Sol-Gel medium characterization using acoustics reverberation methods

Description of the PhD thesis:

This work of thesis will in INSA Centre Val de Loire, in the laboratory of GREMAN. GREMAN, research group on materials, microelectronics, acoustics & nanotechnology, is a joint research laboratory of Tours University and CNRS in partnership with the French alternative energies and atomic energy commission (CEA) and INSA Centre Val de Loire. GREMAN's researches cover all the process from materials to components and systems. This thesis will develop in the team of Acoustics and Piezoelectricity of GREMAN, one of the five technical platforms. The aim of this research group is develop methods and instrumentation for ultrasonic characterization of complex media.

The term “sol gel” was coined in the last 1800s. Contrarily to high-temperature processes, the sol gel technique refers to a low-temperature method using chemical precursors that can produce ceramics and glass with higher purity and better homogeneity. Currently, this process has been used in order to produce a large range of compositions in various forms like fibers, monoliths, composites, powders, porous membranes and organic/inorganic hybrids. The application areas for sol gel-derived products are numerous, such as in electronic, optical, dental, biomedical, food processing, cosmetic, ext... Recent research trends have indeed focused on the monitoring of elastic properties (Young’s modulus, shear modulus) of sol gel products.

In situ and non-destructive monitoring of the state of a material during its transformation (phase change) is an important challenge for the companies, especially in food (like cheese and milk fabrication) or cosmetic industries. The use of ultrasound as an analytical technique for providing information about the physicochemical properties is becoming increasingly popular in these domains. Ultrasound can be used to rapidly and nondestructively measure properties such as product composition, structure and physical state. It can be also used for continuous monitoring of product properties on-line during processing.

Classical techniques used in acoustic emission based on the study of the velocity and the attenuation of only the first received wave packets are commonly used to determine the phase change time and the viscosity of a local studied medium [1]. In this context, we propose a complementary technique based on the study of the reverberant acoustic waves in order to estimate the viscosity and the phase change time of global structure of studied medium.

Though acoustic waves in a diffuse regime are classically used in room acoustics for room characterization such as the absorption of the wall and the sound quality [2, 3], they are not so commonly used in non-destructive testing or structural monitoring. Yet, multipath propagation in a medium with low acoustic attenuation could offer potentially useful information about the structural properties of this medium using only a few sensors. In previous works, this theory has been applied in the characterization of solid plates (1D and 2D problems) [4, 5, 6, 7] and fluids (3D). In a second phase, the laboratory has tested this method in more complex medium in order to estimate the adhesion level between two layers [8].

The goal of this Phd Thesis is the characterization of sol gel transition using the reverberation method. For that, an adaptation of existing analytical models has to be done by the future student in order to predict the reverberation time for a 2-layered medium. This model will be verified using numerical methods and experiments.

Then, the variation of the reverberation time during the sol gel transition will be studied. This variation is due to several parameters (wave velocity, acoustic impedance, and interface transmission) induced by physicochemical reactions. Using inverse problem solving, this variation allows acoustical parameters of the gelification medium to be retrieved, such as density, mechanical constants and attenuation. These parameters are then linked to sol gel transition, such as percolation or gelification time.

Candidates should have a Master's degree in Acoustics or Physics. Candidates must have good skills in modeling and numerical simulation, as well as a strong taste for experiment. Signal processing skills is appreciated.

Contacts:
Louis Pascal Tran Huu Hue: pascal.tran@insa-cvl.fr
Julien Bustillo: julien.bustillo@insa-cvl.fr
Hossep Achdjian: hossep.achdjian@insa-cvl.fr

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