An Ultra-thin, Printed Pressure Sensor for Ventilation Monitoring

N. Glaser, F. Zanella, J. Disser, F. Geister, T. Erb •

A thin, printed pressure sensor is manufactured on a polymeric film and mounted on a tubus for tracheal ventilation monitoring. The prototype developed with the University Children Hospital Basel showcases the potential of a sensor-equipped tube towards lung controlled ventilation to prevent ventilation induced lung damages.

In current ventilation settings, the overpressure for the air volume to be pushed into the lungs is estimated at the respiration machine. Especially for patients with damaged lungs or fragile patients like children, care must be taken to avoid severe damage of the lungs. An actual pressure measurement close to the lung could substantially improve the situation as it would allow for a gentler and more natural intubation. The sensor-equipped tubus will allow for an airway pressure measurement directly in the trachea. Such a system would be a paradigm shift from machine triggered to an actual lung trigged respiration support. A sensor that detects the remaining spontaneous breathing capacity, *e.g.*, of stationary patients, would sustain and gently support natural breathing.

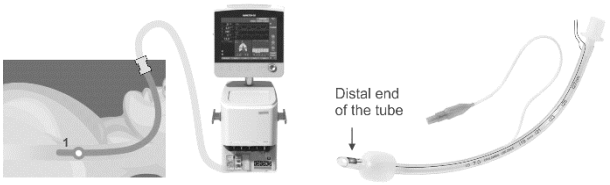

Figure 1: A printed pressure sensor for ventilation monitoring close to the lung at position 1 behind the balloon of the intubation tube.

Here we report the prototype of an ultra-thin, <0.2 mm thick, printed pressure sensor. Electrodes are screenprinted and micro-structured with an elastic dielectric to fabricate a very sensitive, capacitive pressure sensor consisting of a sandwich of two thin foils (Figure 2, patent pending.)

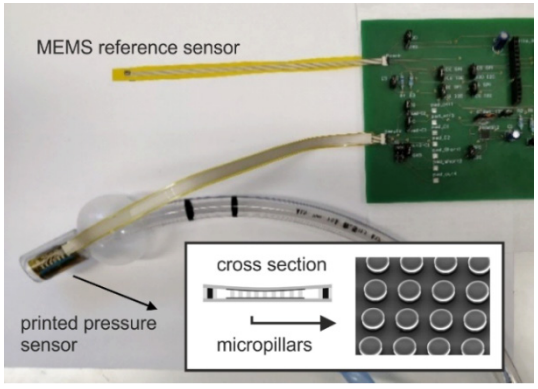

Figure 2: The prototype setup. A reference sensor and the printed sensor are mounted on an intubation tube and then put into a lung model to record different respiration cycles.

A thin layer of PDMS is casted onto the screen-printed electrodes and subsequently imprinted to form micro-domes that deflect under small pressure. A second, thin elastic foil is glued on top to encapsulate the sensing chamber for relative pressure measurements. The long leads to the two electrodes are protected with a printed shielding layer.

The printed sensor is fabricated only with high-throughput compatible technologies, in volume production the costs may range in the single-digit Swiss francs range for this smart add-on.

Even the smallest available of-the-shelf MEMS sensors are too thick to be integrated into a smaller intubation tube as illustrated in Figure 3.

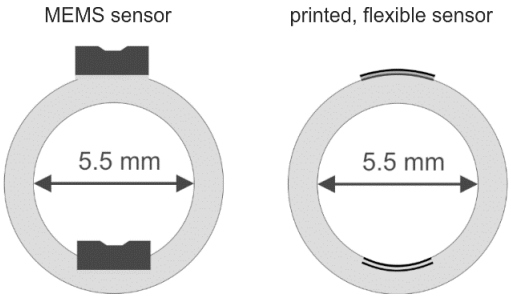

Figure 3: Crosse section of a tube. Integration advantage of a thin, flexible sensor printed on polymer film.

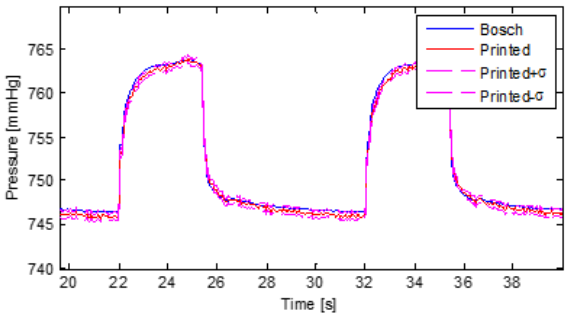

Figure 4: An example of the recorded respiration cycles. Here 1-sigma (deviation) of the pressure sensor is 0.42 mmHg. Recorded at UKBB.

The thin sensor film was successfully integrated on the tip of an endotracheal tubus. Such a sensor may be mounted on the inside or outside of small tubes. We realized a small PCB with a fast-capacitive readout to interface our newly developed sensor. The capacitive signal amplitudes in the range of 0.5 to 2 pF were recorded at a minimum 40 Hz to accurately display respiration cycles as seen in Figure 4. In parallel, the PCB recorded the signal from a Bosch reference pressure sensor which was placed inside the lung model as well. An artificial lung model was used with a plastic tube that modelled the trachea with an inserted sensor-equipped endotracheal tubus. All respiratory cycles could be perfectly recorded with the printed sensor. The amplitude, of the sensor is stable over the full measurement period of 10h.

Characteristic	Results
Dynamic range	-50 to 150 mmHg
Acquisition speed	21-61 Hz
Sensitivity	15-30 fF/mmHg
Resolution	0.4-0.9 mmHg
Footprint	12 x18 mm
Drift	1.2 mmHg/8h
Amplitude stability	<0.1 fF/mmHg/8h

Supported by Innosuisse grant 27100.1 PFLS-LS.

● UKBB, Universitäts-Kinderspital beider Basel