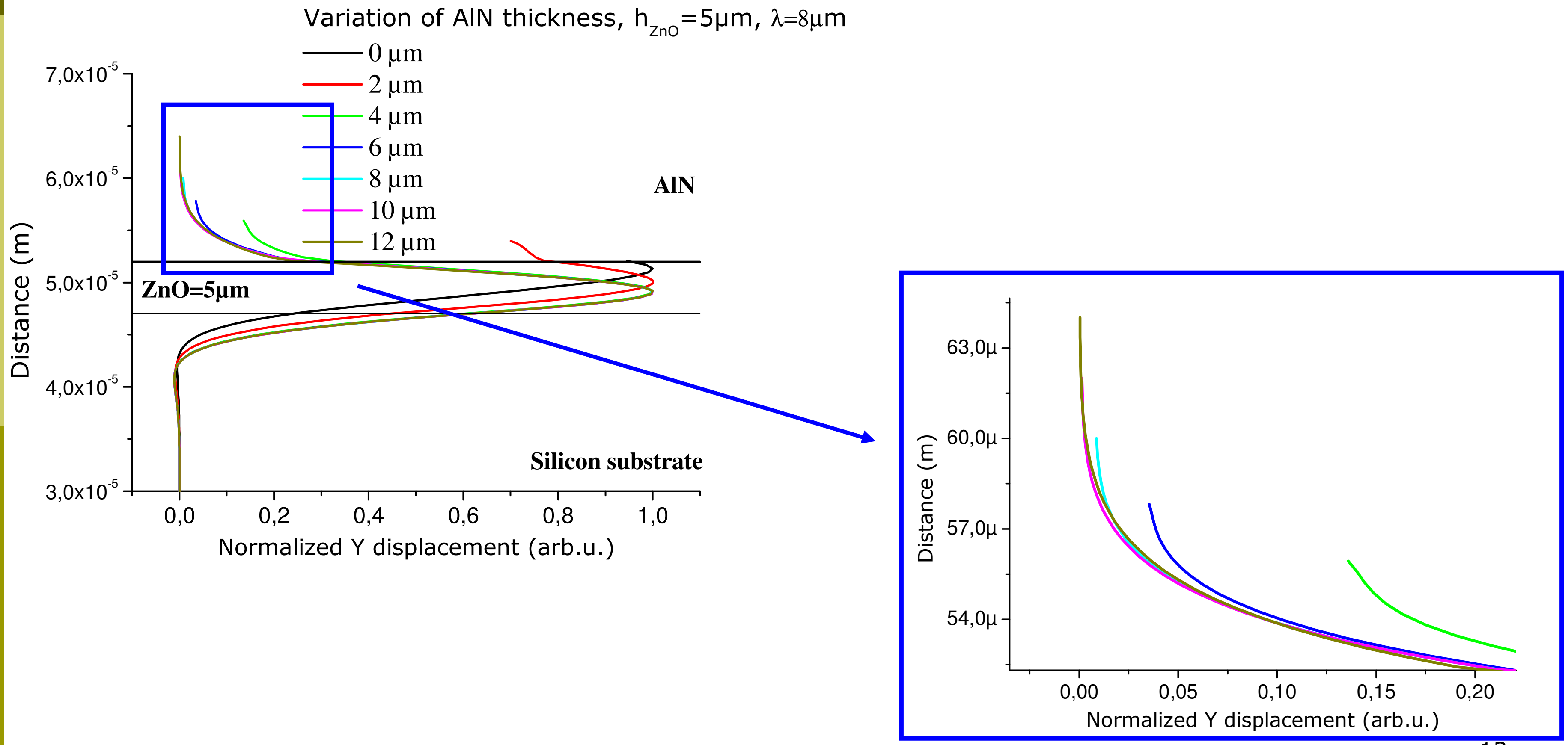


> Large impact of AlN thickness on the structure performance

AlN/ZnO/Si structure

Results

- AlN thickness and wave confinement



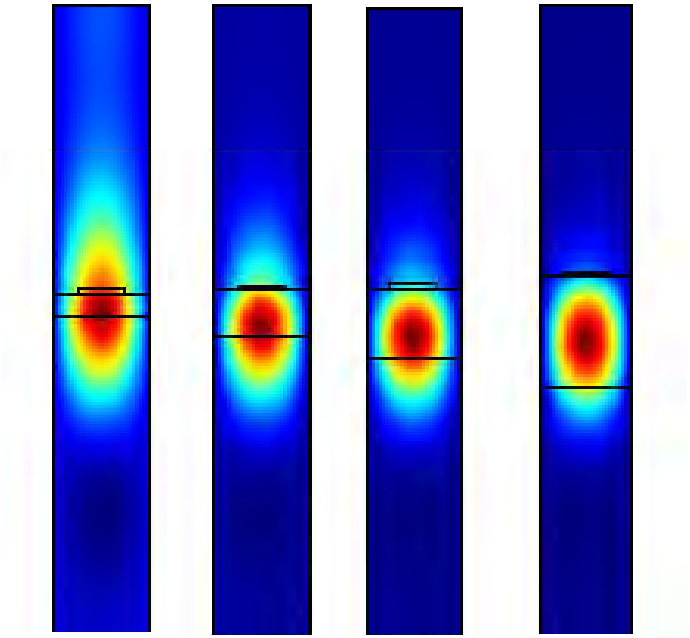
AlN/ZnO/Si structure

Results

- Thickness of ZnO

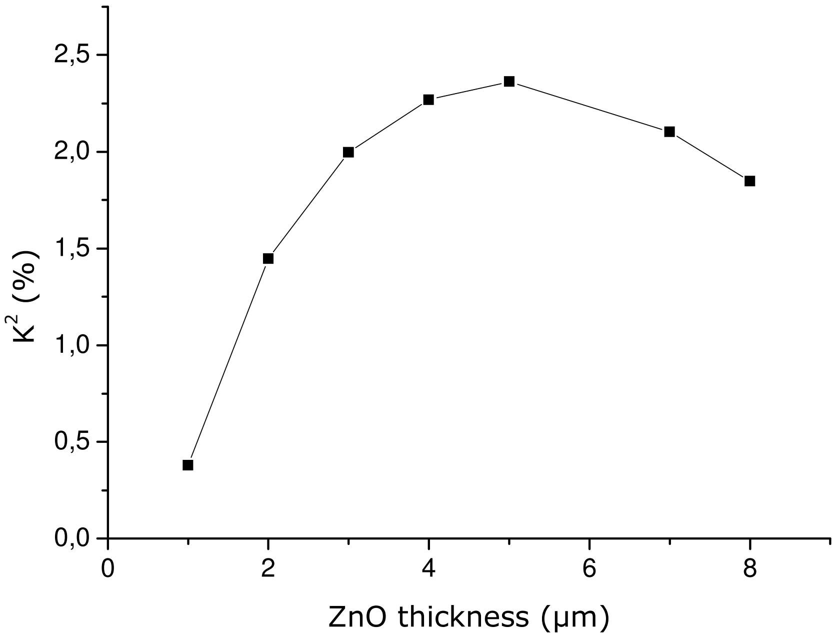
  h_{AlN} = 12µm,

  1µm < h_{ZnO} ≤ 5µm



1 µm 2 µm 4 µm 5 µm

Variation of acoustic field distribution

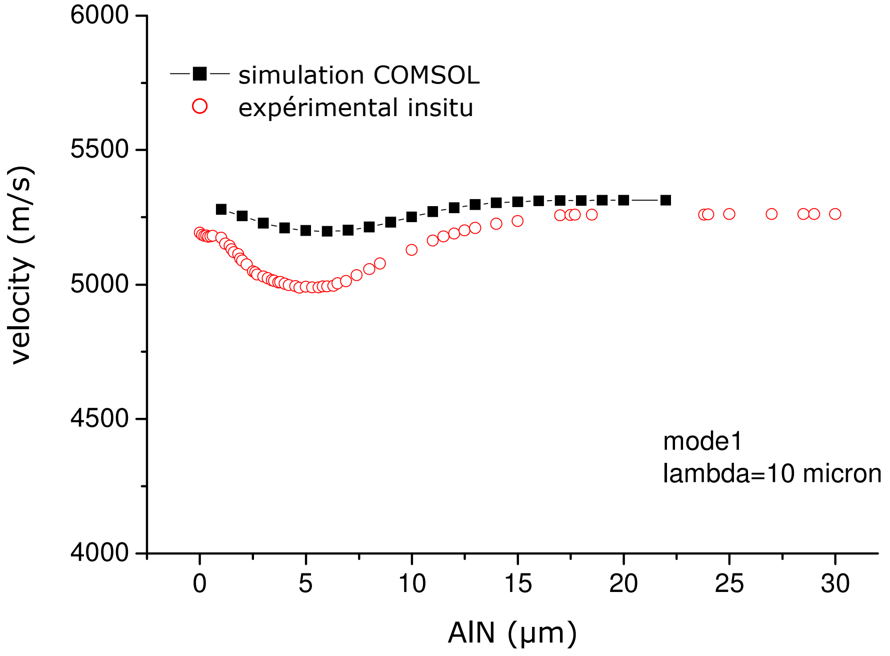


- h_{ZnO} influence on wave confinement

- Best K^2 value for hZnO ~ 3 -7 µm

Conclusion

- An efficient AlN/ZnO/Si structure has been optimized before experiments
- The effects of AlN and ZnO thicknesses on structure have been demonstrated
- Experimental tests have been realized and confirmed the results obtained by modelling



Outlook:

- Influence of IDTs position in the structure
- Other Substrates
- Influence of temperature (TCF)
- More experimental tests

Thank you
for your attention

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