TPIA GROUP
Transduction, Propagation and Acoustic Imaging

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Research activities in acoustic and ultrasound

- The acoustics and ultrasound research activities of the TPIA Group concern the field of physical acoustics. The main objectives are :
  - to understand the interactions of ultrasonic waves with matter,
  - to propose different methods of analysis (inverse problems) adapted to monitoring structure integrity and material properties,
  - to model the behaviour of ultrasonic sources and their interactions with materials
  - to develop tools for the optimal design of systems.

- The cutting-edge research conducted by the TPIA group is based on the skills and expertise accumulated over more than 30 years within the Opto-Acousto-Electronics Department (DOAE) in the field of ultrasound and its interaction with matter.

- The Group's Research Activities cover both fundamental and technological innovations in systems and in R&D corresponding to needs expressed by manufacturers.

Scientific Topics

- The TPIA group's themes are very open to technological progress (microelectronics, MEMS) and cover topics of fundamental nature or linked to industrial needs by adopting a balanced approach between modelling, experimentation, and inverse problem resolution.
- These research themes are all the more important with the emergence of new materials such as functional surface materials (coated with fine or thin layers) and materials with property gradients (commonly used in the field of transport for example), as well as socio-economic issues related to industrial developments such as non-destructive testing methods.

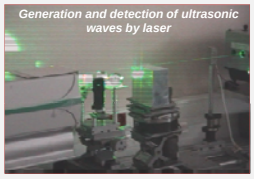
- The research activities are organized around three coherent and complementary themes:

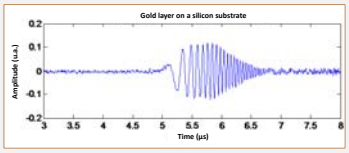
Transduction & Energy Harvesting | **Guided Acoustics & Inverse Problems** | **Imaging using Distributed Acoustic Sensors**

- These research activities cover a broad spectrum in the field of ultrasound, from wave generation to inverse problems and imaging.
- These topics are well-established and have their own sources of funding and collaborations. There are currently more than ten PhDs in progress.

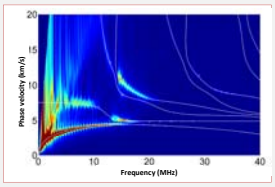
Guided Acoustics and Inverse Problems

- The theme "Guided acoustics and Inverse Problems" aims to improve and optimize the characterization of various structures using the properties of surface acoustic waves and Lamb-type modes.
- The resulting applications are related to many sectors of activity from microelectronics to transportation.
- Non-contact excitation and detection methods can be considered in pulsed or harmonic regimes.

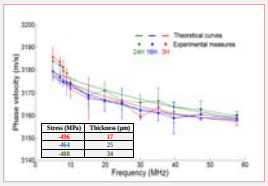




First Rayleigh mode on a Au/Si structure obtained by Laser Ultrasonics [MST 2013]



Thin film characterization using Lamb modes 4 µm indium film deposited on a silicon substrate (Dispersion curves obtained by Laser Ultrasonics) [RSI 2011]



Phase velocities and dispersion curves for three superficial residual stress fields [JASA 2013]

- A wide range of samples, from granular materials to thin films, were investigated. The originality of our work often relies on the inversion methods used. It also relies on the characterization processes and/or devices developed. For example, the use of Laser Ultrasonics (5,10,11,13), SAW-IDT MEMS (1,2,14), air-coupling sensors (6,7,12)…

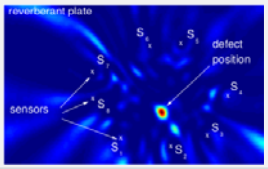
Imaging using Distributed Acoustic Sensors

- This research topic is concerned with damage detection and imaging in reverberant and complex media. One of the objectives is to exploit ambiant acoustic fields instead of driven artificial ultrasonic sources as is customary in conventional NDT techniques (3,4).

Damage detection using passive acoustic sensors (principle) [JAP 2011]

Advantages of this principle:
- low power consumption
- easier sensor setting
- miniaturization, non-intrusiveness, low embedded resources

Recent results:
Defect localisation through processing of the correlation matrices built from a network of a few sensors distributed on a reverberant plate.



Localisation of a defect from noise correlation matrices in a reverberant plate [JASA 2012]

Transduction and Energy Harvesting

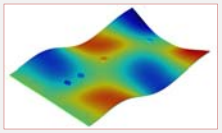
$LiNbO_3$ arrays etched by ICP (Ultrasonics 2012)

Transduction

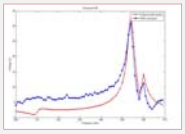
The research activities concern the development of the ultrasonic multi-element transducers (or phased arrays) of very high frequency (more than 100MHz) for applications of nondestructive evaluation and biological cells imaging. The theoretical modeling (with the finites-elements method) permits the optimization of the system performances. The transducers in ZnO or LiNbO3 piezo-material are fabricated with the using of MEMS technologies.

Power Harvesting

This topic involves the development of autonomous Structural Health Monitoring (SHM) systems. Vibration power harvesting is carried out using classical piezoelectric SHM sensors. An experimental test set-up is used to evaluate this technology for different frequencies and different kinds of sensors. In parallel, Finite Element (FE) and analytical models have been developed in order to get a better understanding of the numerous phenomena involved in the energy harvesting process. It will allow optimization of the future systems.



Finite Element Modeling of Power Harvesting System



Comparison of voltage response: experimental / FEM

Skills and Areas of Expertise

- Non Destructive Testing & Evaluation
- Structural Health Monitoring
- Residual Stress Estimation - Acoustoelasticity
- Acoustic Microscopy & Acoustic Material Signature, V(z)
- Resonant Ultrasound Spectroscopy of Surface Acoustic Waves

Research programs

(1) European Program INTERREG IV, PRISTIMAT (2008-2013)
(2) European Program INTERREG III, PRISTIFLEX (2013-2014)
(3) European Program FUI, ALAMSA (2013-20XX)
(4) ANR Program PASNI (2012-2015)
(5) ANR Program Eco CND (2009-2013)
(6) ANR Program SENSO (2006-2009)
(7) ANR Program ENDE (2014-2017)
(8) ANR Program young researchers OVMI (2006-2009)
(9) ANR Blanc IN-ART (2009-2013)
(10) CPER CISIT (2007-2013 & 2014-2020)
(11) Projet Grand Emprunt RAILENIUM (2012-2020)
(12) National Program ACDC (2011-2013)
(13) ARCir Program CECET (2007-2009)
(14) OSEO Program DECOL (2009-2011)

Academic and industrial Collaborations

IEMN Groups : MAMINA, COMNUM , Acoustique Group

Academic collaborations : Bath Univ. (UK), Bydgoszcz Univ. (Pol.), Sherbrooke Univ. (Ca.), MONS Univ. (Be.), Catholic Louvain Univ. (Be.), Tongji Univ. (Shanghai, Ch.), Fudan Univ. (Shanghai, Ch), LMCPA, UPJV, CEA LIST, Institut de Soudure, Institut Langevin (ESPCI), LaMCoS, ONERA, GIPSA, SATIE, LPPI, IFSTTAR, I2M, LMDC, LCND, ISTERRE, School of Microelectronics, FEMTO-ST (RTB network)

Industrial collaborations : CRITT MDTS, INISMA (Be.), SIRRIS (Be.), Holo3, Ixtrem, EADS, Airbus (Fr & UK), PSA, Soben, Vallourec, SKF Aerospace, Soben, ADES, CTIF, NCA Technologies (Be.), St Gobain Glass, Glaverbel (Be.), EDF, GETEC, SOVEP, SETRA, MISTRASS

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