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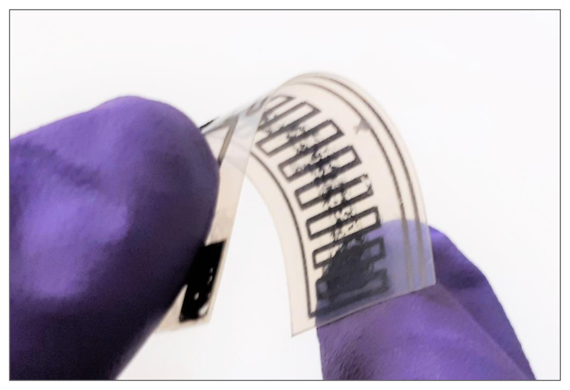

Flexible Temperature Sensors Integrated with Conductive Polyaniline Nanowires for Wearable Applications

Sarah Boucher, Prashanthi Kovur and Carlo Montemagno

Ingenuity Lab, Dept. of Chemical and Materials Engineering, University of Alberta, Edmonton, AB, T6G 2M9, Canada

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INTRODUCTION

- Temperature sensors with improved sensitivity are in great demand for physiological health monitoring
- Flexible printed sensors show potential to improve present patient monitoring options by offering a noninvasive approach ideal for the implementation of remote, real-time healthcare monitoring
- The high surface-to-volume ratio of nanowires may improve sensor response time and sensitivity[1]
- Additionally their low power consumption has the potential to contribute to their applicability to an in-situ, 'on-body' environment
- In previous studies polyaniline (PANi) nanowires have been shown to be effective in gas, chemiresistive and biosensors such as those involved in the detection of pH[2] and glucose[3]
- Resistive temperature sensors (RTDs) function by measuring the influence temperature has on the lattice vibrations of their material. Changes in electrical resistance are measured as the sensor's output

OBJECTIVE

- The purpose of this study is to examine whether integration of PANi nanowires would improve the sensitivity of 2-D printed flexible temperature sensor

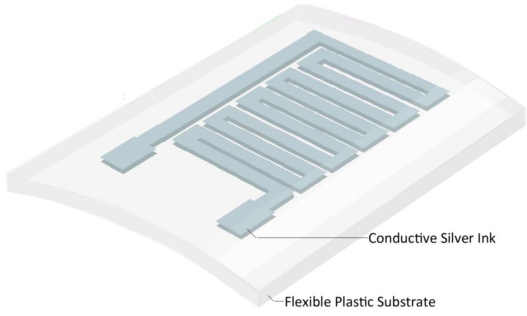

Figure 1: Flexible temperature sensor schematic

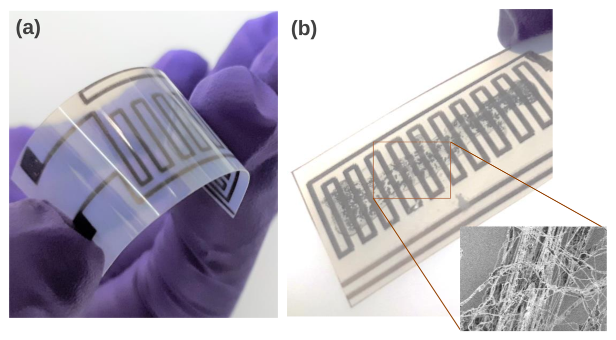

Figure 2: (a) Flexible temperature sensor (b) Temperature sensor modified with PANi nanowires. Inset of Figure 2(b) shows a magnified SEM image of PANi nanowires

METHOD

- The control sensors without nanowires are produced by printing a resistor pattern on flexible polyethylene terephthalate (PET) sheets using conducting silver ink
- The nanowire sensors are produced by depositing a PANi nanowire solution on the surface of the printed sensors. The sensors dry for 24hrs and are then heated to evaporate the remainder of the solution
- A thermoelectric heater is used to control temperature. Changes in the resistance of the sensor are measured using a voltmeter
- The voltage is recorded at room temperature and through a range of 30°C-70°C (0.60A-1.60A heater current range), in both real-time and DC program with a step size of 5 minutes

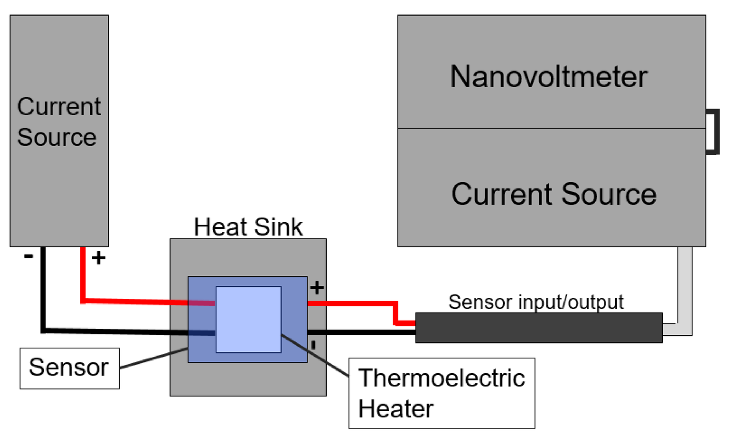

Figure 3: Schematic of the experimental setup used for collecting data from the temperature sensors

RESULTS

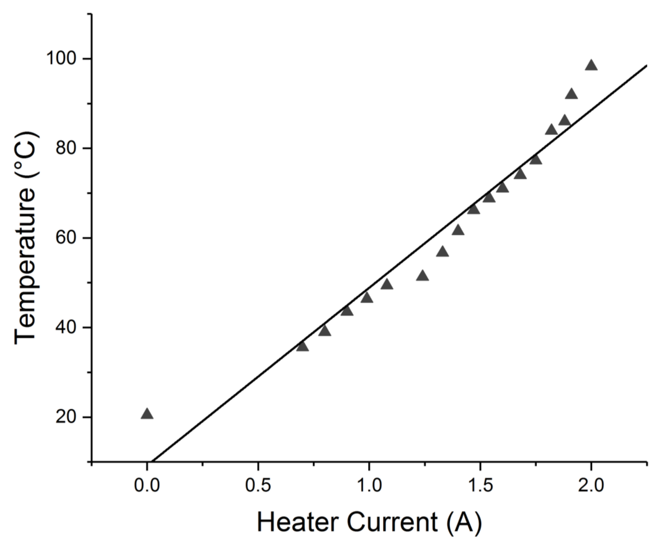

Figure 4: Heater temperature as a function of heater current at increasing temperatures. Heater temperature is measured by a thermocouple.

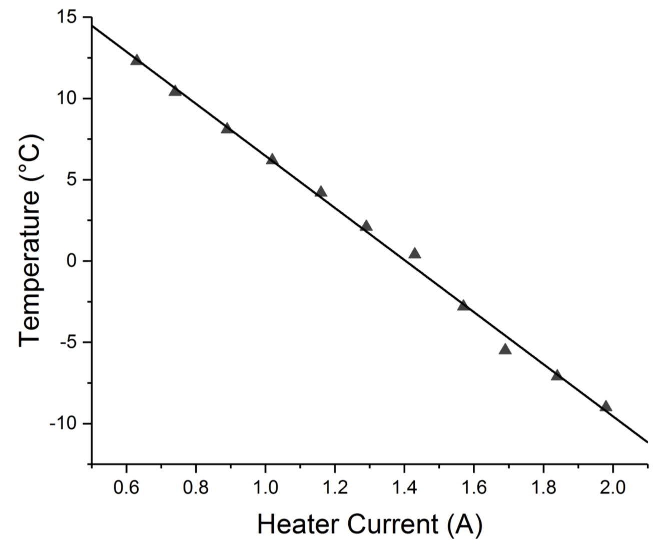

Figure 5: Heater temperature as a function of heater current at low temperatures. Heater temperature is measured by a thermocouple.

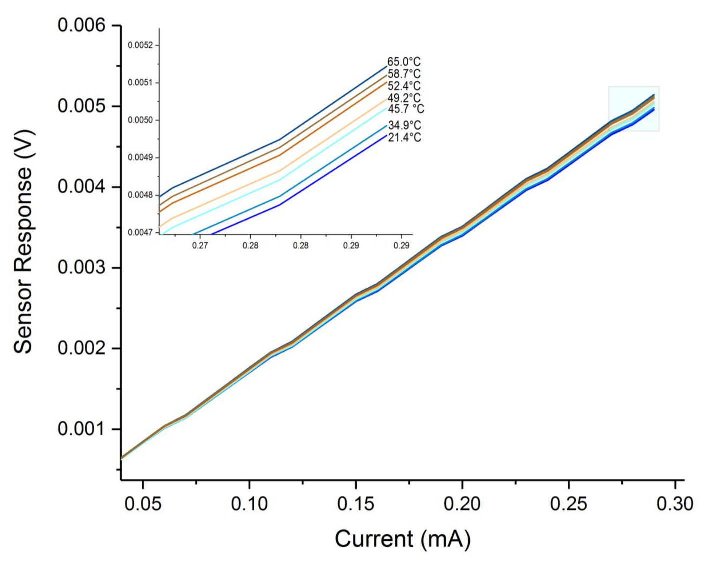

Figure 6: Control Sensor response as a function of current through a heating cycle. An area of the graph is enlarged to show details of the plot.

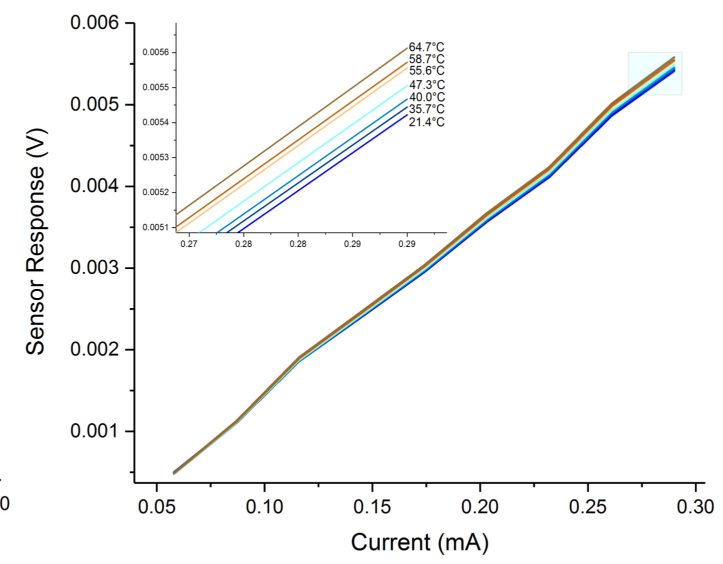

Figure 7: PANi Sensor response as a function of current through a heating cycle. An area of the graph is enlarged to show details of the plot.

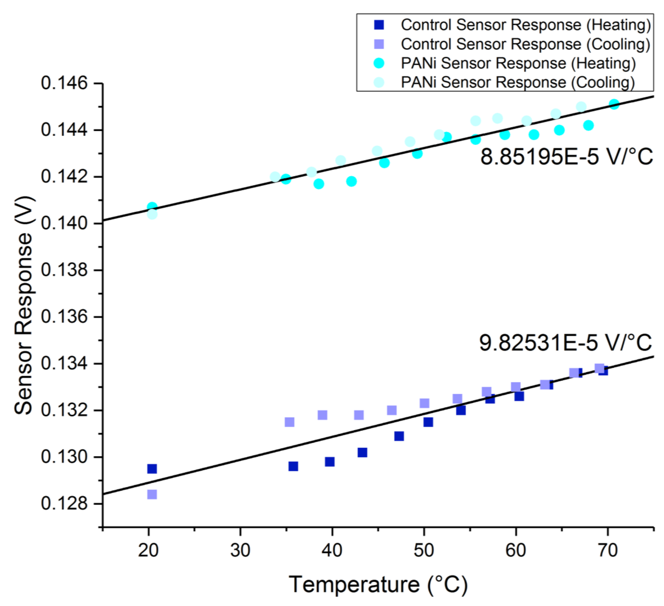

Figure 8: Sensor response as a function of temperature for both the control and PANi sensors with sensitivities through a heating and cooling cycle at 0.29mA.

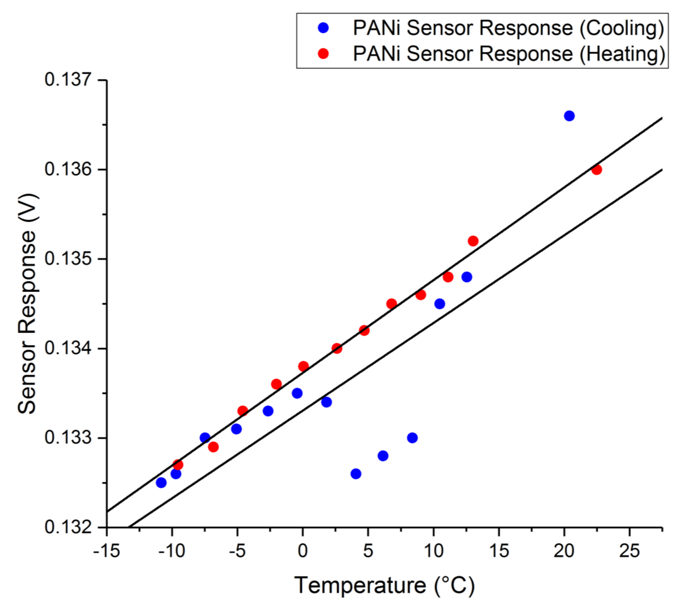

Figure 9: PANi Sensor response as a function of temperature through a low temperature heating and cooling cycle at 0.29mA.

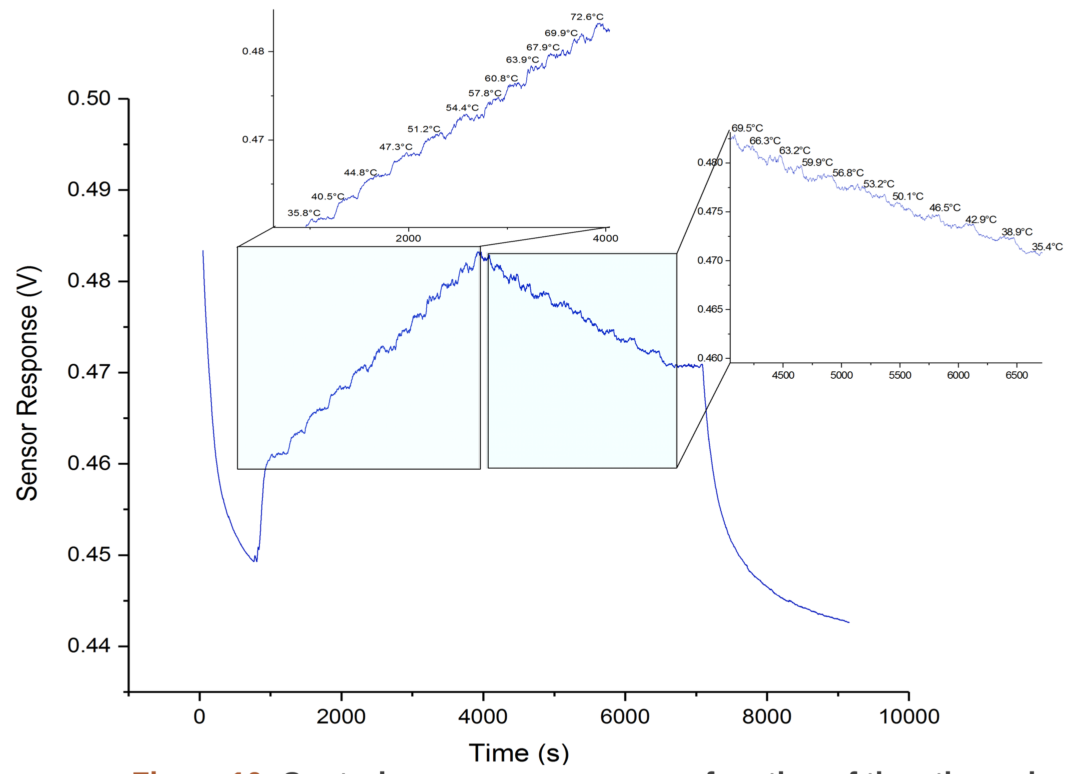

Figure 10: Control sensor response as a function of time through a timed heating and cooling cycle at 1.0mA. Areas of the graph are enlarged to show detail.

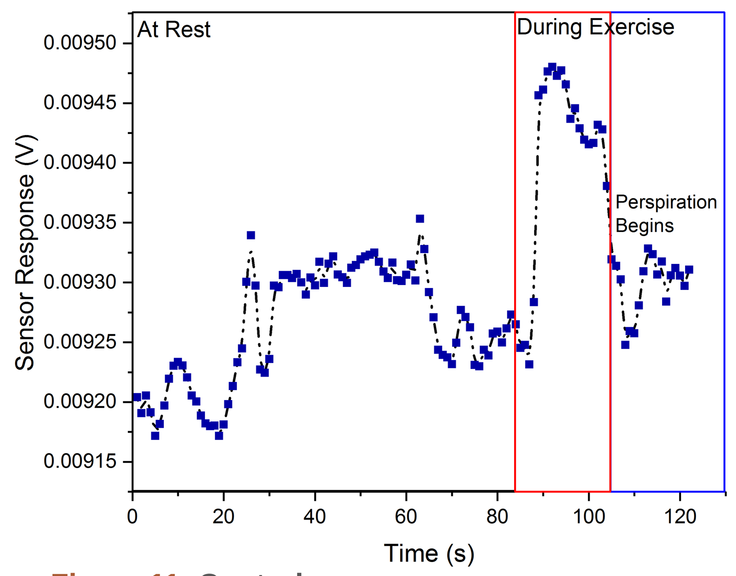

Figure 11: Control sensor response as a function of time during a period of rest, exercise (red) and perspiration (blue). Sensor is attached to the user's wrist.

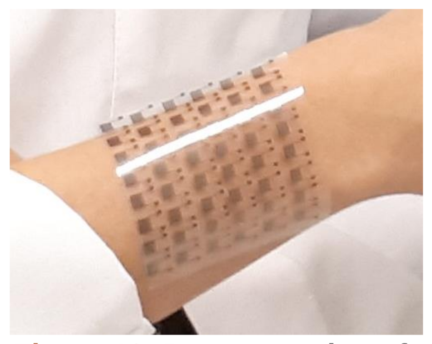

Figure 12: Demonstration of tattoo temperature sensors for wearable applications

CONCLUSIONS

- Results indicate that integration of PANi nanowires reduced hysteresis and demonstrated the ability to function in a low temperature range
- Integration of PANi Nanowires improved response time. The average response time of the control sensor was 0.1729s and the PANi sensor's average response time was 0.0014s
- However, the sensitivity of the sensor did not improve with integration of PANi nanowires. The sensitivity of the control sensor was 9.83E-5 V/°C and the sensitivity of the PANi sensor was 8.85E-5 V/°C
- Aligning the PANi nanowires with a high electric field may improve sensitivity by lowering the sensor's resistance and may produce more consistent results with multiple devices
- Packaging the temperature sensors would potentially isolate them from the ambient air thereby improving signal-to-noise (S/N) ratio

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Ingenuity Lab, 1-070C, 11421 Saskatchewan Drive
Edmonton, Alberta, CANADA T6G 2M9
info@ingenuitylab.ca | ingenuitylab.ca | #ingenuitylab

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