

Dry and Capacitive Electrodes for Long-Term ECG Monitoring

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Dry Electrodes for ECG Monitoring

INTRO

BIOMEDICAL

SOFT

CAPACITIVE

SUMMARY

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SUMMARY

Introduction

- **Cardiovascular diseases frequent in western world**
- **300 000 heart attacks in Germany**
- **Preventive methods must be improved**
 - Promote health
 - Decrease costs
 - Long-term monitoring of risk-groups
- **Limitations of standard gel electrodes:**
 - Dehydrate → artifacts
 - Cause skin irritation
- **Solution: Dry electrodes**



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Goal

- **Design, fabrication and characterization of dry, long term applicable ECG electrodes**
 - Ohmic and capacitive
- **Reduction in contact impedance and motion artifacts as compared to metal plate dry electrodes**
 - Elastic layer to adapt to skin topography and movements
- **Passive suppression of slowly fluctuating offset potentials**
 - High-pass filter
 - Special electrode configuration

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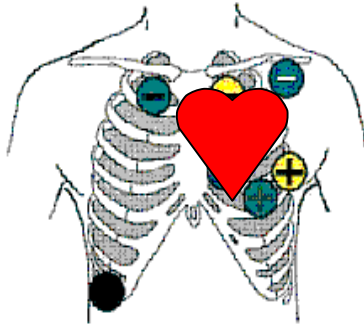
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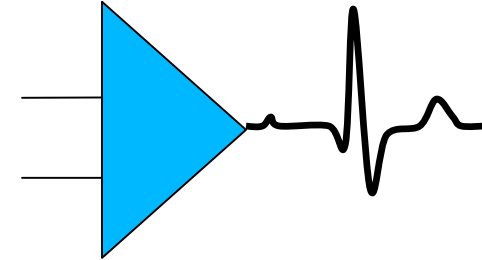
Biomedical Basics



1. Ionic current
(Na⁺, Ca⁺, Cl⁻)



2. Conversion to electron
current (electrode: transducer)



3. Amplification,
filtering, recording

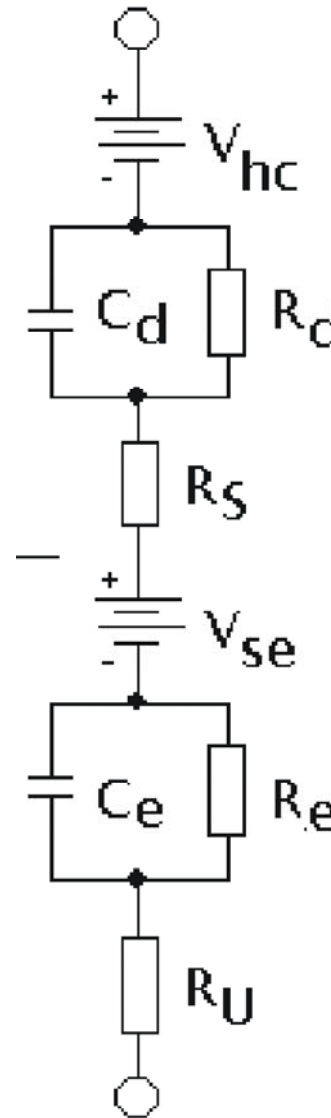
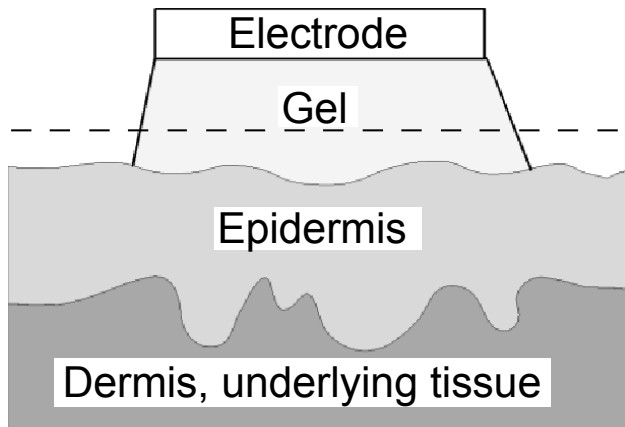
- **Skin is dielectric. Electric double layer at electrode interface**
 - Impaired signal transfer
- **Artifacts caused by**
 - Movements: breathing, walking, etc.
(muscle tremor, change of electrode position relative to heart)
 - Stretching of skin under the electrode

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- SUMMARY

Biomedical Basics

➤ Equivalent circuit of electrode-skin interface



Half cell potential: electrode-gel interface

Electrical double layer: electrode-gel interface

Series resistance: gel

Half cell potential: gel-skin interface

Dielectric properties: outer layer of skin

Body resistance

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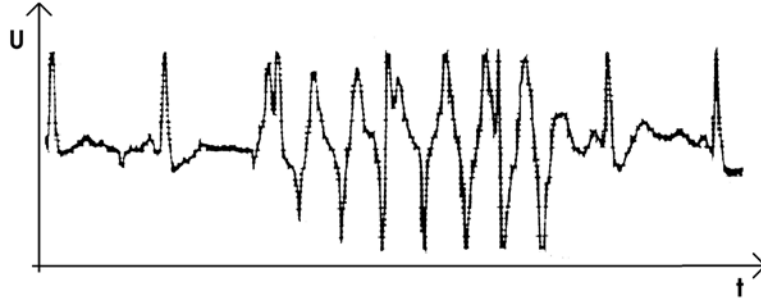
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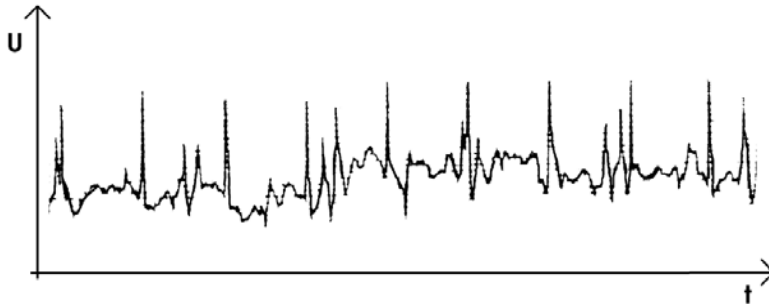
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Biomedical Basics

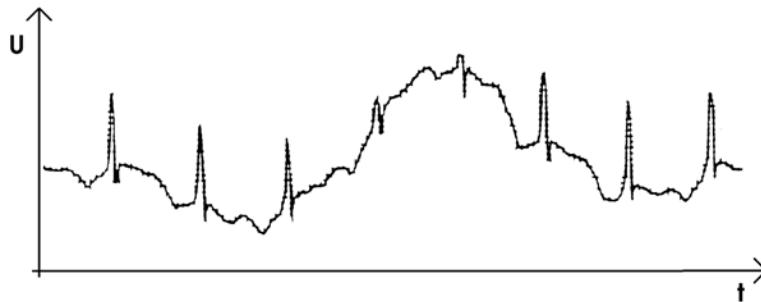


ECG artifacts:

Slow movement



Quick extra cardiac muscle movement



Zero line fluctuation:
very slow movement,
breathing

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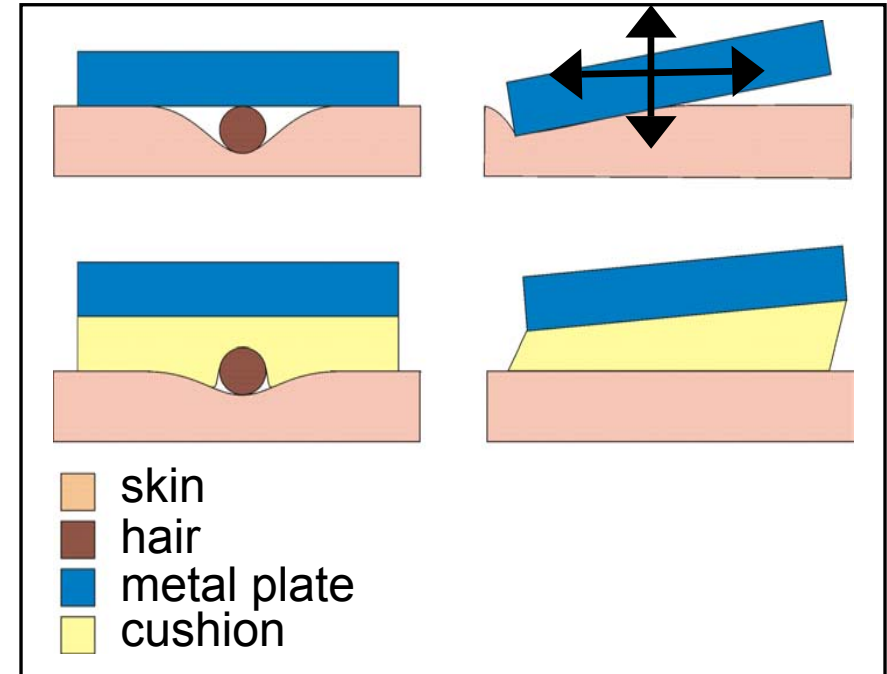
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SUMMARY

Soft Electrodes

- **Metal plate electrode**
- Hairs, uneven skin
- Gaps of 300 μm
- Reduced contact area
- Contact loss in movement
- **Soft electrode contact**
- Improved contact area
- Decreased impedance
- Contact maintained during movements
- Decrease of movement artifacts



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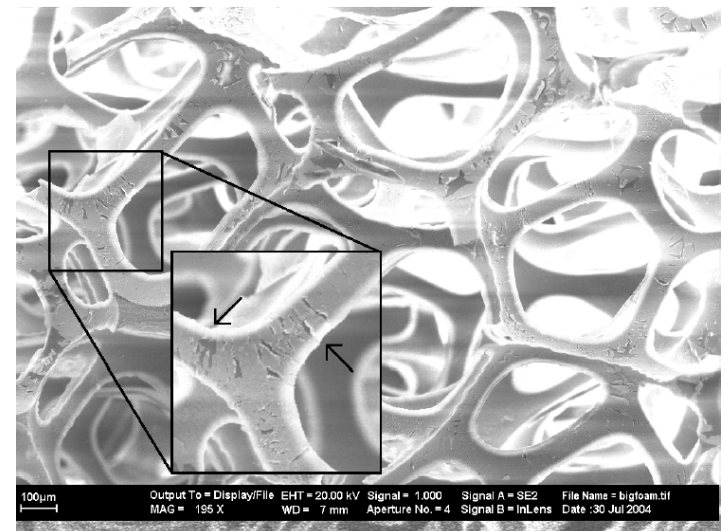
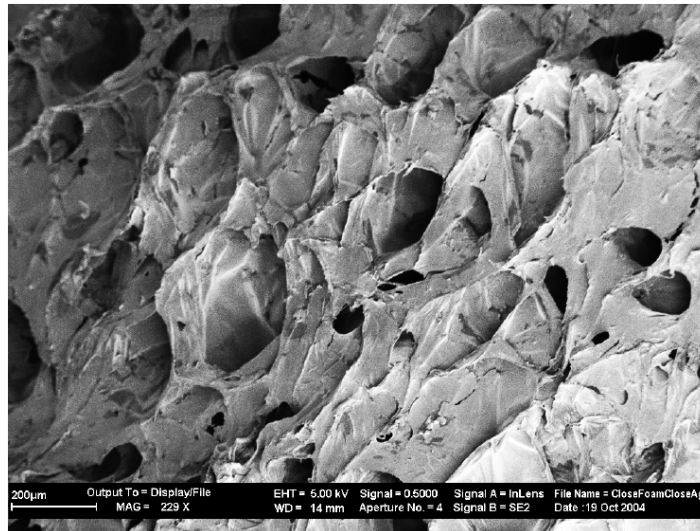
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Manufacturing

Soft ohmic electrodes

- Polymer foam, silver coating
- Rigidity
- Thickness
- Open / closed pores



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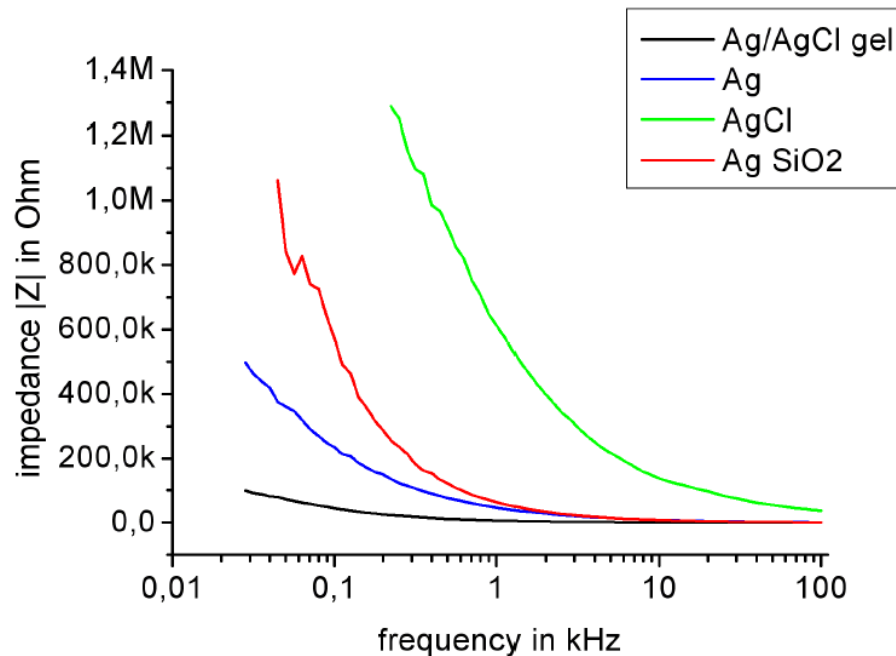
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Results: Contact Impedance

Comparison different types of stiff electrodes vs. wet electrode

- Wet Ag/AgCl gel electrode – low impedance
- Dry Ag/AgCl electrode – high impedance
- Ag SiO₂ electrode – room for improvement



*Impedance as
function of frequency
on hairless skin*

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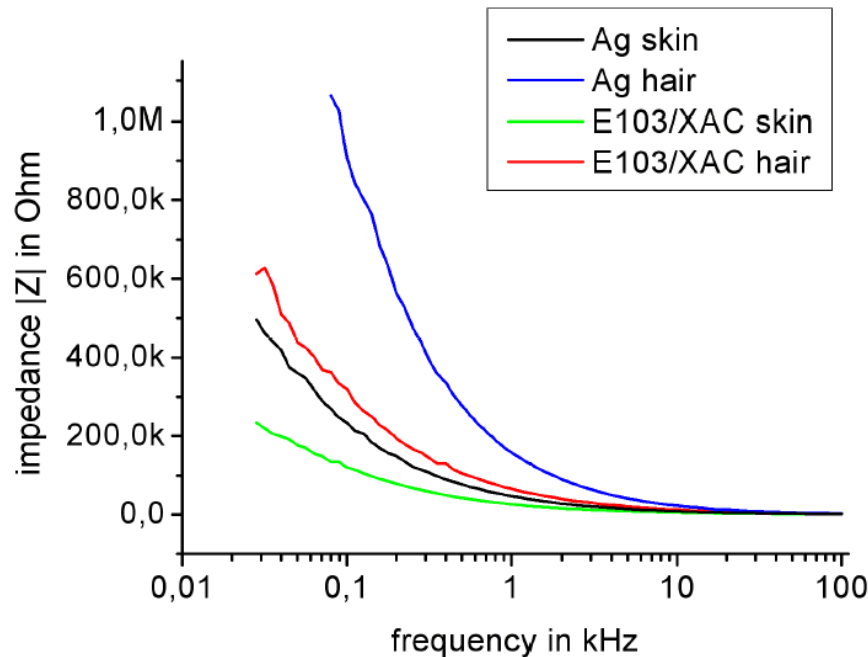
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SUMMARY

Results: Contact Impedance

Foam electrodes vs. rigid metal plate electrodes

- E103/XAC: Closed pores, thickness 3 mm
- Lower impedance than stiff metal plates
- Similar to wet gel electrodes



Impedance as function of frequency on hairy skin and hairless skin

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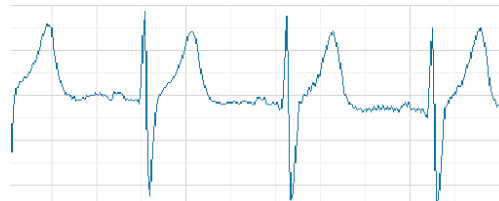
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Results: Movement artefacts

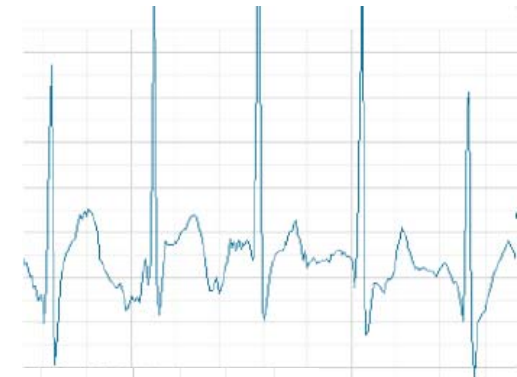
Foam electrodes vs. rigid metal plate electrodes

- E103/HART: Open pores, thickness 5 mm, rigidity same
- Less movement artifacts than with stiff metal plates
- Better than wet gel electrodes

*cushioned dry
electrode*

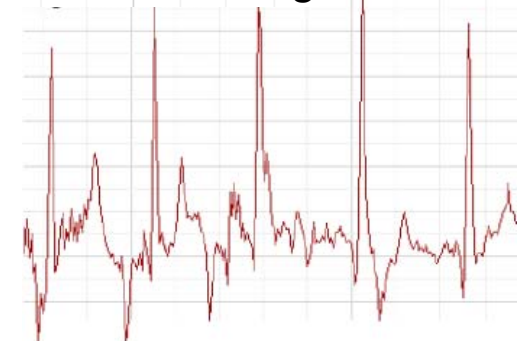
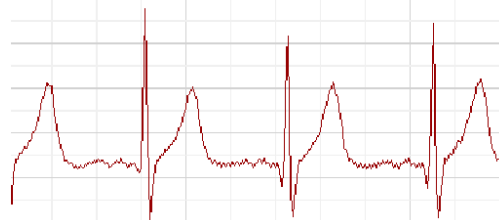


Patient at rest



intensive walking movements

*metal plate
electrode*



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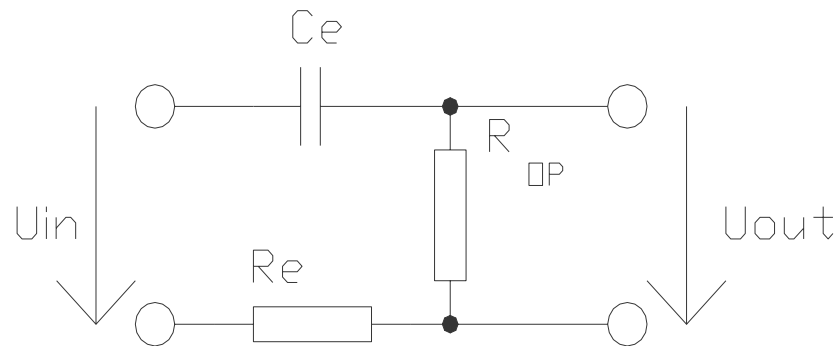
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Passive Filter Setup

- **Frequencies between 1 and 250 Hz of clinical relevance**
- **Zero line fluctuation at frequencies below 1 Hz**
- **Amplitude larger than ECG signal**
- **Advantageous: suppression at origin**
 - Supply the electrodes with passive filter network
 - Combination of ohmic and capacitive electrodes



electrical equivalent circuit of filter electrode setup

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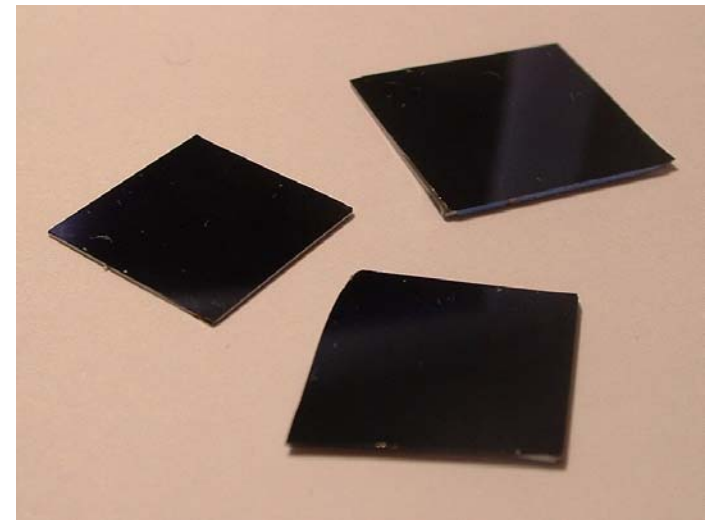
Manufacturing

Capacitive electrodes

- Silicon coated with thin SiO₂ layer
 - Thermal oxide
- Very low impedance capacitor
- Edges covered with tape to prevent skin from scratching

Various parameters tested:

- Doping density
- Oxide thickness
- Size of electrode



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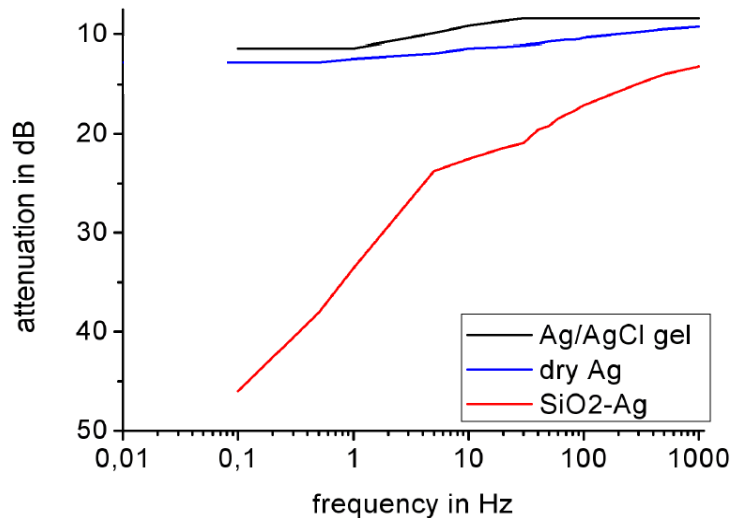
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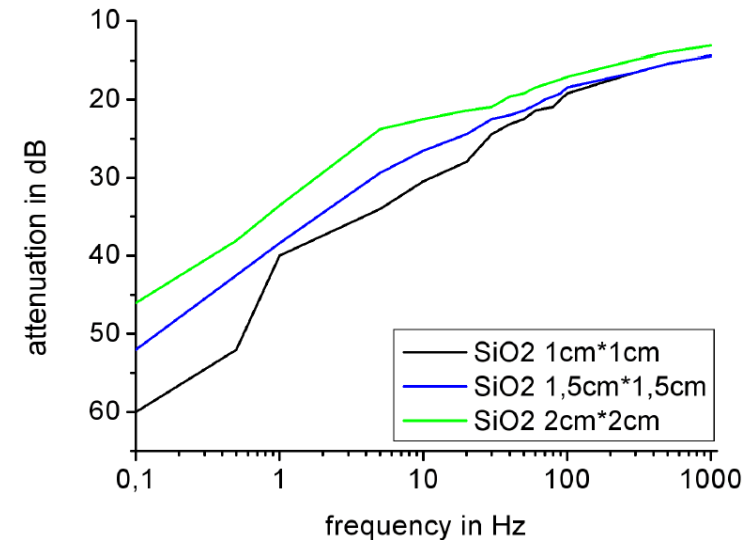
Results: Zero Line Fluctuation

Functioning of the passive filter electrodes demonstrated

- Two port network
- Gel electrodes deliver input signal



*All pass filter (standard gel electrodes)
vs. high pass (capacitive electrode)*



*Influence of electrode size, oxide
thickness, doping minimal*

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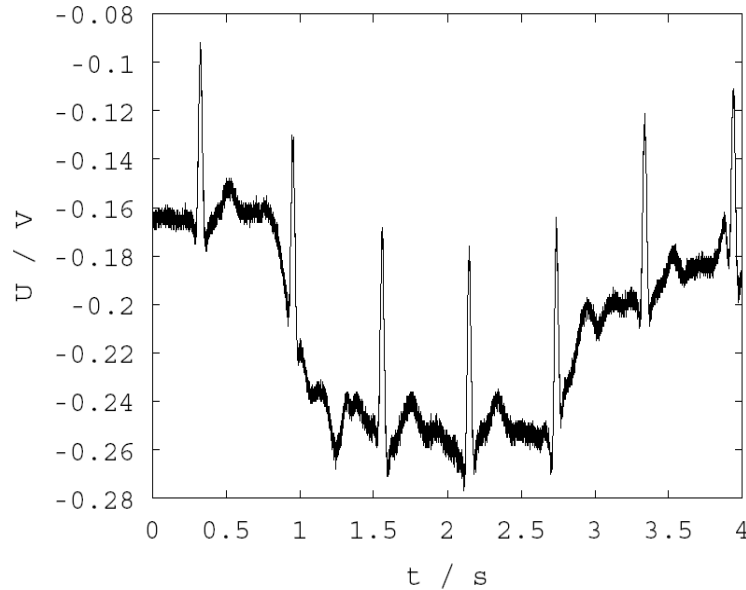
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Results: Zero Line Fluctuation

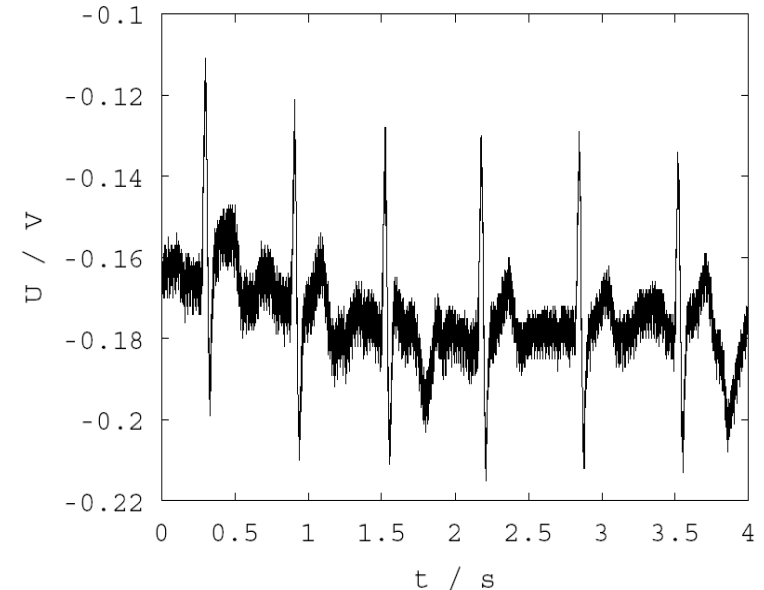


ECG measurement with standard wet gel electrodes

zero line fluctuation is evident, caused by a deep breath

ECG measurement with the developed filter electrode setup consisting of a capacitive electrode and an ohmic electrode

zero line fluctuation suppressed



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Summary and Outlook

New dry and capacitive ECG electrodes – promising alternative for standard electrodes in long term monitoring of risk patients

Soft skin adaptive electrodes – reduction of

- contact impedance
- skin irritation
- movement artifacts

Capacitive electrode

- filtering of zero line fluctuation passively directly at origin
- robust dielectric by thermal oxidation

Future work

- development of soft capacitive electrodes
- combination of relevant electrode properties of soft ohmic electrodes as well as stiff capacitive electrodes achieved in this work