Wearable respiratory belt for human breathing control

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Detection principle of the respiratory belt

The wearable respiratory belt is a system to measure and to monitor human respiration.
While the belt is strapped around the chest, expansion and contraction of the chest during breathing, causes the belt elongation. The elongation in its turn results in inductance and/or resistance change in the conductive yarn. Such changes are detected and processed by the electronic embedded into/on the belt and transmitted to the base station.

Respiratory belt (1)
Electrodes embedded in textile (2)
Smart clothes with the integrated respiratory belt (3)

The respiratory belt features

2 types of respiratory belts have been studied:

- a copper wire yarn (3 copper wires of 112 µm) (named as a copper belt)
- a silver plated polymer core yarn (named as a silver belt)

Electronic circuit:

- 2 inverters
- 2 capacitors to form an oscillating circuit.

The components are assembled on 0.3mm thick PCB of 8mm x 8mm using standard assembly technique.

Assembly process flow

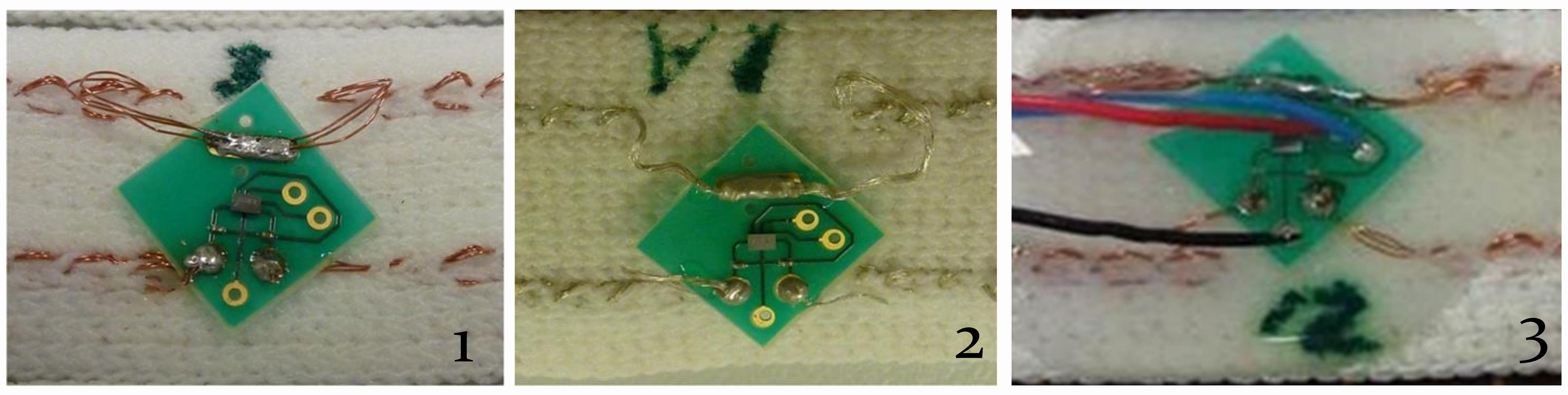
Challenge: To integrate electronic to/on textile

Copper belt
To interconnect the copper yarn belt we used a standard soldering technique realized by a soldering iron. A localized contact with the soldering iron for a very short period of time causes no damage to thermo-sensitive fabrics of the breathing belt.

Silver belt
The standard soldering technique will damage a plastic core of silver plated yarn, that's why we used a conductive silver filled epoxy paste to create the electrical interconnection between the electronic and the breathing belt. The paste was applied by dispensing, followed by low temperature curing (60°C).

Encapsulation

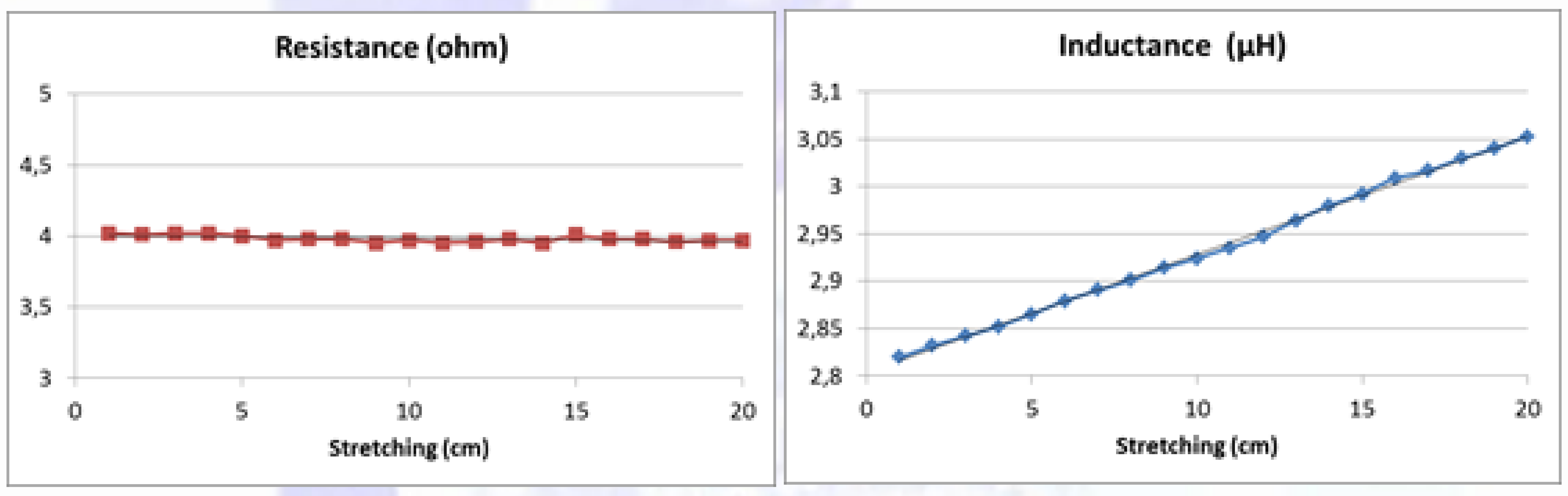
Purpose: to protect electronic from environment (mechanical impact, chemical exposure etc.) and integrate in into/on textile
Method: glob top by biocompatible PDMS from Dow Corning: SILASTIC® MDX4-4210
Curing: 60°C, 8 h, alternative to that RT cure for 24h
Biocompatibility: suitable for skin contact regime as a part of a surface device, and for prolonged contact: 24h to 30 days.



The breathing belt capture: electronic is electrically interconnected to the breathing belt: copper belt (1) and silver belt (2), and the electronic is encapsulated and embedded on breathing belt (3).

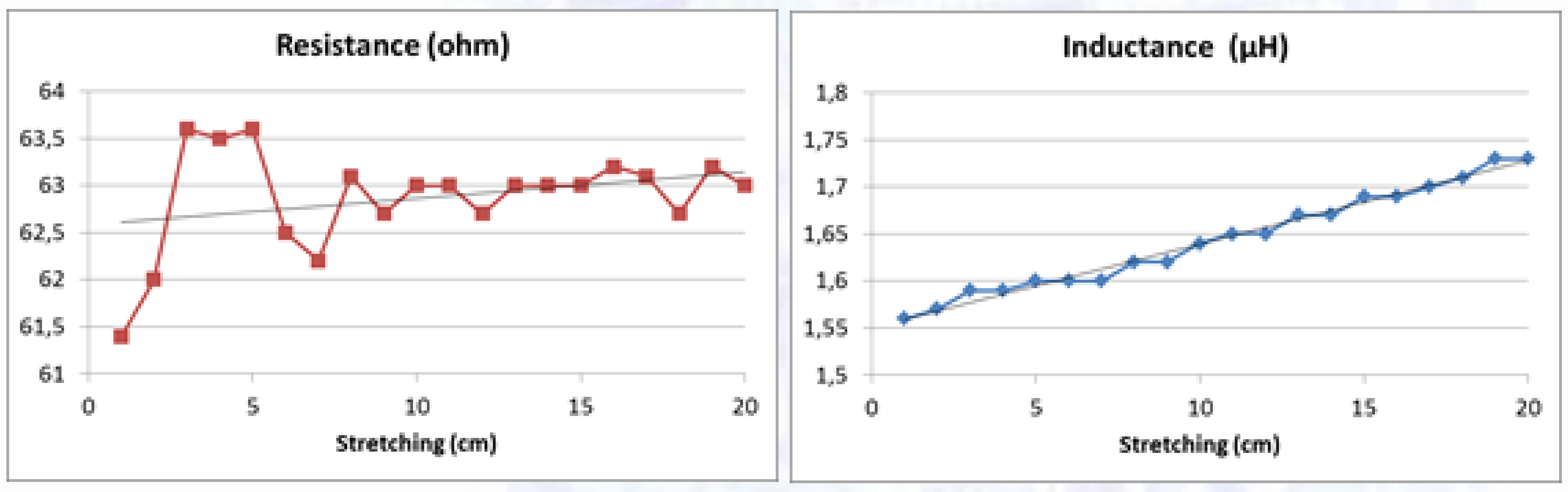
Electrical characterization

Copper yarn belt: typical resistance (left) and inductance (right) (at 2 MHz) versus belt elongation:



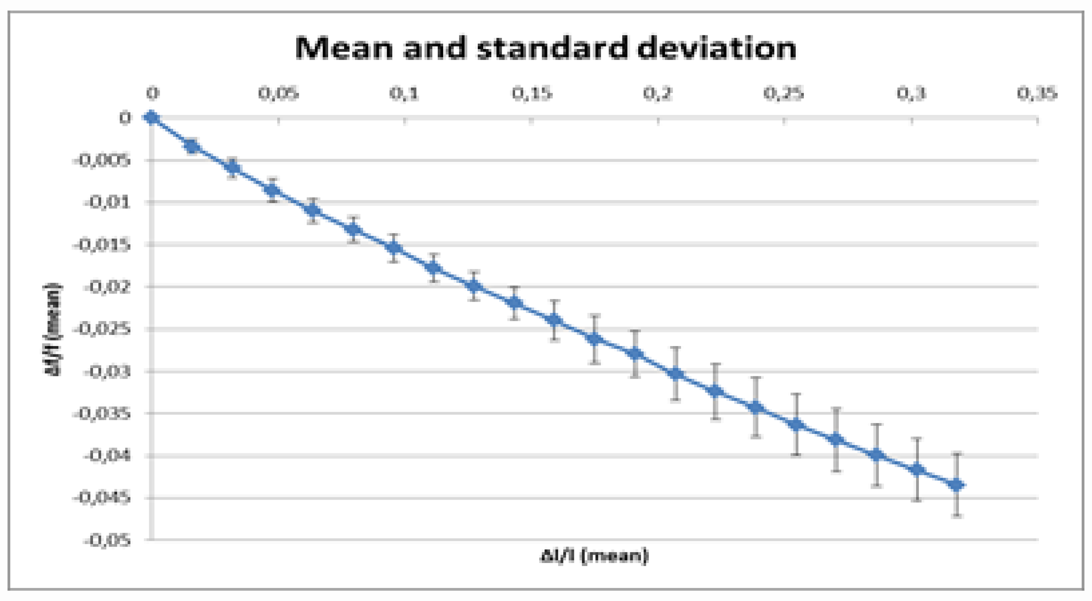
For the copper yarn belts the resistance varies linearly when the belt is stretched (correlation factor is 0.998). This variation is not significant and is in the range of 0.3% to 0.4% of the total value for each centimeter of elongation, but this is sufficient to measure a variation in the oscillator frequency.

Silver yarn belt: typical resistance (left) and inductance (right) (at 2 MHz) versus belt elongation:



For the silver belts the resistance varies irregularly and differs from one belt to another and is 20 times higher as for the copper belts. Because of instability and poor quality factor for the silver belt (Q =1-2), versus copper belt (Q=20-25) the oscillator frequency is too noisy.

Resonance frequency for each copper yarn
The resonance frequency for each copper yarn belt with no elongation is in the range of 4.5 MHz and 4.6MHz. We measured frequency change versus the belt elongation, the result of relative frequency change (mean value and 1 sigma standard deviation) versus relative belt elongation is plotted on the chart (13 samples measured).



In case of the copper belt the elongation in the respiratory belt caused by human respiration results in a resonance frequency change. This change is accurate enough to monitor the human respiration.

Results and Conclusion

We built a working prototype of a wearable respiratory belt using out off-the-shelf electronic components. The prototype proofs the concept that the elongation in the respiratory belt caused by human respiration is accurate enough to monitor a human respiration. The system is intended for remote health monitoring (human respiration).

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