Fabrication of ECG Sensor

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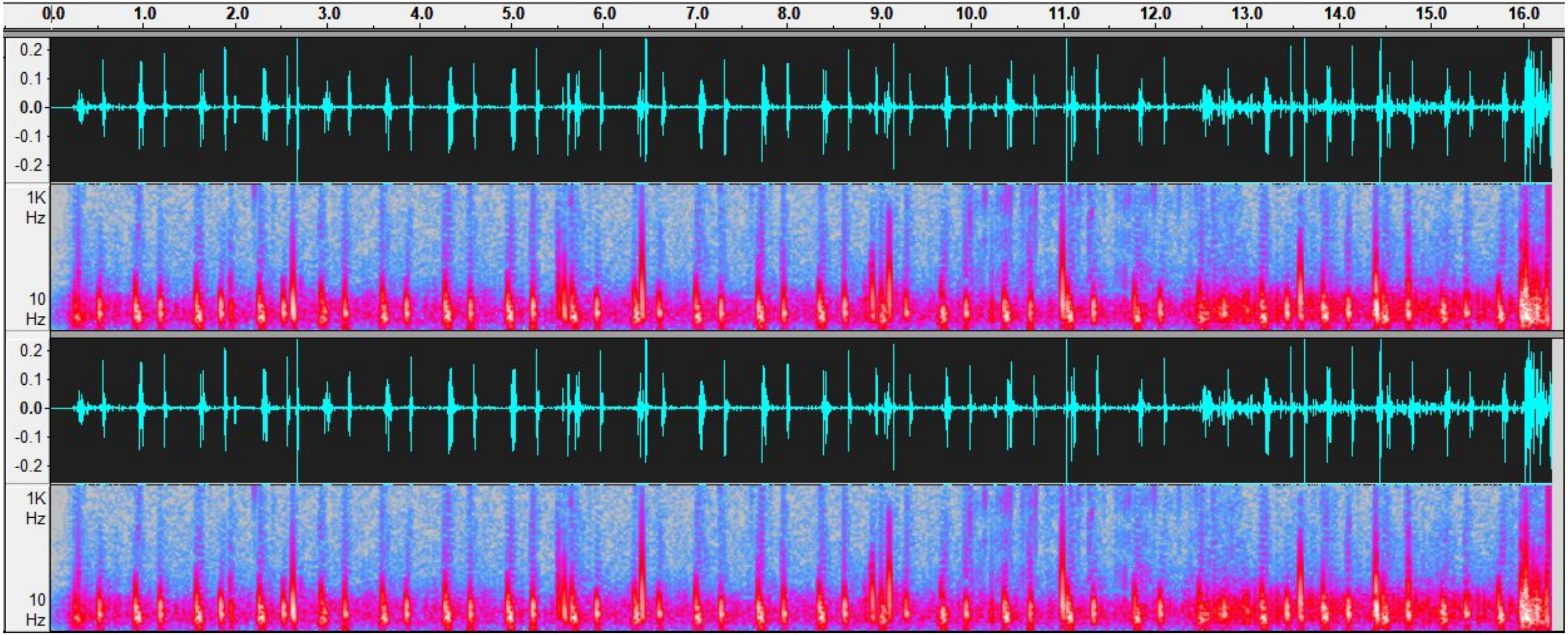
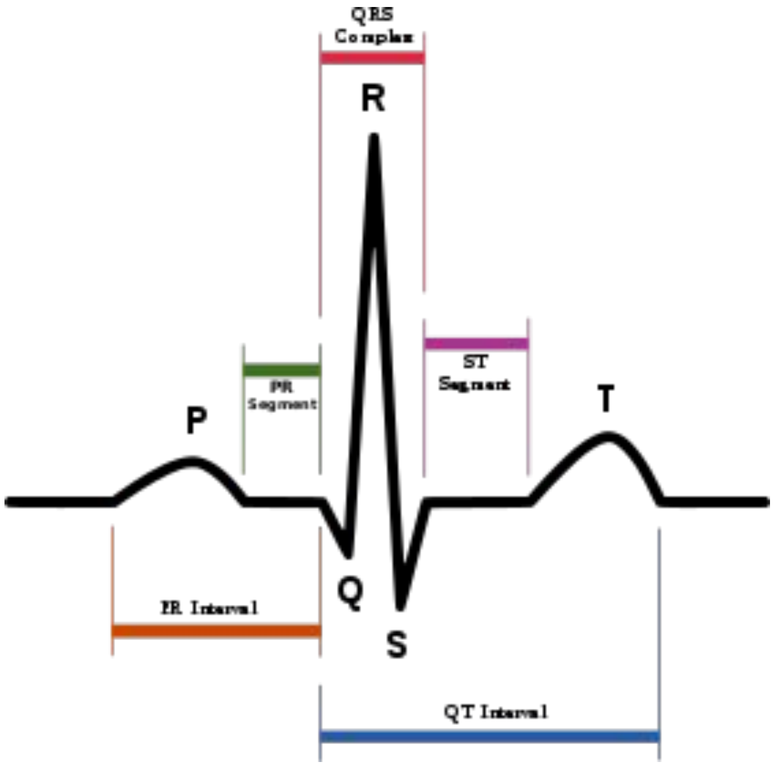
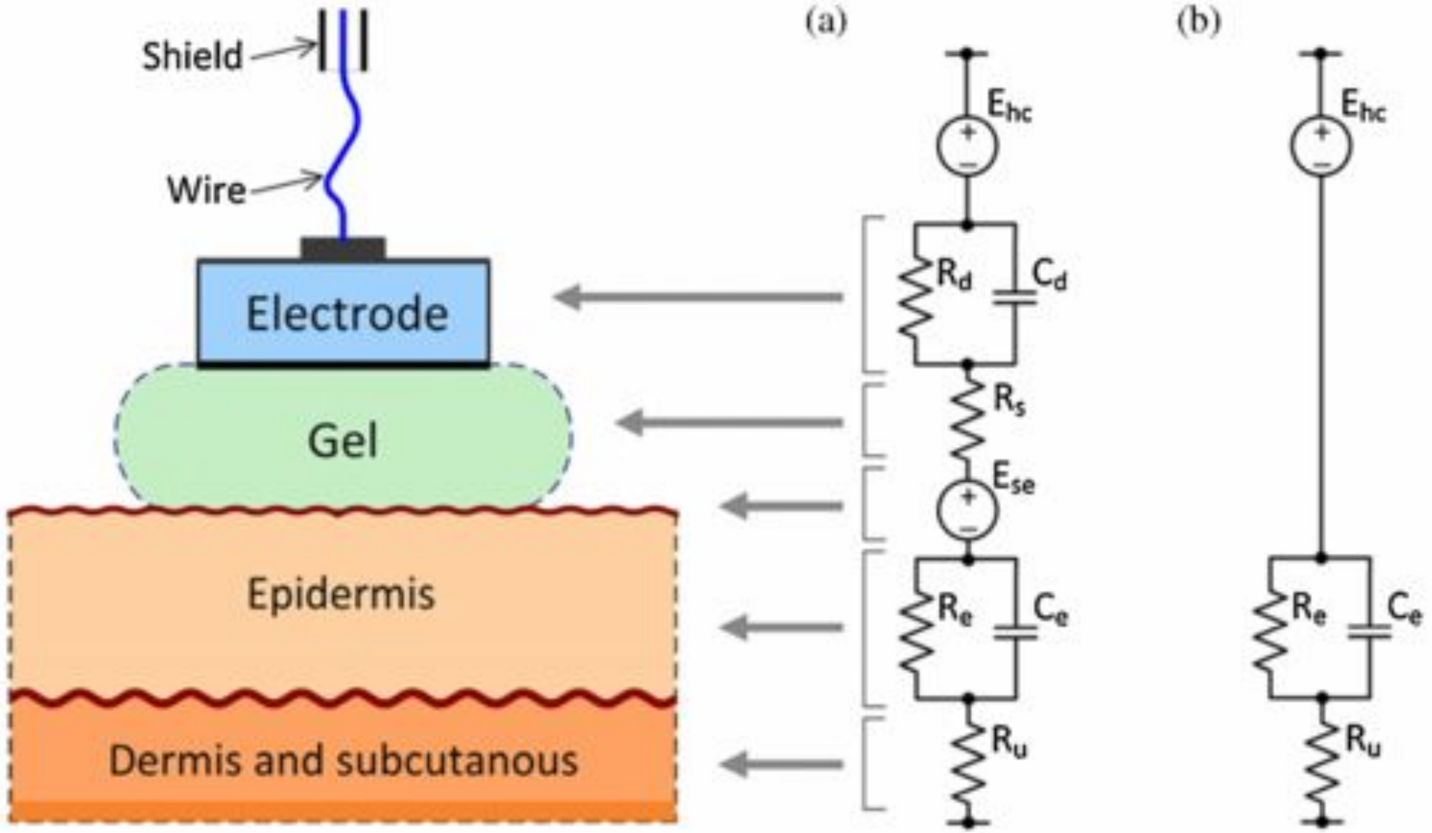
Un-filtered Noised Basic ECG signal



Normal ECG signal

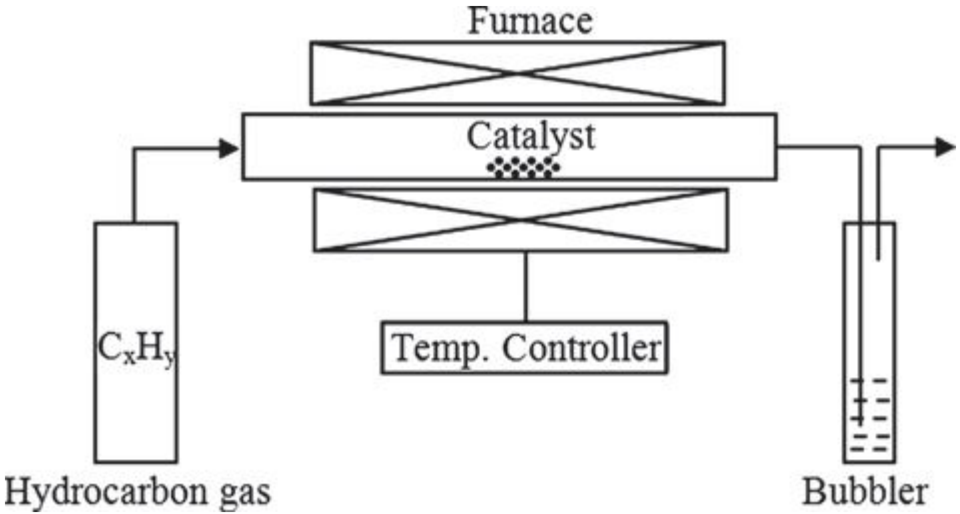


Electrical Model of (a)Gel and (b)Dry Electrodes



Chemical Vapor Decomposition

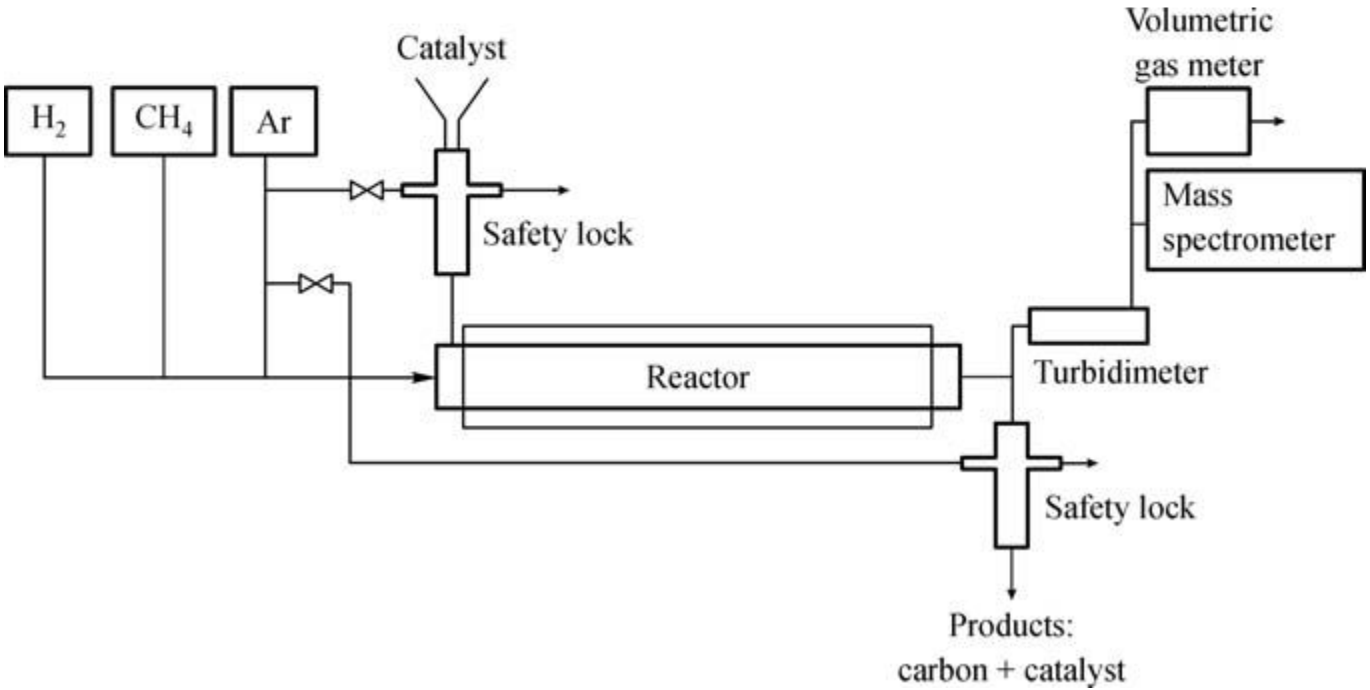
The thermal decomposition of a hydrocarbon vapor is achieved in the presence of a metal catalyst.



CNT synthesis through CVD

The process involves passing a hydrocarbon vapor (typically 15–60 min) through in which a catalyst material is present at sufficiently high temperature (600–1200 C) to decompose the hydrocarbon. CNTs grow on the catalyst in the reactor, which are collected upon cooling the system to room temperature. Volatile materials (camphor, ferrocence etc.) directly turn from solid to vapor, and perform CVD while passing over the catalyst kept in the high-temperature zone. Pyrolysis of the catalyst vapor at a suitable temperature liberates metal nanoparticles in-situ (such a process is known as floating catalyst method)

Production of MW-CNTs using rotation reactor



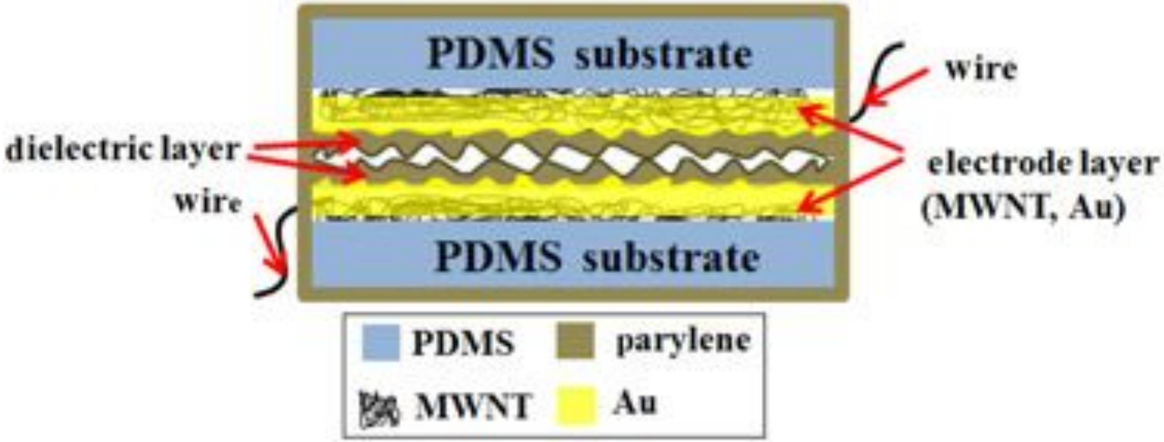
CNT

The relationship between the coefficients (n1 and n2) of the translational vector ch= n1a1+ n2a2, which connects two crystallographically equivalent sites, determines the conducting properties mod(n1−n2, 3) = 0 1 2, where mod1 and mod2 SWNTS are semiconducting while mod0 SWNTS (n1 < n2) are metallic at room temperature, and exhibit a small chirality-dependent energy gap, corresponding to quasi-metallic conduction, at lower temperatures, the case n1 = n2 denotes armchair nanotubes that are truly metallic

Flexible Piezo-Capacitive Sensor

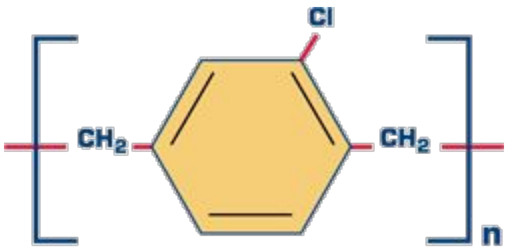
The dielectric layer has the advantages of low stiffness, biocompatibility, and CMOS/MEMS process compatibility, is a thin layer of parylene C deposited through chemical vapour deposition (CVD). In this sensor, the top and the bottom sides of the dielectric layer were symmetrical, which were composed of flexible PDMS substrates and MWNT electrodes. The PDMS substrates were used to transfer force, and the electrodes consisted of MWNT films with metal deposition. MWNT films were not only used as conducting layer, but also naturally created numerous micro–nano structures on the surface of the flexible substrate. In addition, the metal layer deposited on the MWNT film could further improve the conductivity of the electrodes.

Sensor


PDMS substrate
wire
dielectric layer
electrode layer
(MWNT, Au)
wire
PDMS substrate
PDMS
parylene
MWNT
Au

Fabrication of Dielectric Layer

- 1-μm-thick parylene C was initially deposited on the surface of MWNT electrodes through CVD
- Parylene C demonstrated good shape retention and coverage property, a very low permeability to moisture and corrosive gases and other surface treatment properties



Parylene C

Fabrication of porous elastomer films

- Polydimethylsiloxane (PDMS; Sylgard 184)was chosen as a base material and deionized (DI) water was selected as a dispersion substance.
- A solution of the PDMS prepolymers, mixed with a curing agent at the weight ratio of 10:1, and water were first mechanically stirred in a container at the rate of 2600 rpm for 10 min.
- Micro-droplets of DI water were uniformly dispersed in the PDMS solution. The PDMS solution containing micro-droplets of water was then placed between two glass substrates that were treated to be hydrophobic by dip-coating in a solution of a chemically inert fluoropolymer (EGC-1700, 3M) at the concentration of 2% in a hydrofluoroether solvent. The dipping speed was 80 mm/min.
- The assembled sample was heated at the curing temperature of the PDMS prepolymer (70°C) for 24 h to achieve the thermal cross-linking of the PDMS and the evaporation of water confined in the PDMS.

Fabrication of electrode layers

- After preparing the PDMS substrates, we need MWNTs to fabricate the electrode layer. The concentration of MWNT in the alcohol solution was 0.1 mg/ml.
- MWNT solution need be dispersed by ultrasound for 30 min, and free standing MWNTs were floating in the solution.
- The PDMS substrate was inserted into the solution containing MWNTs. The PDMS substrate attached to the MWNT films was removed from the solution and was put in the oven at 200 °C for 30 min to improve their adhesion

Fabrication

a Preparation of the PDMS substrate on a silicon wafer

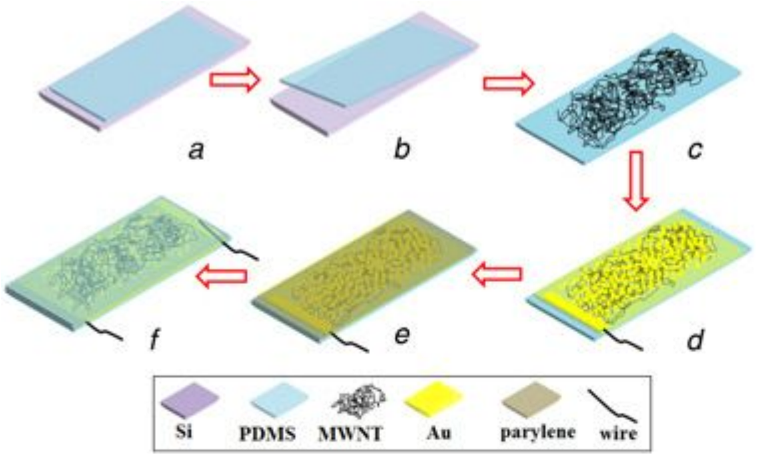
b Peeling off the PDMS from the silicon wafer

c Coating the MWNT film on the PDMS substrate

d Au deposition on the MWNT film

e Preparation of the parylene C dielectric layer

f Assembly and completion of fabrication of the flexible capacitive pressure sensor



Introduction

The ECG is the process of recording the electrical activity of the heart over a period of time using electrodes placed on the skin. These electrodes detect the tiny electrical changes on the skin that arise from the heart muscle's electrophysiologic pattern of depolarizing and repolarizing during each heartbeat.

Multi Walled CNTs and Ag nanoparticle

Materials:

- PDMS monomer and curing agent: Dow Corning Sylgard (a silicone elastomer)
- Absolute Ethanol (AR grade)

Technique:

- Bath Ultrasonicator
- Mechanical stirrer

Introducing PDMS

PDMS elastomer an essentially dielectric substance is extensively used in medical fields for its relative inertness ,flexibility,non-toxicity and stability over a wide temperature range.

When CNTs are added to it the material formed should give promising electrically conductive nature to the PDMS base.It thus can be used as electrodes for various biomedical and electrocardiographic instruments

Though parallel alignment of carbon nanotubes would have made it even more conductive/sensitive we do not have any means to do it.However as the disalignment is limited to 2*3.14 Steradians , we can compensate it by adding optimum amount of CNTs.

Process Literature

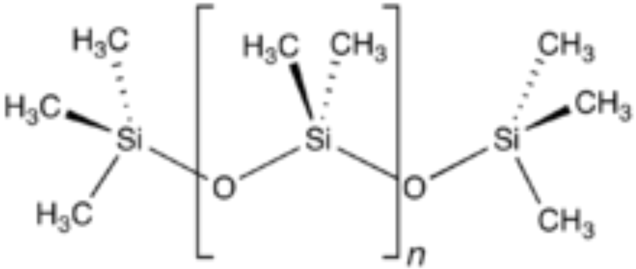
Dispersion of Ag-CNTs in thermosetting PDMS medium:

- **CNTs are treated with Ethanol solution and ultrasonicated**
- **Dimethylsilicoxane monomer -(CH3)2SiO- and CNT ethanol suspension are added,ultrasonicated and mechanically stirred to form homogenous mixture**

In-situ polymerisation:

- **Suitable curing agent was added to the mixture to form the Polydimethylsilcoxane(PDMS) polymer with Ag-CNTs in-situ**

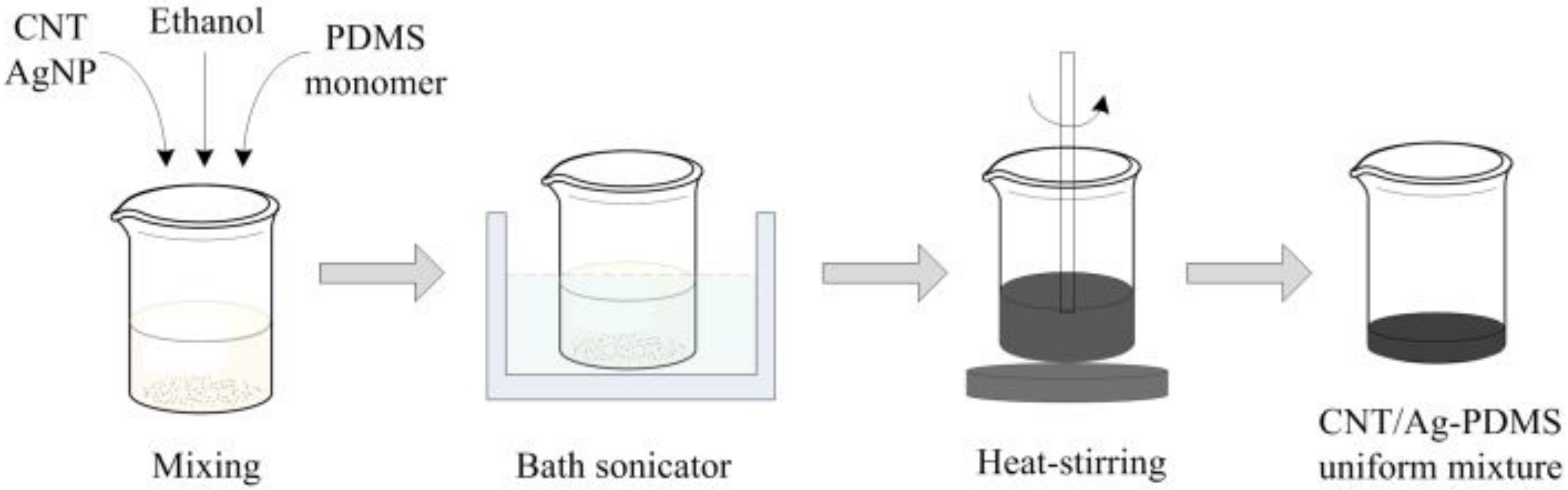
Multi walled Carbon NanoTubes



PDMS monomer(In braces)

Conductive Polymer Mixture Fabrication

- MW-CNTs and Ag nanoparticles with PDMS monomer and ethanol are mixed
- Mixture placed in Bath Ultrasonicator and stirred for 30 mins
- Mixture then placed on a hot plate and heated to remove most of the solvent.
- Again heated in oven to remove the remaining solvent
- Curing agent was added at a ratio of PDMS monomer: curing agent=10:1
- Homogeneous CNT/Ag-PDMS mixture is prepared

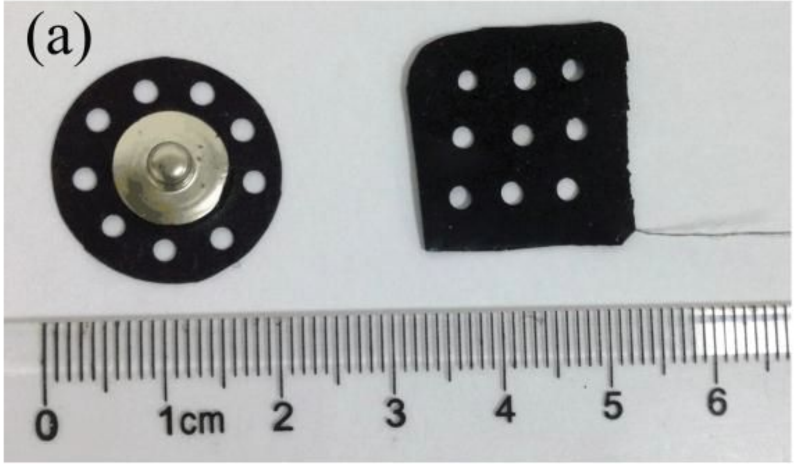


CNT
AgNP
Ethanol
PDMS
monomer
Mixing
Bath sonicator
Heat-stirring
CNT/Ag-PDMS
uniform mixture

Polymer Electrode and Electrode Patch

- CNT/Ag-PDMS mixture was coated on a glass substrate, scraped with another glass plate and a metal snap is placed to connect it tightly
- Whole structure was finally cured in an oven at 100°C for 24 hours
- Cured electrode was peeled from the glass substrate and cut into circles
- Adhesive used to fix the electrodes to the skin was hydrofilm

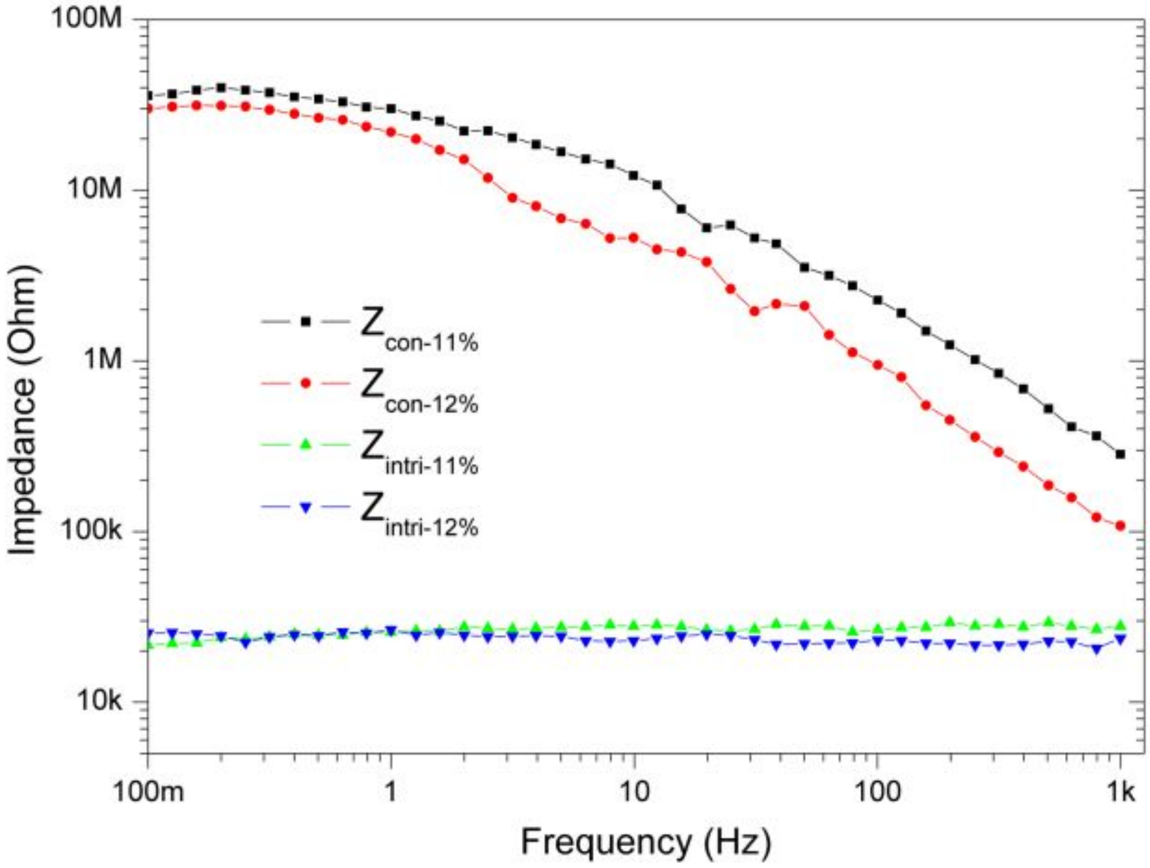
Polymer Electrode and Electrode Patch (Dia.)



Impedance Measurements

- The electrodes are in direct contact with epidermis. The epidermis layer behaves as a parallel resistor-capacitor circuit.
- The intrinsic impedance is resistive and almost constant for all frequencies. No serious differences were observed for the two electrodes at different CNT contents.
- The contact impedance decreased as the frequency increased from 0.1 Hz to 1 kHz
- At low-frequency biopotentials, the resistance is the major source of the observed impedance changes. While at high frequencies, the capacitive impedance dominated.
- The higher the CNT content, the lower the contact impedance, however, the harder the fabrication process.

Impedance Measurement (Dia.)

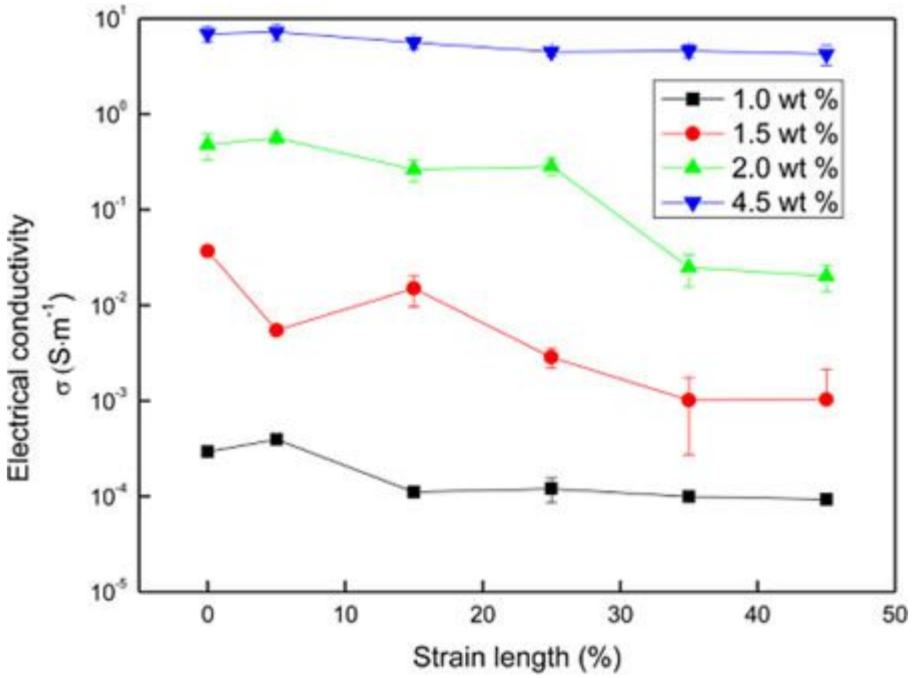


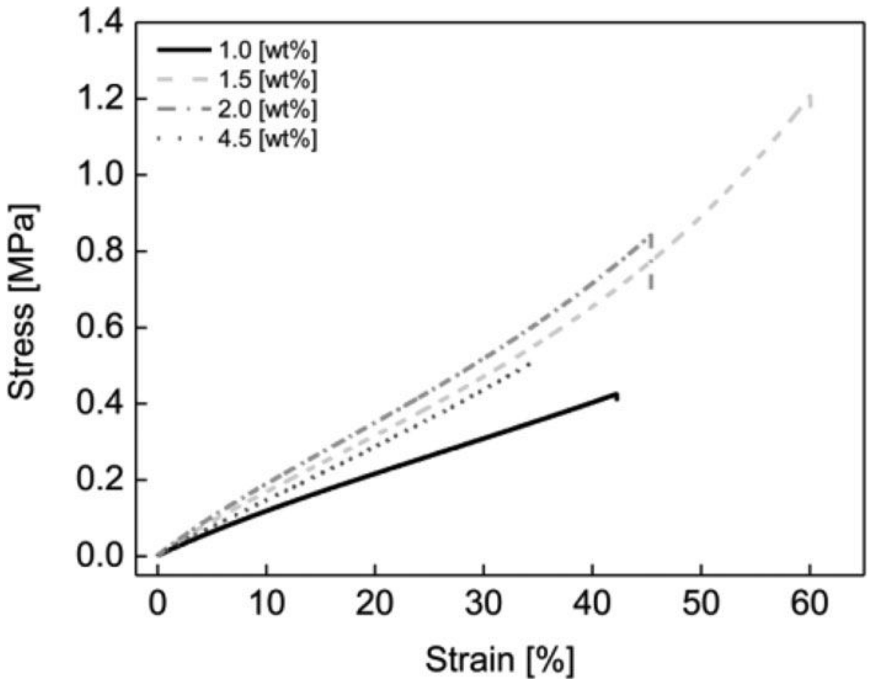
Contact impedance: Zcon,
intrinsic impedance: Zintri

CNT dispersion in PDMS

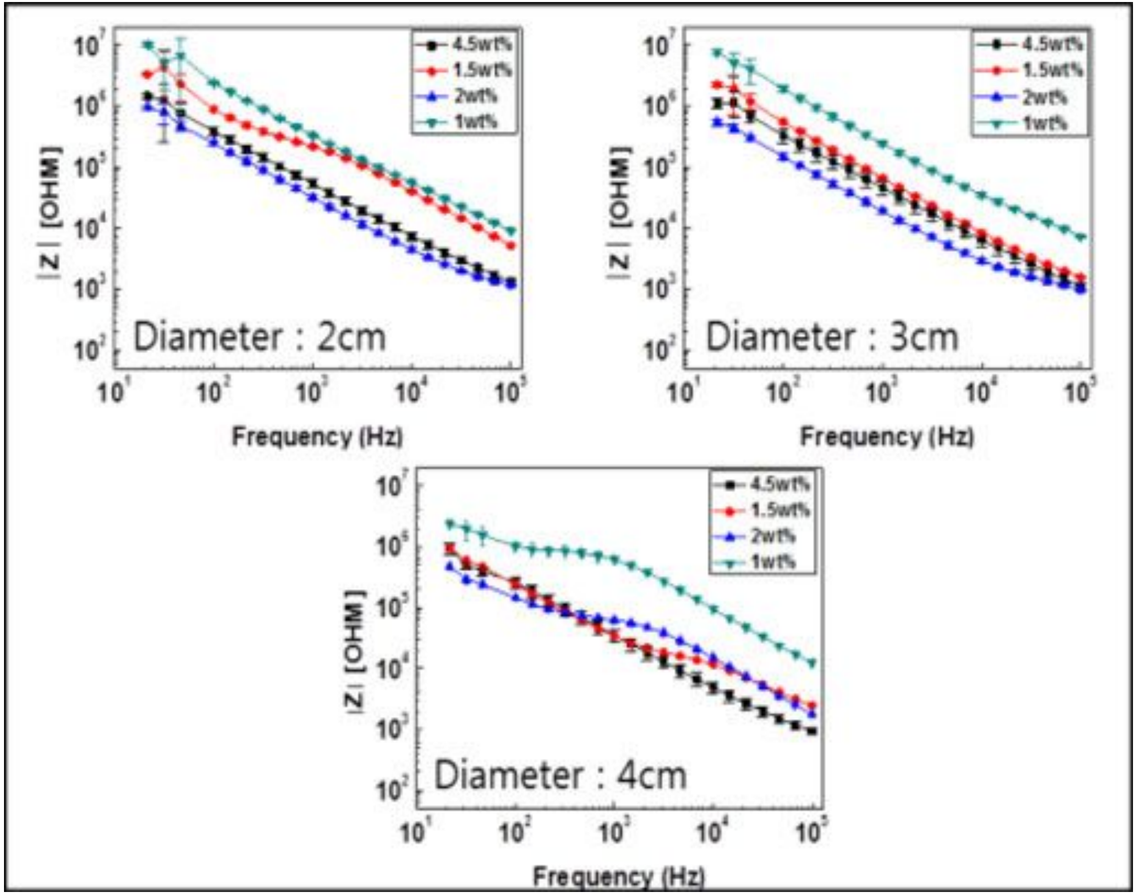
CNTs have a large surface area (>500m2 /g), strong van der Waals interactions are present between CNTs. These interactions make CNTs form aggregates easily, which should be disentangled to

CNT/PDMS electrode





Impedance of CNT/PDMS



Thank you