Surface Acoustic Waves Sensors Based Lithium Niobate And Quartz For Particulate Matter measurements

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Resume of the presenter

I'm Dbibih Fatima-Ezzahraa, PhD student at Femto-St institute in Franche Comté University in France.
Currently working on the development and optimization of Particulates matter measurements system using Surface Acoustic wave sensors combined with a cascade impactor.

Summary

Introduction

- Surface Acoustic Waves sensors
- Experimental protocol
- Experimental results

Conclusion

Introduction

What are particulates matter (PM)?

PM **describes a wide variety of airborne material produces from:**

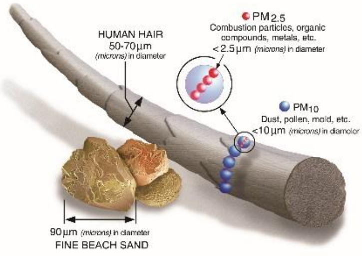
Natural sources (sea salt, volcanic activity…)
Man-made sources (road traffic, industrial activity…)

The size of particles is directly linked to their potential for causing health problems

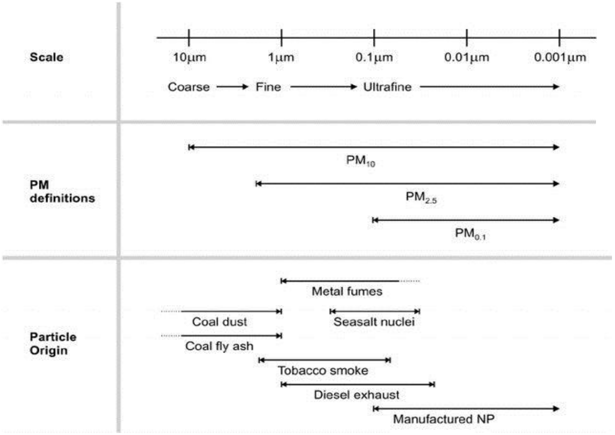
What is health effect of particulates matter ?

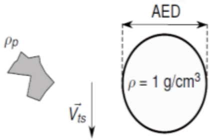
- Decreased lung function
- Cardiac arrytmias
- Premature death

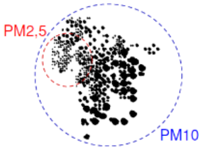
Fundamental need of monitoring the PM concentration



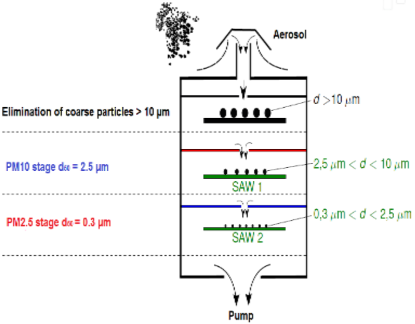
Classification of PM

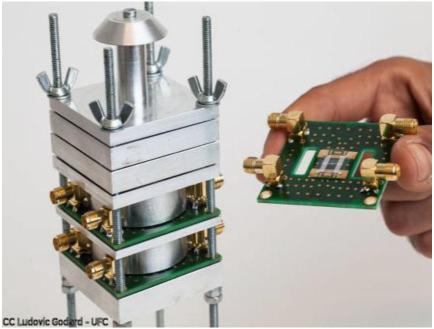






Real time cascade impactor

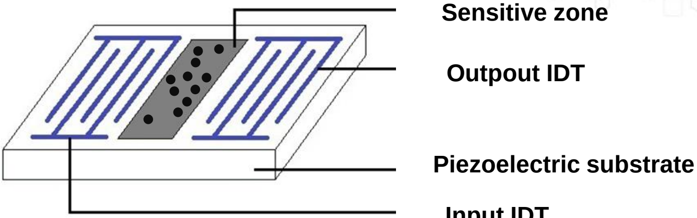




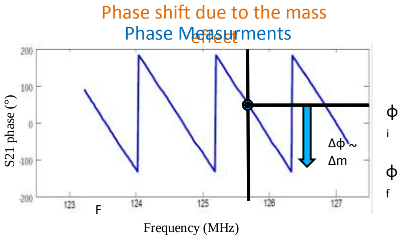
Combination of a cascade impactor and a Surface Acoustic Wave Sensors

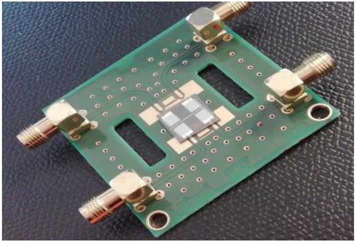
Real time cascade impactor with Surface Acoustic waves (SAW) sensors is a smaller and cheaper instruments of PM measurements

Principle of PM measurement by SAW wave sensors



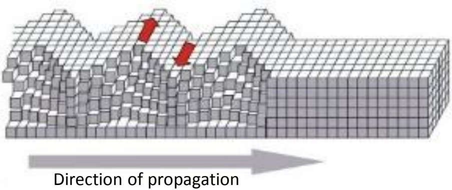
IDT : Interdigitated transducteur

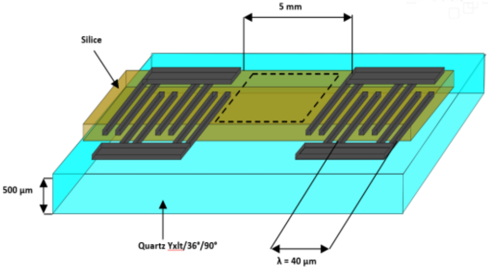




SAW Sensors based Love wave

Love wave



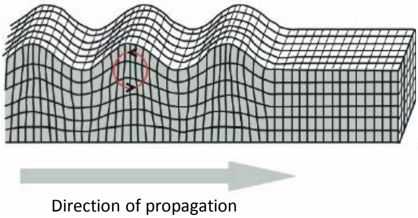


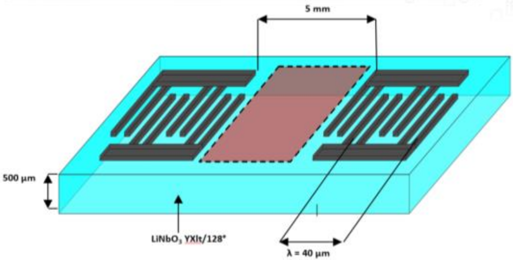
- Horizontal polarization: transverse wave
- Propagation in non-homogeneous solids, can only exist in the presence of a waveguide with a propagation speed Vs <that of the wave
- Deposit of a layer of silica of 1,5 µm

Material	**Orientation**	**V(m/s)**	**K^2 (%)**	**Propagation mode**
Quartz	YXlt/36°/90°(AT – X)	5100	0.14	Love

SAW Sensors based Rayleigh wave

Rayleigh Wave





- Elliptical polarization: Double horizontal and vertical component
- Deformation of the material in the sagittal plane
- non-dispersive: their propagation speed does not depend on the frequency

Material	Orientation	V(m/s)	K^2 (%)	Propagation mode
$LiNbO_3$	Y+128° – X	3950	5.5	Rayleigh

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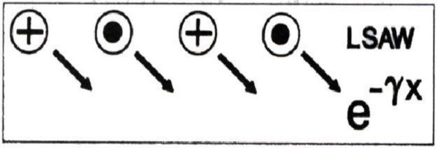
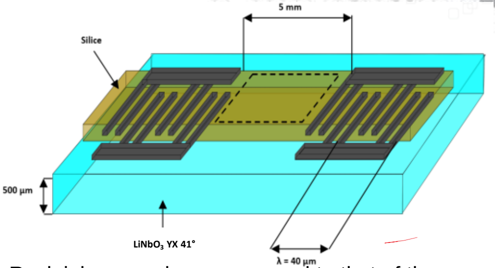
SAW Sensors based PSAW wave

PSAW wave or Leaky wave





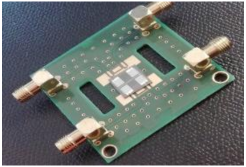
- Leaky waves appears when the speed of the Rayleigh waves becomes equal to that of the slowest quasi-transverse volume wave
- The losses are very low in some cuts and propagation directions, which makes 'Leaky Waves' very interesting because their electromechanical coupling coefficient is generally significantly higher than that of Rayleigh
- Deposit of a layer of silica of 1,5 µm

Material	Orientation	V(m/s)	K^2 (%)	Mode de propagation
$LiNbO_3$	Y+41° – X	4450	17,2	PSAW

SAW sensors characteristics

Material	Orientation	V (m/s)	K^2 (%)	Working Frequency (MHz)	Propagation mode
Quartz	AT – X	5100	0.16	125	Love wave
$LiNbO_3$	Y+128° – X	3950	5.5	100	Rayleigh wave
$LiNbO_3$	Y + 41°– X	4450	17.2	115	Pseudo SAW

- 128° YX-$LiNbO_3$ and 41° YX $LiNbO_3$ have a large electromechanical factor
- The working frequency depends on the velocity of wave and the design of interdigitated transducers



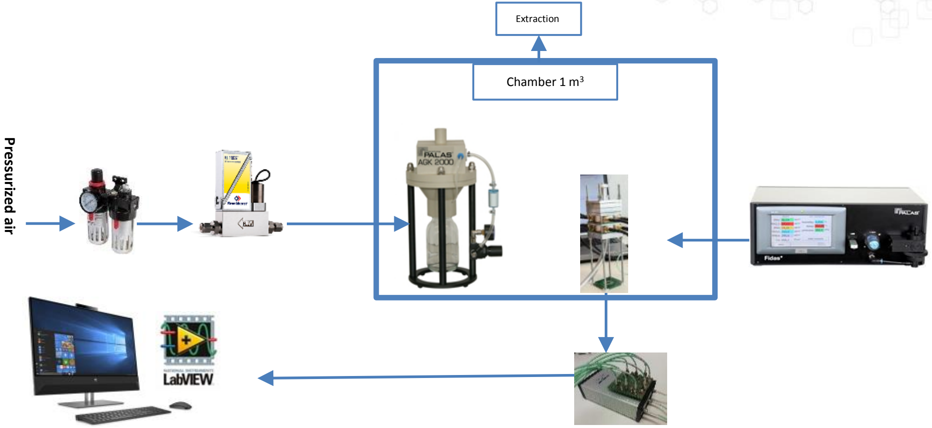
SAW delay lines fabrication process

Fabrication process :

- Photolithograpy/Lift off process
- E-beam evaporation for interdigitated electrodes (IDT's)
- E-beam evaporation for Silica guiding layer

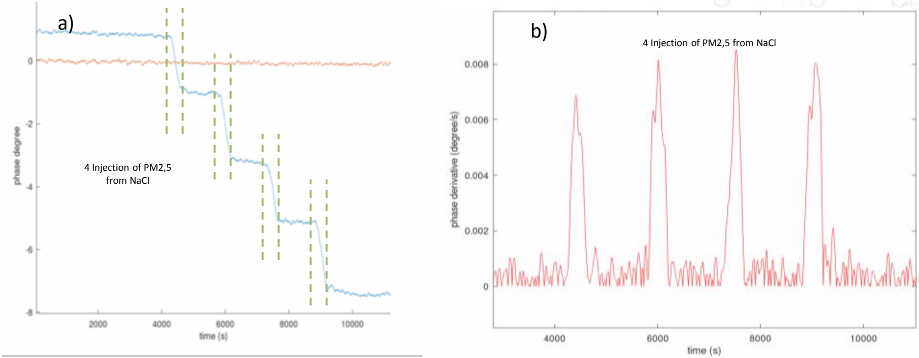
Parameter	**Value**
Metallization	Aluminum
Metallization thickness	300 nm
Wavelength λ_0	~ 35 µm
Fingers per wavelength	4
Acoustic aperture	43 λ_0
Transducer length	30 λ_0
Gap length	74 λ_0

Measurements setup



- EL-press regulator
- Particles generator AGK-2000
- Optical analyzer of particles FIDAS 100 Palas
- Dedicated electronic for sensor's interrogation

Experimental results

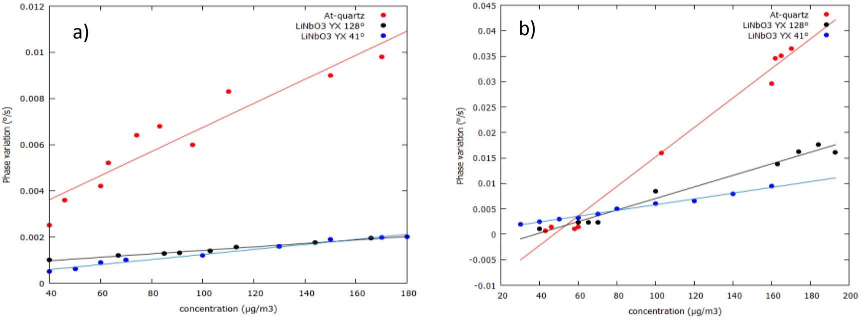


Example of a) phase response of PM 10 stage (blue) and PM2,5 (orange) and b) phase derivative to mass concentration of PM 2,5

- The sensitivity was investigated using two type of aerosols PM2.5 and PM10 in the [0-200] µg/m$_3$ concentration range

- The Measurements were performed 4 times for the same concentration

Experimental results

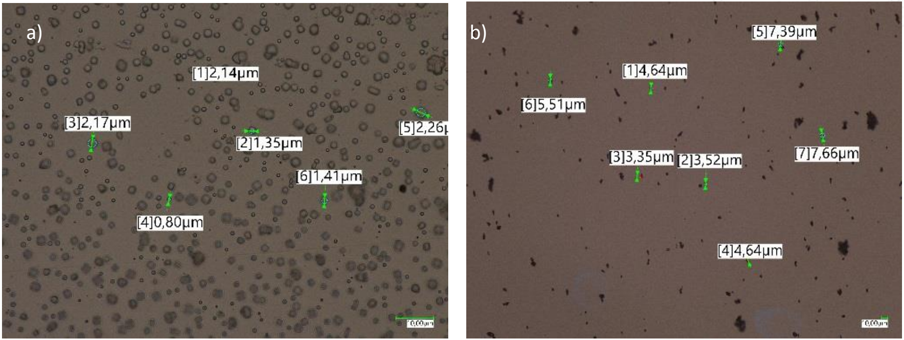


Phase variation dφ/dt of sensors based AT-Quartz (in red), 128° YX $LiNbO_3$ (in black) and 41° YX $LiNbO_3$ (in blue) with the concentration for a) PM2.5 and b) PM10, respectively, measured with the optical system FIDAS®

- Good linearity of response for the 3 types of sensors

- Love wave sensor are more sensitive than Rayleigh wave and PSAW wave sensor for PM 2.5 and PM 10

Experimental results



Photographs of particles diameters measurements for a) PM 2,5 and b) PM2,5 stages SAW sensor

Material	Orientation	Sensitivity to PM2,5 ($°s^{-1}µg^{-1}m^3$)	Sensitivity to PM 10 ($°s^{-1}µg^{-1}m^3$)
Quartz	AT – X	3.10^{-4}	5.10^{-5}
$LiNbO_3$	Y+128° – X	1.10^{-4}	1.10^{-5}
$LiNbO_3$	Y + 41°– X	6.10^{-5}	1.10^{-4}

Conclusion

- Different piezoelectric substrates of surface wave sensors have been tested for PM measurements of different diameters and concentration.

- Love wave sensors based on AT quartz cut shows the best sensitivity for both PM2.5 and PM10. In the second range, Rayleigh wave based 128° YX $LiNbO_3$ shows higher sensitivity than PSAW wave sensors for both type of particles PM10 and PM 2.5.

- Although the SAW sensors are promising for PM measurements, We have found a small lives pan and rebound phenomenon from PM 10 stage

Perspectives

- The sensors on $LiNbO_3$ Y-X 128° and LiNbO3 Y-X 41° although less sensitive are promising because they offer a strong electromechanical coupling which allows the cleaning of the surface after saturation using RF power.

- The response on the PM 10 stage can be improved by depositing an anti-rebound layer.A study is underway to remedy this problem using a layer of Teflon.