

Fabrication of Wearable Heart Monitor Using Organic Amplifier Circuit

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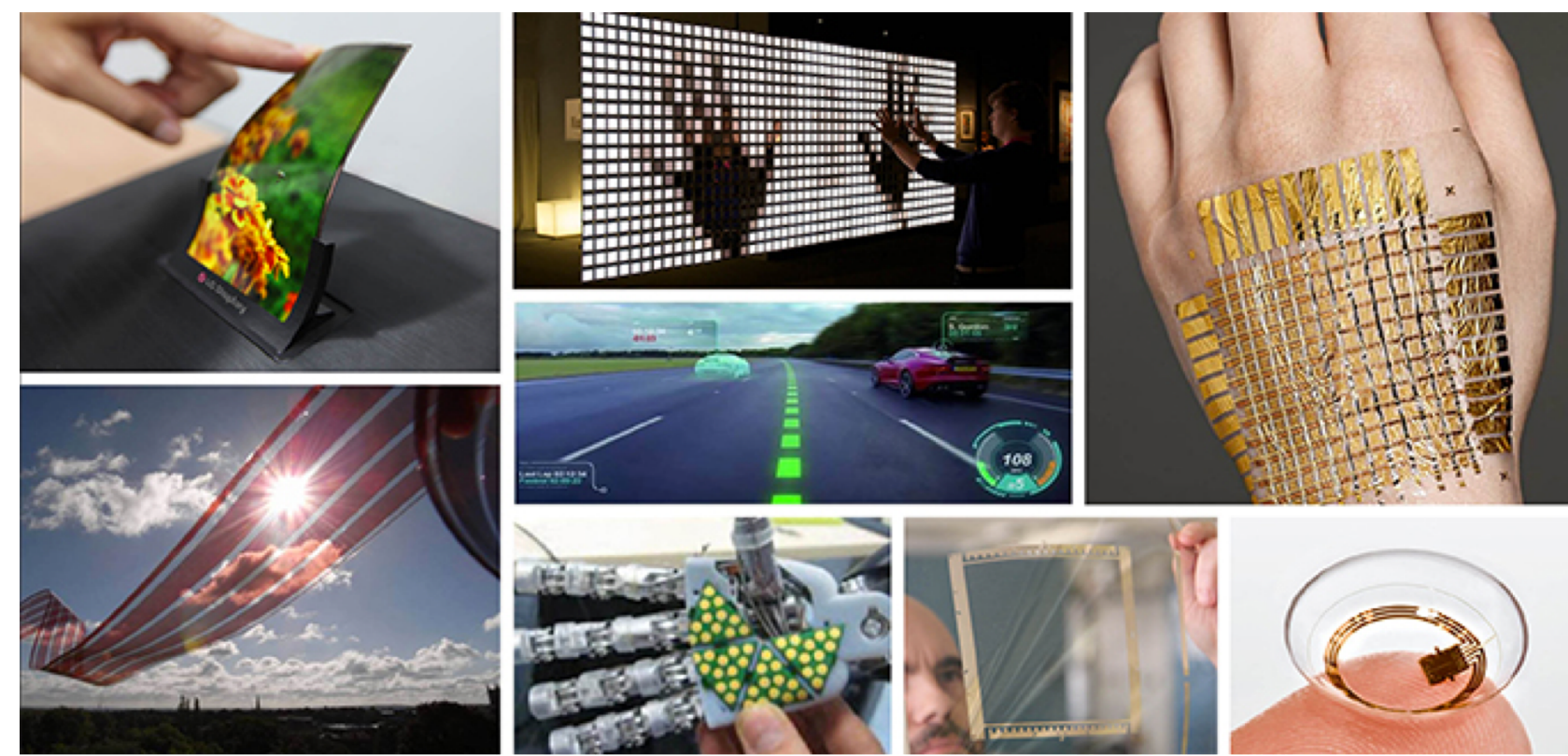
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An aging population has led to a high demand for easy, inexpensive access to healthcare. We demonstrate the functionality of a wearable heart monitor that can benefit this situation. While modern sensors are typically rigid and silicon-based, our device utilizes an aluminum electrode deposited on polyvinylidene fluoride (PVDF) film interfaced with a Pseudo-CMOS amplifier circuit to detect pulse signals. This yields a thin, flexible system that can be worn comfortably on an individual's wrist to monitor for heart failure, heart disease, and safe exercise. The device is interfaced with a wireless module to allow for real time transmission and processing via Bluetooth. The Pseudo-CMOS circuit permits over 10x amplification of pulse signals and minimizes effects from electronic noise. Since the organic materials are soluble, the device can be manufactured inexpensively on large areas via inkjet printing. The large amplification gain and ease of fabrication provide additional applications in the fabrication of monitoring systems, flexible displays, and other biosensors, which allows for the realization of cyber-physical systems on a large scale.

Potential of Wearable Devices

- Internet of Things (IoT): network of cyber-physical devices
 - Increased demand for medical access and health monitoring systems due to aging population
 - Remote heart rate monitoring to identify heart failure, cardiovascular disease, and safe exercise^[1]
- Organic electronics key to developing IoT
 - Printable for large area, inexpensive fabrication
 - Soft material = flexible, stretchable
 - Ideal for use in medical devices^[2]

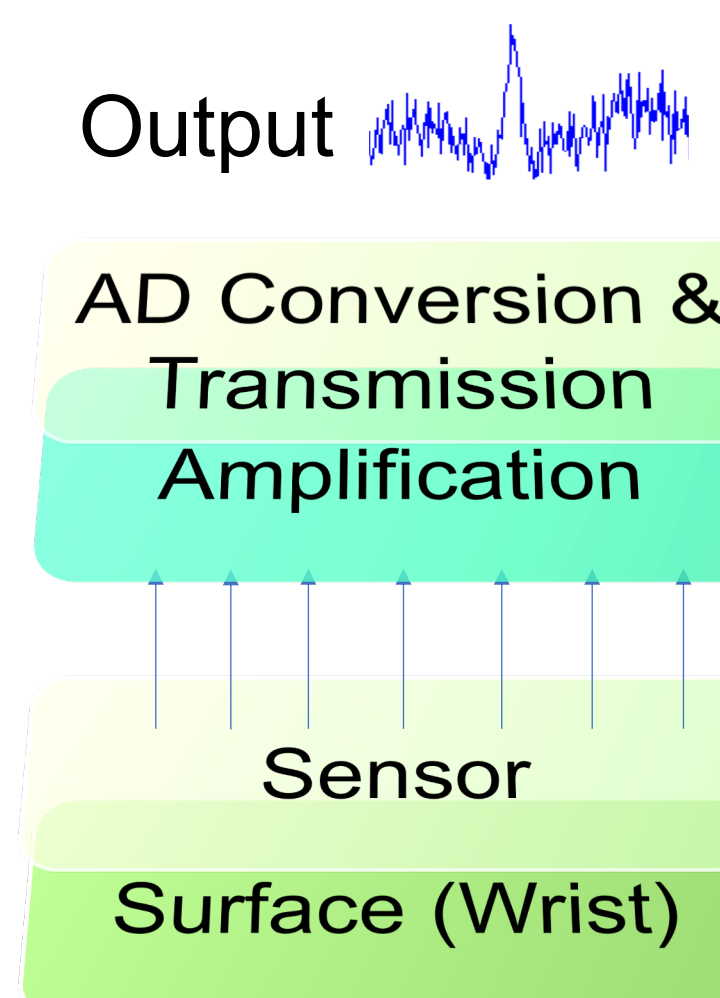


Organic electronics have many applications including flexible displays, monitoring systems, e-skins, and biosensors

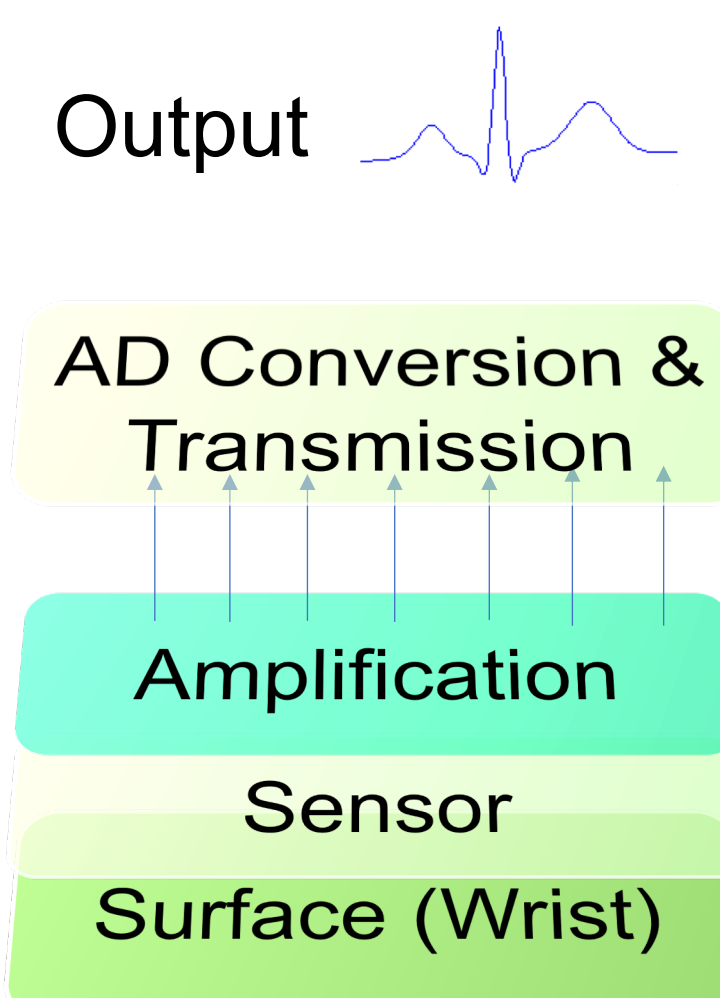
Advantages of Organic Amplifier

- Pseudo-CMOS organic amplifier: amplifies signals before processing
 - Eliminates noise amplification, making biosignals (μV -mV scale) easier to detect

Conventional Devices:



Pseudo-CMOS:



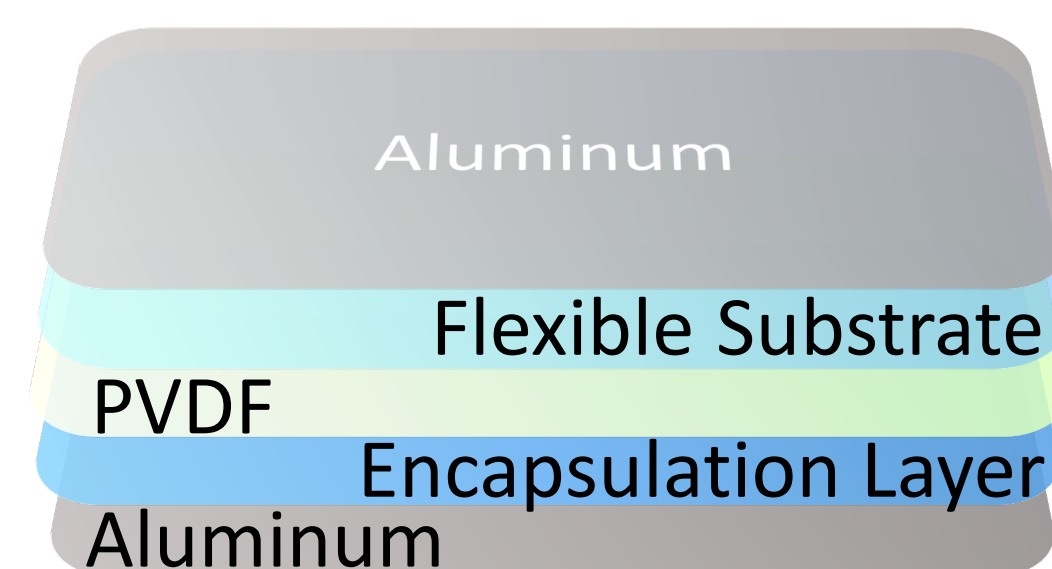
By changing location of amplification, biosignals become less noisy easier to detect

- Easier fabrication, can make adjustments post-manufacture
- Completely flexible device vs. conventional rigid, silicon-based technology^[3]

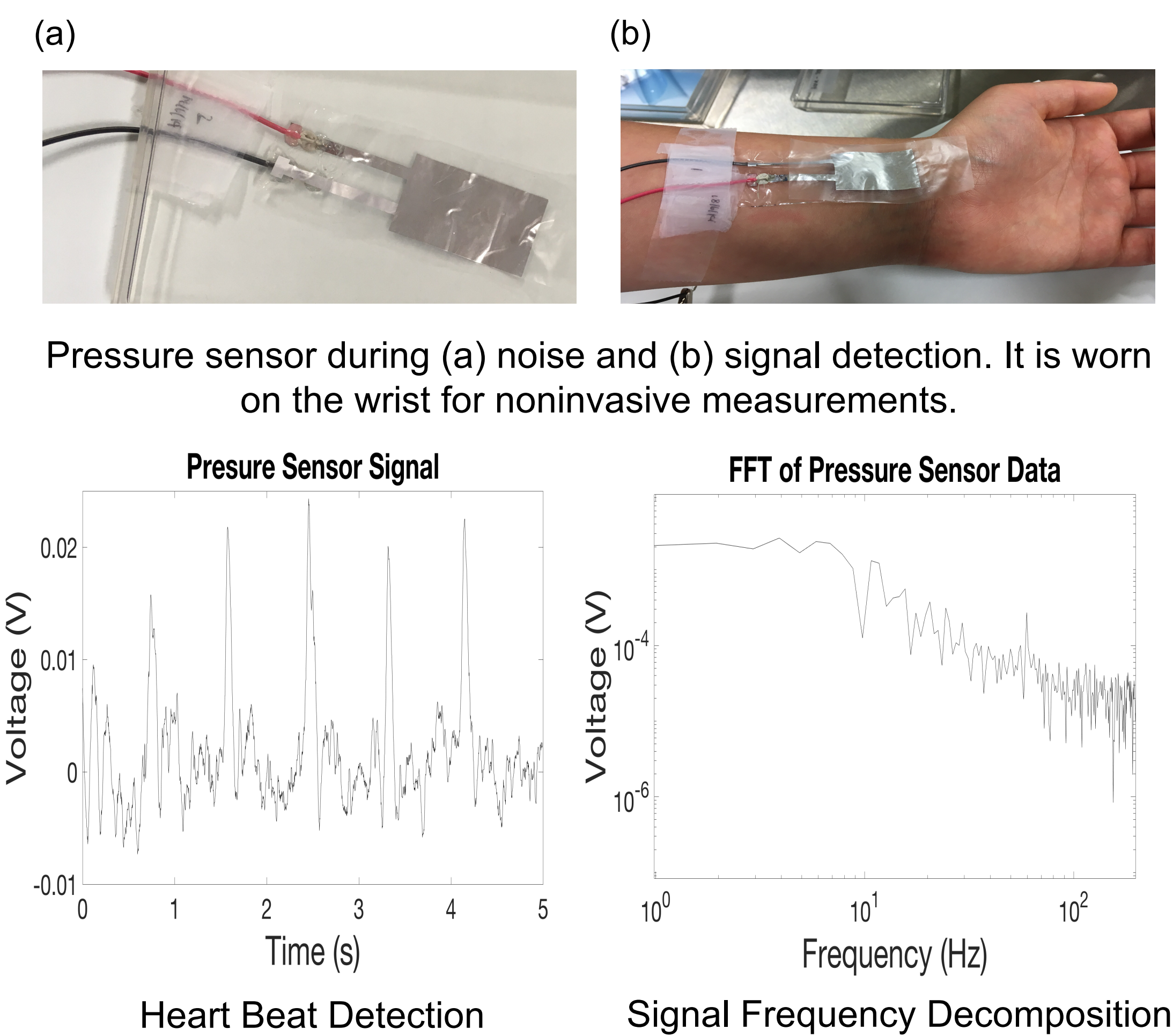
Signal Detection with Pressure Sensor

- Detect pulse with aluminum electrode deposited on piezoelectric film (PVDF)
- Need high signal-to-noise ratio (SNR) to amplify without destroying signal
 - Achieved SNR = 6-10x for sensor area larger than 140 mm x 175 mm
- Signals measured by securing sensor to wrist with external pressure

Pressure Sensor

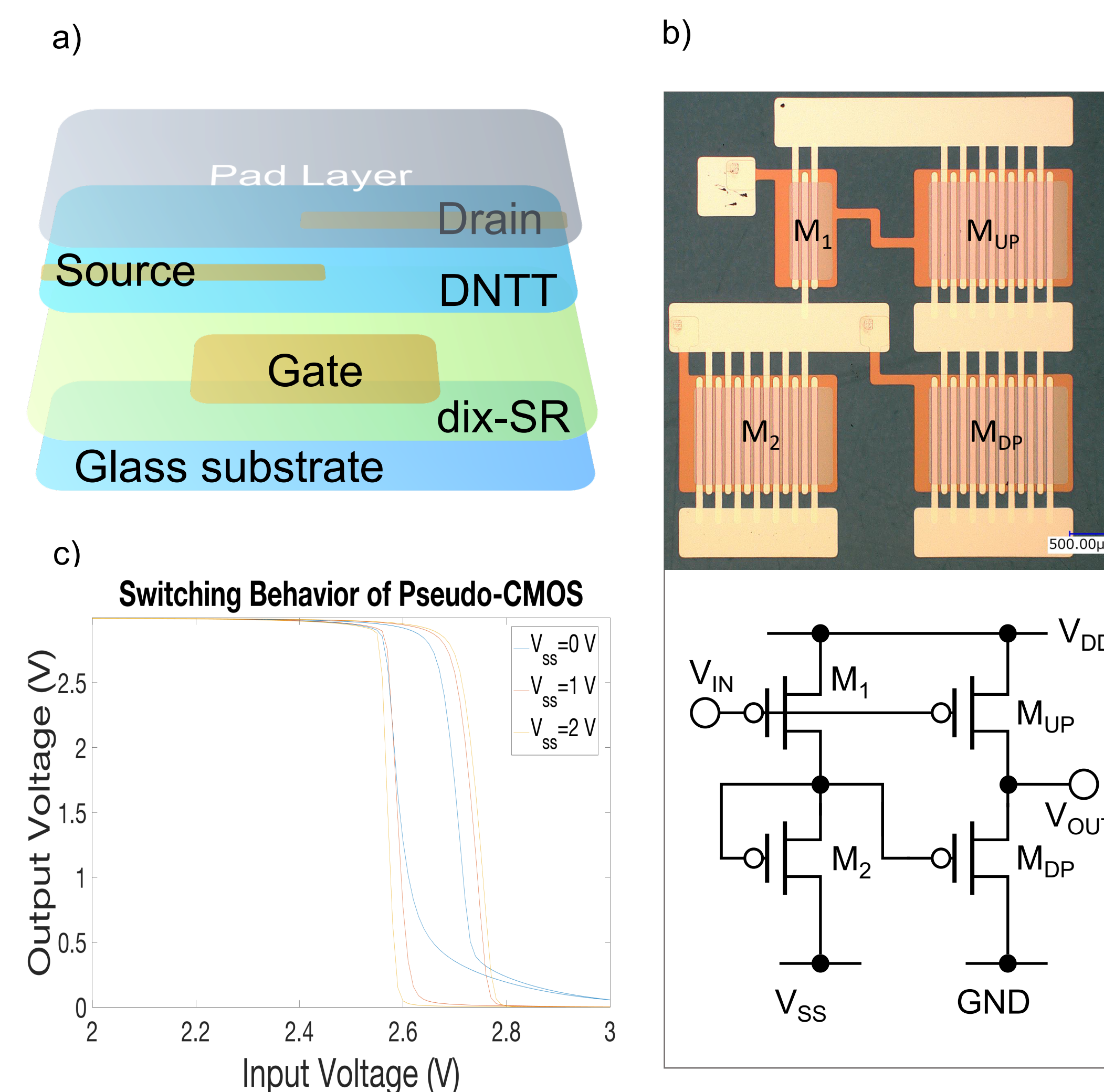


Pressure sensor structure. Aluminum electrode fabricated via vacuum deposition.



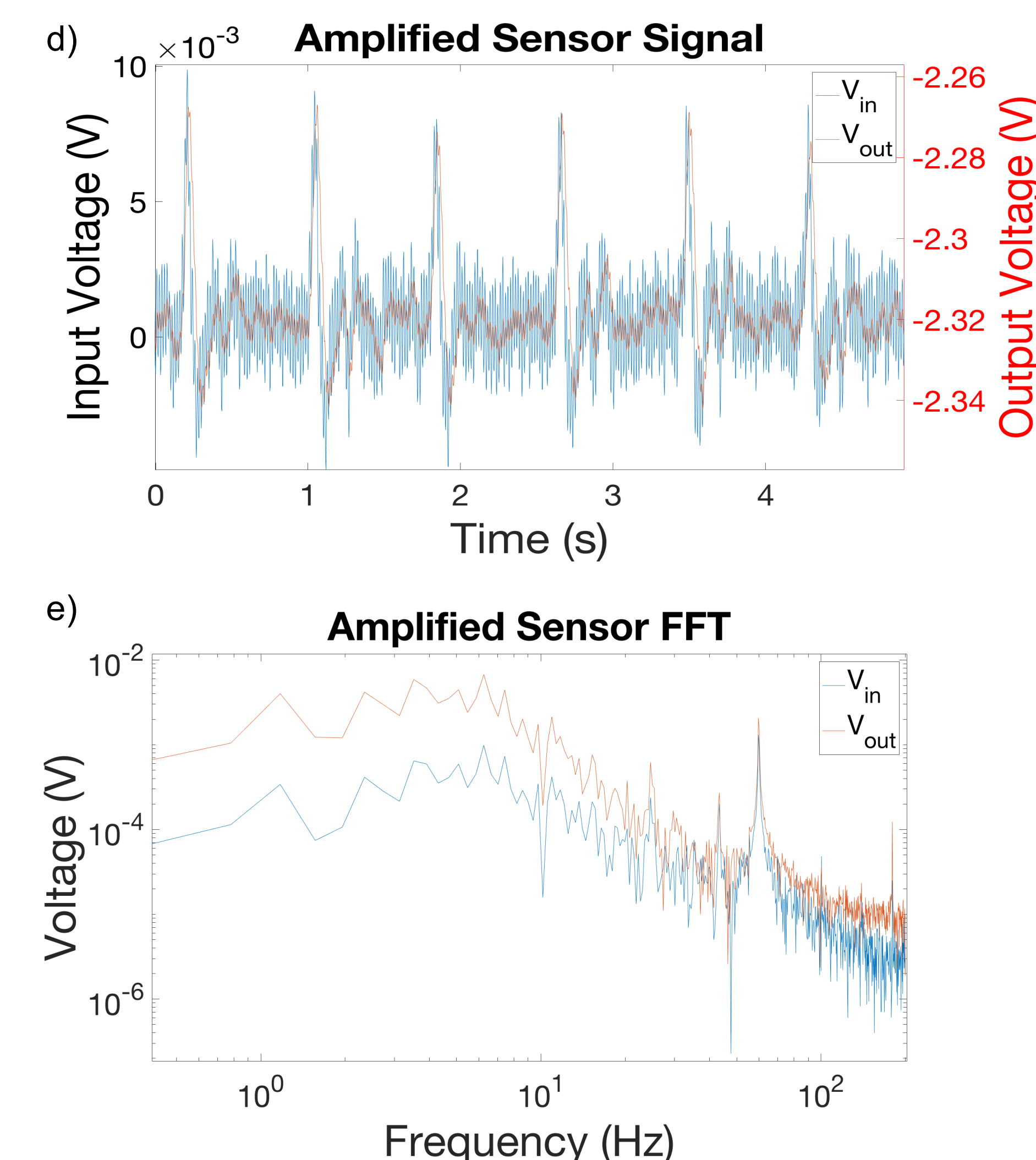
Signal Amplification with Organic Circuit

Pseudo-CMOS Circuit



Pseudo-CMOS (a) layer by layer (30 nm Au Gate, 50 nm parylene gate dielectric, 50 nm DNTT organic semiconductor, 50 nm Au source and drain contacts, 50 nm Au pad layer fabricated via vacuum deposition. Via holes drilled to connect Source and Drain to Gate) and (b) under microscope. (c) Switching behavior for V_{DD} = 3 V (operational at V_{DD} = 1 V and 2 V)

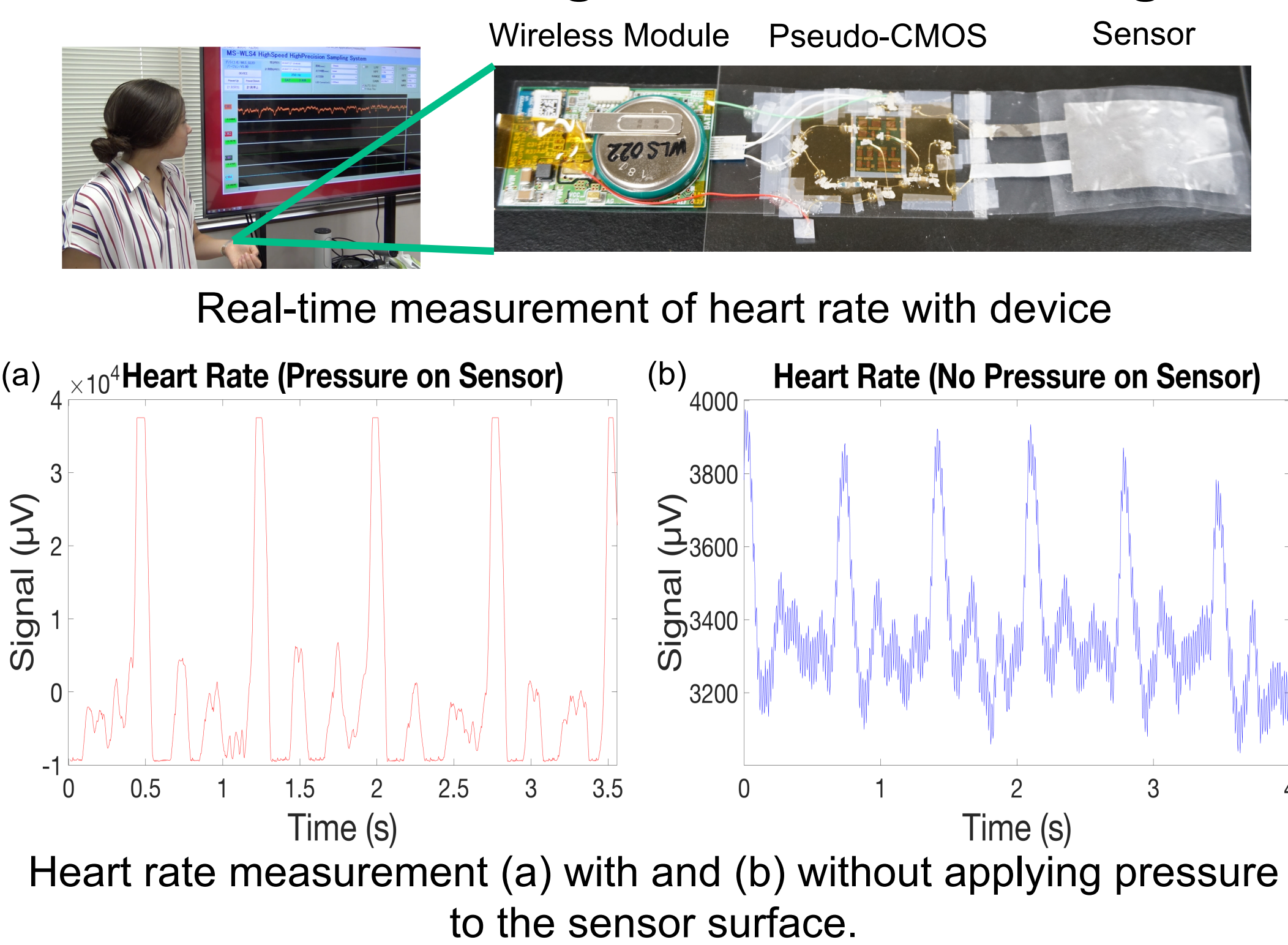
- Pseudo-CMOS Type-D (1:6):
 - Pressure Sensor Connected at V_{in}
 - V_{ss} = 0 V to minimize power consumption
 - Negative feedback and low pass filter maximizes gain for pulse signals
- Over 10x signal amplification below 10 Hz



(d) Original (V_{in}) and amplified (V_{out}) pressure sensor signal. Signal is improved. (e) Frequency decomposition of sensor signal. Low frequency pulse signal is amplified while higher frequency noise remains constant.

Data Transmission & Processing

- Integrated sensor with Pseudo-CMOS circuit and wireless module
- Effectively measured pulse signals
 - Large signal amplification observed
 - Clipping when secured with pressure
 - Can measure signals without securing



Conclusion

- Demonstrated application of organic electronics to wrist-based heart-monitoring
- Created flexible, wearable device that detects and amplifies pulse for easy transmission and analysis

Future Work

- Optimize impedance to eliminate clipping
- Optimize sensor area and orientation
- Eliminate motion artifacts
- Apply to other biosensors

References

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- [3] T. Huang, et. al., 2010 Design, Automation & Test in Europe Conference & Exhibition (2010)

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