PHD THESIS: HIGH-FREQUENCY ULTRASOUND AS A NON-DESTRUCTIVE CHARACTERISATION TECHNIQUE FOR MICROELECTRONIC COMPONENTS AND ARCHAEOLOGICAL ARTEFACTS

Key words: ultrasonic waves, non-destructive evaluation, microelectronic components, archaeological materials, ceramics, porous materials, acoustic signature.

GREMAN laboratory (UMR CNRS 7347 - University of Tours - INSA Centre Val de Loire)

GREMAN is research group on materials, microelectronics, acoustics & nanotechnology, a laboratory of over 100 persons with 48 permanent academic staff, 16 administrative & technical staff, 38 PhD students and 10 post-doctoral researchers. Since its creation in 2012, this joint research laboratory of Tours University, INSA Centre Val de Loire and CNRS focuses its activities on 4 key topics:

- ❖ novel functional oxides for energy efficiency;
- ❖ magnetic and optical properties of ferroic and electronic correlation materials;
- ❖ ultrasonic devices and characterization
- ❖ energy , components, systems, microelectronics

LAT research group (part of CITERES UMR CNRS 7324 - University of Tours)

LAT (Laboratoire Archéologie et Territoires) is one of the main research centres on French metropolitan archaeology, from recent Prehistory to the Modern Age. Since its creation in 1992, it has brought together archaeologists and historians to study the relationships of societies both in terms of time and localisation.

Background and motivation

Ultrasonic waves have proven to be a very efficient way to obtain images and quantified data from complex media in applications such as medical diagnostics and industrial defect detection, just to name a few. This is due to the fact they are non-ionizing, to their relatively low cost and ease of use as well as to their non-invasive and non-destructive character. Acoustic microscopy is a technique that uses high-frequency ultrasonic waves that allow both images and mechanical & structural properties of small objects to be obtained at microscopic scale.

Members of GREMAN research group have long-term expertise on ultrasonic techniques for applications such as medical diagnostics, including high-frequency imaging (M. LETHIECQ, R. LOU-MOELLER, J.A. KETTERLING, F. LEVASSORT, L.P. TRAN-HUU-HUE, E. FILOUX, R.H. SILVERMAN, W.W. WOLNY, “Non-Planar Pad-Printed Thick-Film Focused High-Frequency Ultrasonic Transducers for Imaging and Therapeutic Applications” in IEEE trans. UFFC 59(9) pp. 1976-1982, 2012). Acoustic microscopy is currently used in fields such as microelectronics and MEMS characterisation as well as medical diagnostics (M. LETHIECQ, M. BERSON, G.

FEUILLARD, F. PATAT. "Principles and applications of high frequency medical imaging." Advances in Acoustic Microscopy, Vol. 2, Chapter 2, pp 39-102, Edited by Andrew Briggs and Walter Arnold, Plenum Press, New-York, (1996)). The laboratory has recently setup a state-of-the-art acoustic microscope with extended functionalities through collaboration with a system manufacturer. Recent work of the group has concerned use of this technique to investigate microelectronic component failures (Modeling and numerical study of the influence of imperfect interface properties on the reflection coefficient for isotropic multilayered structures, Loukkal A., Lematre M., Bavencoffe M., Lethiecq M. In: Ultrasonics (2020)). In the microelectronics industry, multilayer structures, often correspond to electronic devices such as power components or hybrid circuits. These devices must be encapsulated in polymer resins which play a protective role and must allow heat to escape. It is therefore essential to control the quality of the interfaces in order to ensure the reliability and proper functioning of these components. Delamination at interfaces is one of the major problems encountered by this industry. The most common case of delamination occurs between the packaging (epoxy resin) and internal metallic materials. The implementation of non-destructive testing (NDT) methods such as ultrasonic methods, in particular by acoustic microscopy, should allow to better identify and characterize the problems of delamination in this type of component.

To this date, no research has been published on the use of acoustic microscopy to study artefacts from archaeological sites. Ceramic artefacts are a current family of objects that can reveal valuable archaeological information. Indeed, their composition, porosity, rigidity and structural characteristics depend on the type of raw material they are made of, their fabrication technique and their use. Measurement of the acoustical properties at microscopic scale should allow discrimination between different ceramic samples to be facilitated, by offering new data that can be combined with that currently available.

Members of LAT-CITERES research group are leading scientists on ceramic archaeological artefacts (La céramique du haut Moyen Âge dans le Centre-ouest de la France : de la chrono-typologie aux aires culturelles. Directed by Philippe Husi, 49e Supplément à la Revue Archéologique du Centre de la France, FERACF, Tours, 284 pages (2013)). Dr. Philippe Husi is in charge of the Medieval to Modern Ceramic Repository of the ICERAMM network.

Objective and methods

This PhD project aims at using high-frequency ultrasound including acoustic microscopy as a technique to obtain quantitative parameters associated with delamination type problems that occur especially in the packaging of microelectronic components. The other part of the study will consist in obtaining quantitative parameters, such as elastic constants, in ceramic samples from different periods and geographical sites, in order to determine its potential for archaeological studies. Particular attention will be paid to the effect of porosity on acoustic properties. Both classical measurements and imaging as well as the V(z) acoustic signature method will be investigated. Other types of archaeological materials such as metals and glass will also be characterised for comparison and to identify other potential applications.

Required profile

The candidate should be trained in applied physics or engineering and have strong experimental expertise, as well as some modelling capabilities. A Masters level degree that includes courses in electronics/electrical engineering and/or materials science and/or signal processing and/or mechanical engineering is required, ideally in the field of acoustics / ultrasound.

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