Highly Flexible and Stretchable Sensor using Soft Optical Waveguides

Celeste To, Tess Hellebrekers, and Yong-Lae Park

Department of Mechanical Engineering and Robotics Institute, Carnegie Mellon University

Motivation

As robotic systems start to interact more closely with humans, there is a rising need for more safe sensors. Although liquid metals are popularly used, they are difficult to fabricate with and can be harmful. In this project, we propose an optical soft sensor with a gold waveguide that can detect multiple modes of deformation. This provides the flexibility and safety necessary for interaction with humans.

Theory

Light is guided to the photodiode by the gold layer, which creates total internal reflection. Upon deformation, micro-cracks in the gold allow light to escape the channel, modulating the signal.

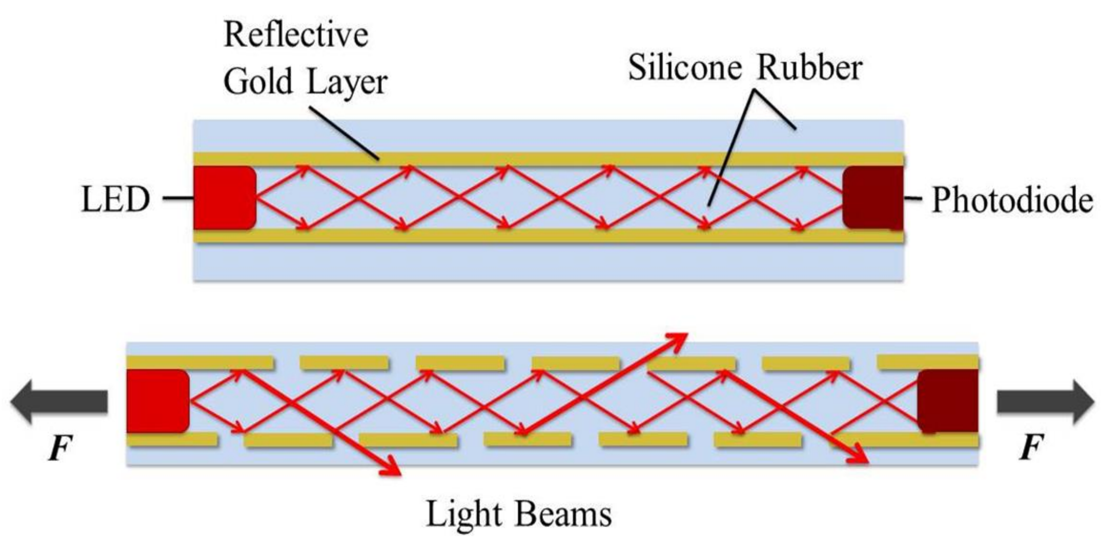

Figure 1. Light intensity modulation in the waveguide

Fabrication

With two cure steps and three molds, each sensor can be fabricated in approximately 5 hours, with 1 hour of work time and 4 hours of wait time.

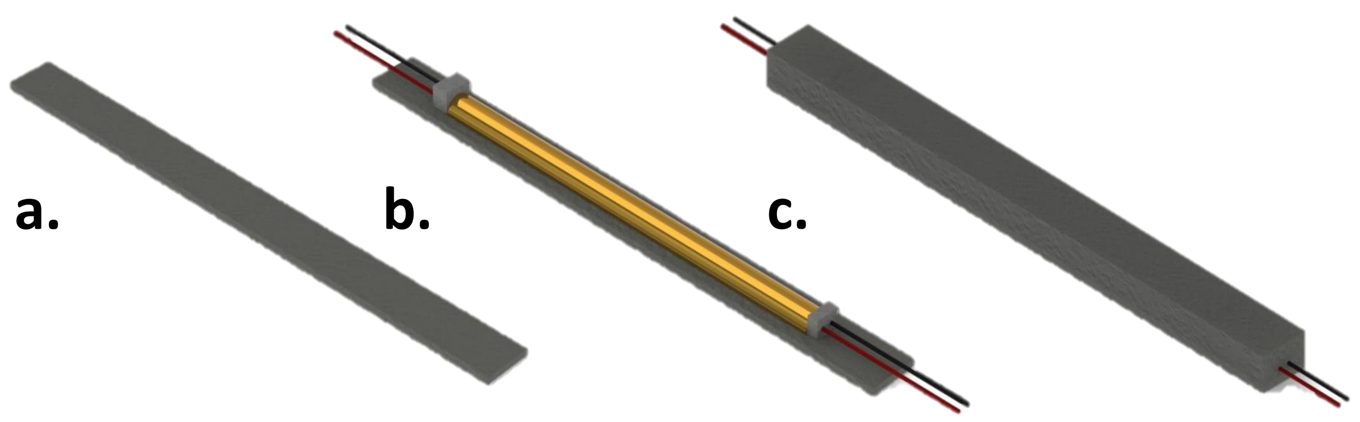

Figure 2. (a) bottom layer (b) adding gold covered waveguide (c) encasing sensor with black silicone

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Results

Final Prototype

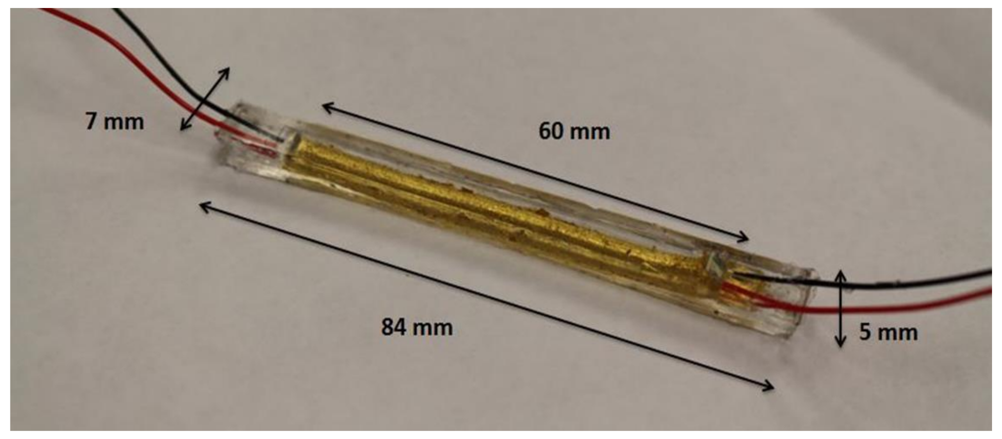


Figure 3. Clear version of the final prototype with visible gold covered channel and dimensions.

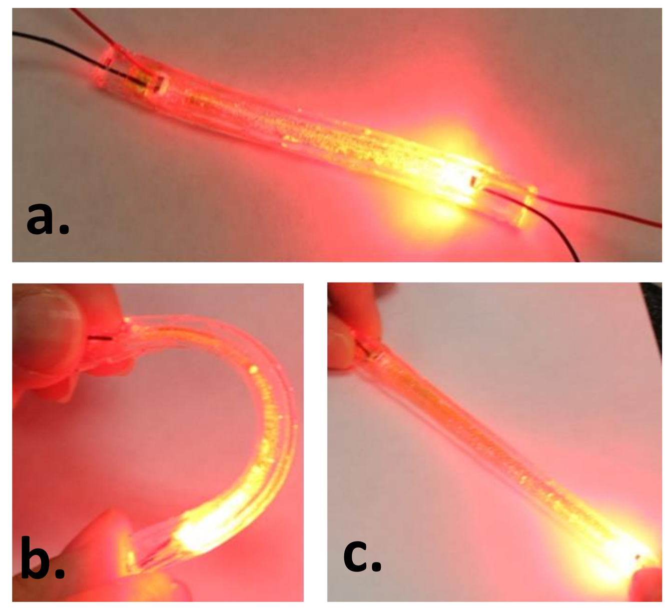
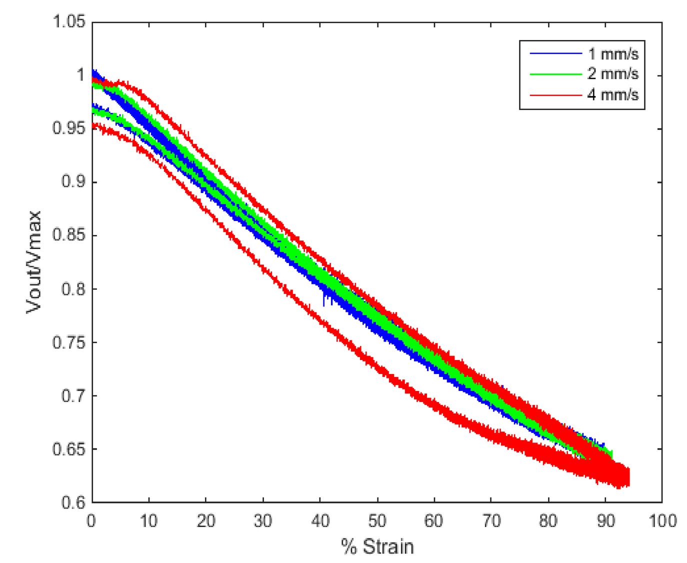
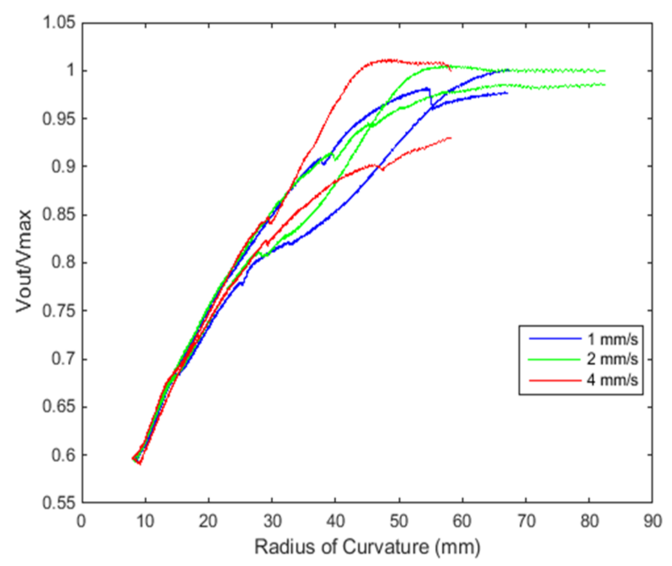


Figure 4. (a) Active sensor with (b) curvature and (c) strain

Characterization of the Sensor

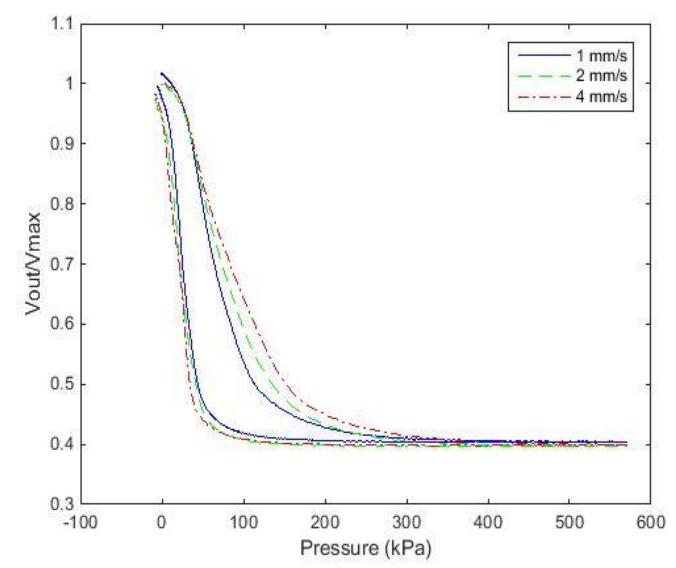
With a standard tensile break strain test, results show the sensor safely extends to 120% strain. Straining one sensor to 80% at three different speeds shows the signal is independent of strain rate.

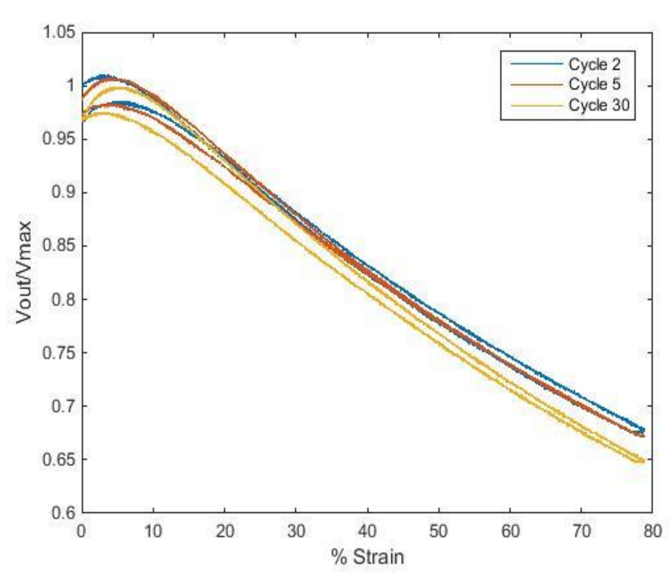




The radius of curvature is the approximation of the bend. As we bend the sensor, the radius of curvature decreases with the signal in a predictable manner.

Pressure tests show a 0-250 kPa working range and a convergence to 0.4. The unloading signals show signs of hysteresis.





The sensor was axially stretched to 80% strain for 30 cycles. The results on the left show the signal is repeatable and the sensor is robust.

Conclusions

A stretchable, soft optical sensor has been designed, tested, and fabricated. The signals for pressure, curvature, and stretch are linear and manufacturing methods are cheaper than traditional liquid metal sensors. With continued optimization, this soft optical sensor has the potential to replace current microfluidic sensors in many applications.

Future Work

Switching to fiber optic components will allow us to put the wiring outside the main body, and reduce the size. In addition, we are embedding multiple waveguides into cylinders to detect bends and twists.

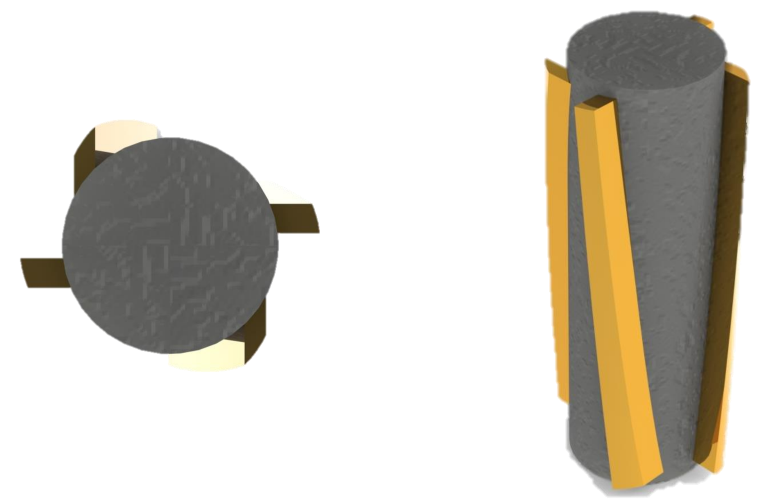


Figure 5. (a) top view and (b) isometric view of multimodal sensor concept

Acknowledgements

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References

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