In situ ultrasonic characterization of photocatalytic thin films

Supervisors:

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Description of the GREMAN Laboratory:

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 research topics cover all the process from materials to components and systems.

Research topics are focused on five main themes:

• Functional oxides for energy efficiency: combinatory synthesis and nanostructuration.
• Magnetic & optical properties of ferroic and electronic correlation materials.
• Innovative materials and components for power and RF microelectronics: wide bandgap & porous SCs and their applications.
• Piezoelectric & capacitive micro & nano systems for ultrasound transducers and energy conversion.
• Methods and instrumentation for ultrasonic characterization of complex media.

This PhD Thesis will take place at the INSA Centre Val de Loire platform, dedicated to “Piezoelectric & capacitive micro & nano systems for ultrasound transducers and energy conversion” and to “Methods and instrumentation for ultrasonic characterization of complex media”.

Description of the PhD thesis:

SAW sensors are now widely used for the detection of chemical vapors. These systems use a thin film which is highly sensitive to the environment and cause a variation on the mass or on the apparent length of the acoustic wave [1], [2]. More precisely, studies have been conducted by L. Blanc to monitor photocatalytic degradation of pollutants using thin porous
TiO2 films [3], [4]. Frequency shift during the reaction has been measured allowing parameters such as reaction kinetics to be determined.

Yet the frequency shift directly depends on the variation of wave celerity and on the pathway length. By assuming that the pathway is invariant, only wave celerity is studied. This variation depends on two phenomena causing a negative, for the “mass effect”, and a positive effect, for the “stiffening effect” [5]:

\[
\frac{\Delta v}{v_0} = \left( -Cm_1 \rho + Cm_2 \left( \frac{\lambda + \mu}{\lambda + 2\mu} \right) \mu \right) f_0 h,
\]

where \( \rho, h, \lambda \) and \( \mu \) are respectively the density, the thickness and the Lamé coefficients of the layer. \( Cm_1 \) and \( Cm_2 \) are parameters depending on the substrate used for the SAW device. In case of pollutants adsorption and desorption, both effects occurs and cannot be discriminated using frequency shift measurements.

Measurement of the density and the Lamé parameters using an ultrasonic spectroscopy method allows to understand more precisely the phenomena observed by a SAW sensor during the photocatalytic degradation.

The main goal of this thesis project is the determination of the film parameters in real time during the SAW measurement to correct the stiffening effect.

![Figure 1: frequency shift observed during the photocatalytic degradation of stearic acid.](image)

In the first phase, an analytical model has to be developed and implemented to determine the density and the Lamé parameters of the thin film using the ultrasonic spectroscopy. This
model has to take account to the porous behavior of the thin film [6], [7]. This model needs to be validated on experiments giving decoupled “mass effect” and “stiffening effect”.

The second phase of this thesis will be the in-situ monitoring of the photocatalytic degradation on a SAW device. The determination of both stiffening and mass effect will be compared to frequency shift measured during the adsorption and desorption.

Finally these results will be used to optimize the thin film parameters, such as porosity, thickness and formulation, in order to enhance the SAW sensor sensitivity for photocatalysis monitoring.

Candidates should have a Master’s degree in Acoustics or Physics. Only candidates with good grades from bachelor and master studies will be considered. Candidates must have good skills in modeling and numerical simulation, as well as a strong taste for experiment.

References:


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