Vital Ring: a Wearable Wireless Multi-Lead ECG Sensor on a Finger Ring

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

SCHOOL OF ENGINEERING & APPLIED SCIENCE

Quan Dong[1], Can Korman[2], Mona Zaghloul[2], Zhenyu Li[1]

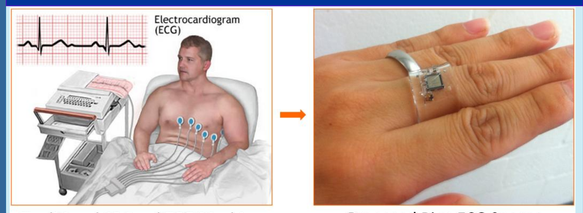
[1]Department of Biomedical Engineering, [2]Department of Electrical and Computer Engineering

Background & Significance

Every year over **380,000** Americans die from a heart attack, of which **one third** happens outside a hospital.

A **personalized cardiac monitoring device** capable of on-demand diagnosis may help reduce this number and save lives.

Innovation



Traditional 12 Lead ECG Machine

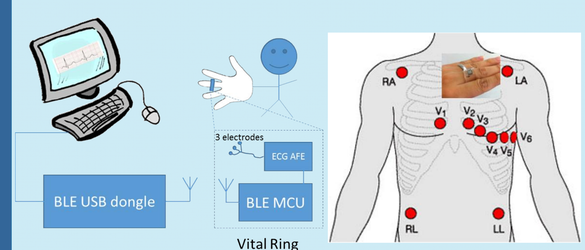
Proposed Ring ECG Sensor

Traditional 12 lead ECG is not feasible for point-of-care settings.

We aim to build a **multi-lead ECG sensor on a finger ring** enabled by the soft electronics technology recently demonstrated and patented by us [1]. By simply touching the ring to different positions on the body, multi-lead ECG can be obtained with a single ring. Moreover, this device is the **first truly self-contained ring-shaped sensor** system that has a sensor, a microcontroller, a radio and a battery.

[1] B. Zhang, et al., "Flexible packaging of solid-state integrated circuit chips with elastomeric microfluidics", Sci Rep. 3: 1098, 2013.
Z.Y. Li. et al., Flexible IC/Microfluidic Integration and Packaging, US Patent Application 20130243655

System Design

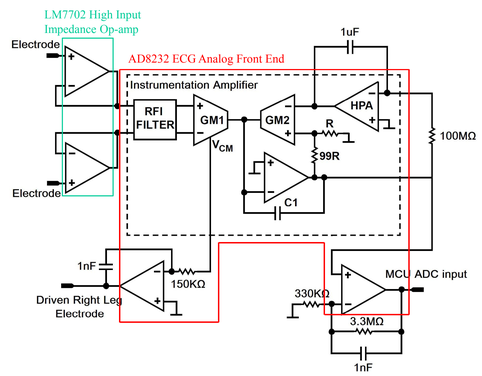


Vital Ring

The whole system consists of the ring sensor and a Bluetooth Low Energy(BLE) host device, which can communicate with the ring to initiate or terminate the measurement. The host can be a computer, or a BLE enabled smartphone.

Touching the ring to different positions on the body, multi-lead ECG can be obtained.

Circuit Design

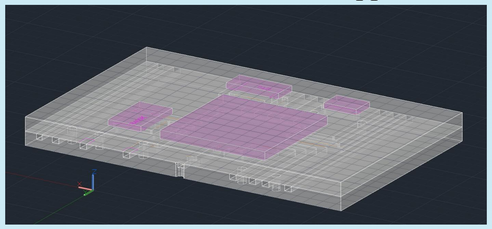


Analog Front End Circuit Schematic

The design is a classical one lead ECG circuit with driven right leg circuit and high input impedance buffer. The electronics components chosen here are of very small package to make sure the whole system can be integrated on a ring sized device.

Experimental Approach

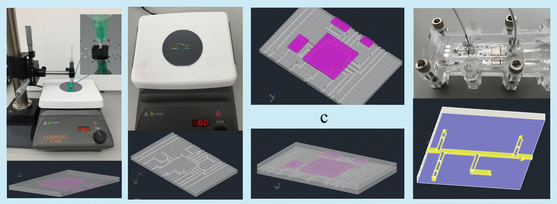
In our work, we adjusted the conventional process to make multilayer PDMS devices to suit for our flexible electronics application.



The ECG ring sensor is composed of two layers:

- The top **electronics layer** (purple), with MCU, ECG AFE and BLE chips.
- The bottom **microfluidic layer**, with microfluidic channels filled with liquid metal acting as bendable and stretchable interconnects.

Fabrication process:



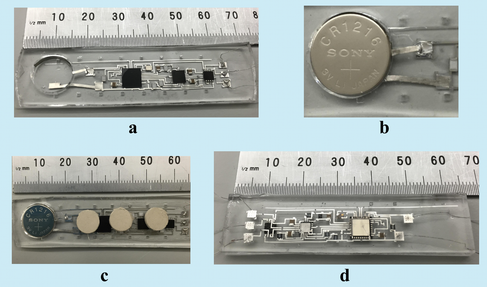
a b c d e

a. Fabrication of the electronics layer. Each IC is placed on a Si wafer at a location predefined by photolithography. Small amount of PDMS is used to glue the IC to the wafer. This process is repeated until all the components are fixed on the wafer. Then PDMS is poured onto the wafer to form a continuous layer. **b. Fabrication of the microfluidic layer**. Soft lithography is used to make the microfluidic layer. The mold has features with two different heights. The low height features define microfluidic channels. The higher features (500μm) define vias. **c. Alignment and bonding**. The two layers are aligned and bonded under a stereoscope after plasma treatment. **d.** The two layer device after alignment and bonding. **e. Injection of liquid metal**. Liquid metal is filled into the channels through a third PDMS layer which has channels connecting all the vias to the injection port, but without bonding. A custom built clamp is used to hold the device and injection layer together.

Results

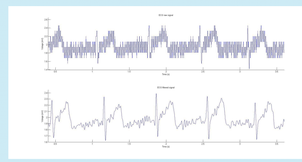
Fabricated devices:

All the fabricated devices shown here are the original form before rolled into a ring format. The size is suited for a ring, which is less than 8cm long and ~2cm wide.



a b c d

a. The ring sensor without battery and electrodes. The three wires on the right will be connected to the electrodes. b. The battery holder after a battery is inserted. c. Complete device after both the battery and electrodes are installed. d. a test device has wires (2 on right) that can connected to a DC power supply.



Measured ECG signal. The top figure shows the raw data. The bottom figure shows the signal after digital filter. Sampling rate was 500 Hz.

Discussion

This work proposed a new approach to achieve wearable sensor systems with a finger-ring format.

In the future, by integrating the traditional PDMS microfluidics with flexible electronics, it is feasible to build wearable lab-on-chip systems for sweat or other body fluid monitoring.

Acknowledgement:
This work is supported by the GW IBE Interdisciplinary Research Award.