Surface Acoustic Wave Sensors for Fine Particle Detection Air Quality Monitoring

Lyes Djoumi
and Virginie Blondeau-Patissier
and Meddy Vanotti
Département Temps-Fréquence
FEMTO-ST
Besançon, France
e-mail: lyes.djoumi@femto-st.fr
e-mail: virginie.blondeau@femto-st.fr
e-mail: meddy.vanotti@femto-st.fr

Etienne Quivet
and Daphne Buiron
Laboratoire de Chimie de l'Environement
Université Aix-Marseille
Marseille, France
e-mail: etienne.quivet@univ-amu.fr
e-mail: daphne.buiron@univ-amu.fr

***Abstract*—Surface acoustic wave (SAW) sensors consisting of delay lines built on Quartz are used for fine particle detection. Sensors based on either Rayleigh or Love waves using different guiding layers such as silica and resin were tested. A comparison of these different sensors capabilities has been achieved. Our SAW sensors proved to be able to detect PM10 and PM2.5 particles in the $0-100$ $\mu g/m^3$ concentration range. The influence of the guiding layer thickness on the Love wave sensors sensitivity was also investigated.**

Keywords–SAW sensors; Love wave; fine particles; air quality.

I. INTRODUCTION

According to the World Health Organization (WHO), air pollution is responsible for approximately two million premature deaths per year. Therefore, it is of great importance to be able to precisely measure particle concentration in the air so that proper actions could be taken in order to reduce it. Particles smaller than 10 microns and 2.5 microns in diameter, respectively PM10 and PM2.5, are a major cause of health issues since they are likely to deeply penetrate the human lungs. Instruments currently used to measure micro particle concentration are both large and expensive. Using micro-acoustic devices for that purpose offers many possibilities in terms of cost and size. They also tend to be very sensitive as they are used for gas detection applications [1], [2]. They could also be potentially wireless [3]. The SAW sensors designed for this work are based on delay lines built on quartz (AT cut). They consist of 200 nm thick aluminum interdigited electrodes (IDTs), (cf Figure 1). The wavelength is $\lambda = 40$ μm. Since $c = f.\lambda$, the resulted frequency for Rayleigh type waves is $f = 78.5$ MHz as the wave velocity is approximately $c = 3100$ $m.s^{-1}$. On the other hand, the Love wave, which is faster $c = 5000$ $m.s^{-1}$, operates at higher frequency $f = 125$ MHz.

In this paper, the experiment setup in which the SAW sensors were tested is first described in section II. In section III, the results of these different experiements are reported and discussed before finishing with a short conclusion and a brief perspective on our ongoing works.

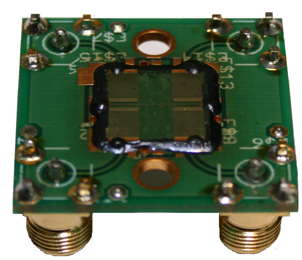

Figure 1. Surface Acoustic Wave sensor

II. EXPERIMENTS

SAW sensors were exposed to PM2.5 particles within a VCE1000 room in which particles concentration is monitored using an Optical Particle Counter (Grimm OPC). PM10 and PM2.5 micro particles are generated from a burning candle. Particle concentration, which varies in the $0-100$ $\mu g/m^3$ range, is measured simultaneously by the OPC. The particles adsorbed on the sensitive zone induce a gravimetric effect that slows the acoustic wave down. The wave velocity decrease results in a phase shift at a constant frequency (125 MHz for Love waves and 78.5 MHz for Rayleigh waves). This phases shift is continuously monitored using dedicated electronics [4] . It is then compared with the particle concentration in the room measured with the OPC. The particles are injected the first time resulting in an increase of the concentration; the injection is stopped when the concentration reaches approximately 100 $\mu g/m^3$. As soon as the injection is stopped, particle concentration drops down. The cycle is repeated a second time during the experiment.

III. RESULTS

A. *Love Wave Devices*

Love waves are horizontally polarized surface waves. For the Love wave to appear, it requires a guiding layer that has a lower acoustic velocity than that of the quartz substrate. Love wave based sensors using different guiding layers were tested in this work.

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1) Resin guiding layer: As shown in Figure 2, sensors using 1.8 μm thick photosensitive resin as a guiding layer responded by a phase decrease as soon as the particle concentration increased. The phase decrease is due to particle adsorption onto the sensor's surface. Conversely, the particles desorbed from the surface when particle concentration dropped down inducing the phase to increase. These sensors demonstrated a quick response and a sensitivity of 11.5 $m°.\mu g^{-1}.m^3$.

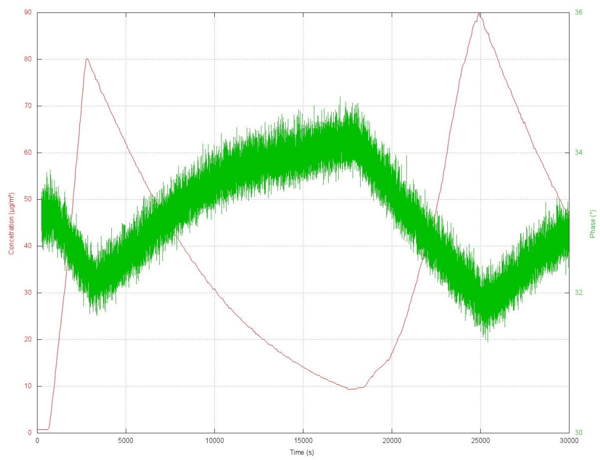

Figure 2. Phase response (green curve) with particle concentration variation (red curve) for a Love wave sensor with a photo-resistive resin guiding layer.

2) Silica guiding Layer: As it is shown in Figure 3, sensors using silica as a guiding layer also showed a quick response and exhibited a much higher sensitivity compared to the resin based sensors. It was approximately 50.9 $m°.\mu g^{-1}.m^3$. Different silica layer thicknesses from 700 nm to 1.8 μm presented a similar behaviour.

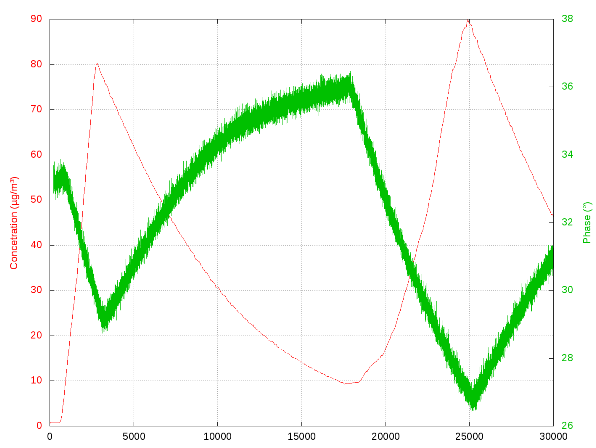

Figure 3. Phase response (green curve) with particle concentration variation (red curve) for a Love wave sensor with a 1.8 μm silica guiding layer.

B. Rayleigh Wave Devices

In constrast to Love wave based sensors, Figure 4 shows that Rayleigh wave sensors did not respond at all to the particles. Indeed, the phase was almost constant during the two particle injection cycles. This type of devices should therefore not be used for this type of applications.

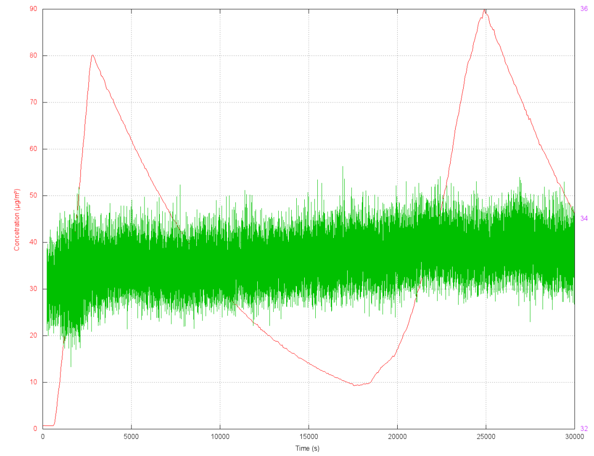

Figure 4. Phase response (green curve) with particle concentration variation (red curve) for a Rayleigh wave sensor.

IV. Conclusion

In this work, we demonstrated the potential of using surface acoustic wave sensors for fine particle detection in the $0 - 100$ $\mu g/m^3$ concentration range. In particular, Love wave based sensors proved to be very sensitive and quick to respond. However, this type of devices are not able to distinguish particles by size. In particular PM10 and PM2.5 particles, which represent the biggest threat to health, would induce the same response at equal mass. The SAW sensors therefore require the use of a filtering system beforehand. The design of a such filtering system and integrating it with the SAW sensors is the focus of our current research work. An operating prototype has been finalized and will soon be published.

Acknowledgment

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