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Tattooed surface acoustic wave sensors for wireless, passive and imperceptible "e-skin" applications

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In our modern society, the need for continuous knowledge of the human body's parameters is a growing trend. From potentially life-saving healthcare applications to more casual cosmetics, wellness/sport use, connected objects that monitor body parameters are part of a multibillion dollar - and growing - market. In particular, the silver economy - i.e. the economy of elderly people - monitoring is a target.

Yet, the need for possibly uncomfortable wires, bracelets or sometimes belts prevents the end-users from long-term continuous use of such monitoring objects. In this context, a new field has emerged: "epidermal electronics" [1] i.e. a new class of electronics, with devices that are tattooed on the skin in a seamless way, and that can stretch, bent, twist or conform to any shape. Yet, epidermal electronics still suffers a few limitations: it often requires the use of inconvenient electrodes to measure different parameters (temperature, strain, EEG, EMG), and on the other hand the implementation of batteries and RF radios to make active transceivers in this format is extremely challenging.

In this context, Surface Acoustic Wave (SAW) devices are particularly relevant. The resonance frequency (if resonators are used) and the signal transmission delay of SAW devices (if reflective relay lines are used) can be very sensitive to the physical parameters of the environment, SAW devices are increasingly used as sensors for a large variety of parameters: gas, pressure, force, temperature, strain, radiation, magnetic field. The SAW-based sensors present the advantage to be fully passive (battery-less) and can be interrogated using wireless techniques.

The goal of an ongoing project at IJL is to develop a new generation of imperceptible wireless on-skin stretchable surface acoustic wave sensors. This talk will focus on various routes to yield this new class of sensors with emphasis on:

- Packageless WLAW (Waveguiding Layer Acoustic wave) sensors and the route to ultrathin devices.
- Stretchable on-skin antennas using advanced stretchable electronics micro-fabrication.
- Applications to temperature [2] and magnetic field [3] sensors. Wireless sensors measurements.

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[2] C. Floer, S. Hage-Ali, S. Zhgoon, M. Moutaouekkil, F. Bartoli, H. Mishra, S. Mc Murtry, P. Pigeat, T. Aubert, O. Bou Matar, A. Talbi, and O. Elmazria, "AlN/ZnO/LiNbO3 packageless structure as a low-profile sensor for on-body applications", submitted to IEEE Transactions On UFFC

[3] V. Polewczyk, K. Dumesnil, D. Lacour, M. Moutaouekkil, H. Mjahed, N. Tiercelin, S. Petit Watelot, H. Mishra, Y. Dusch, S. Hage-Ali, O. Elmazria, F. Montaigne, A. Talbi, Olivier Bou Matar, M. Hehn, "High field unipolar and bipolar magnetic field sensors based on Surface Acoustic Wave resonators", Phys. Rev. Applied, vol. 8, pp.024001, 2017

Sami Hage-Ali was born in Strasbourg, France, in 1982. He received an Engineering Degree from Ecole Centrale de Lille and a M.S in micro-nanotechnology from University of Lille 1 in 2005. He received another Master's Degree in international projects engineering from University of Lille 1 in 2006. He received a Ph.D. in micro-nanotechnology acoustics and telecommunications in 2011. In 2011, Dr Hage-Ali was awarded a Fulbright grant and became a post-doctoral fellow in John Rogers' group at University of Illinois at Urbana-Champaign, USA. Since 2014, he is an Associate professor at University of Lorraine and is with the Micro-nanosystems group of Institut Jean Lamour, Nancy. Dr Hage-Ali's areas of research are: flexible/stretchable electronics, micro-nanosystems, microwaves and antennas, surface acoustic wave sensors. He is currently serving as chairman of the IEEE France Section Sensors Council Chapter.