



Built-in Test of Electrode Degradation of Micro-Electrode Array Biosensors

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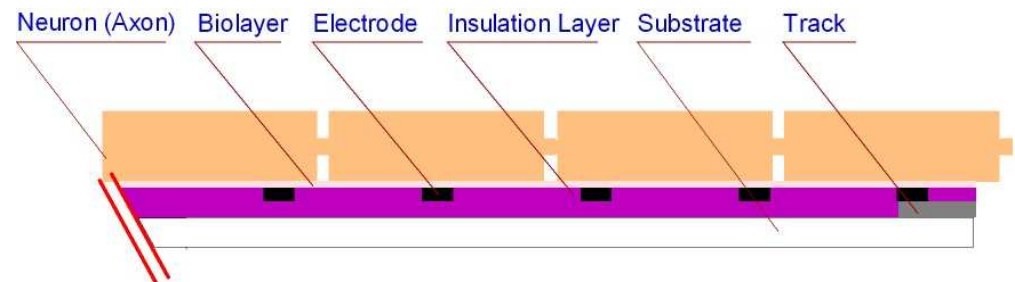
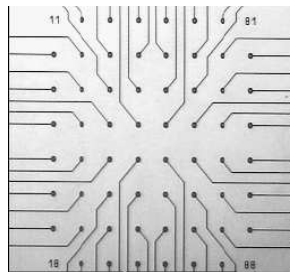
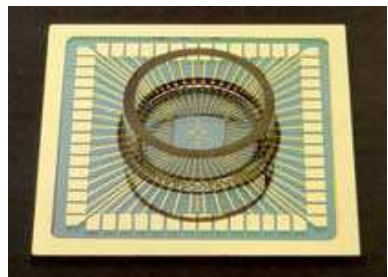
R. Heal

«Design for Micro & Nano Manufacture (NoE PATENT-DfMM)»

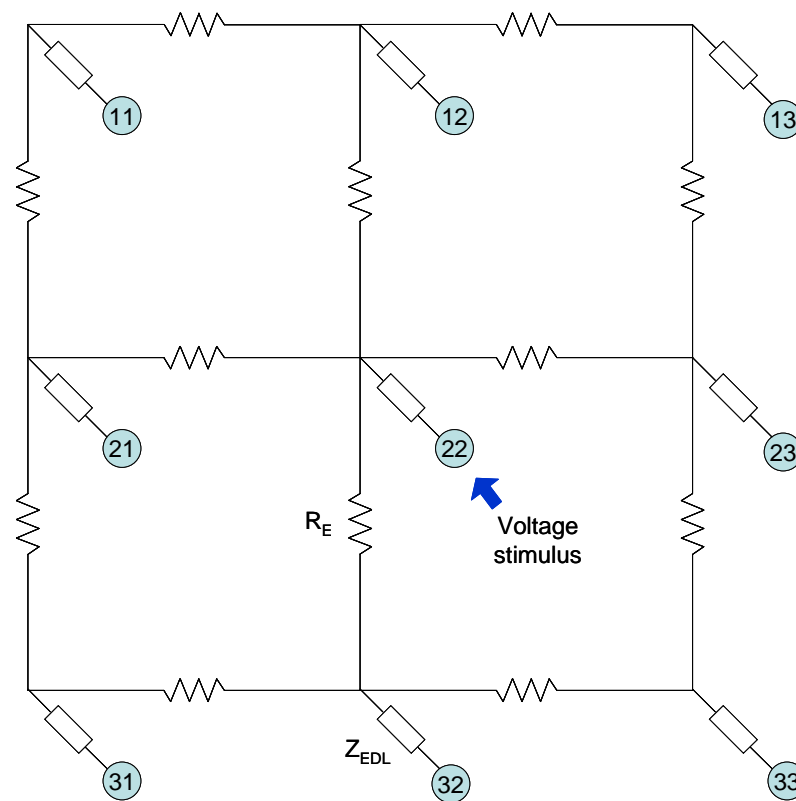
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- Introduction
- Proposed test method and preliminary evaluation
- Micro electrodes degradation analysis
- Experiment data analysis
- Conclusion & future work plan

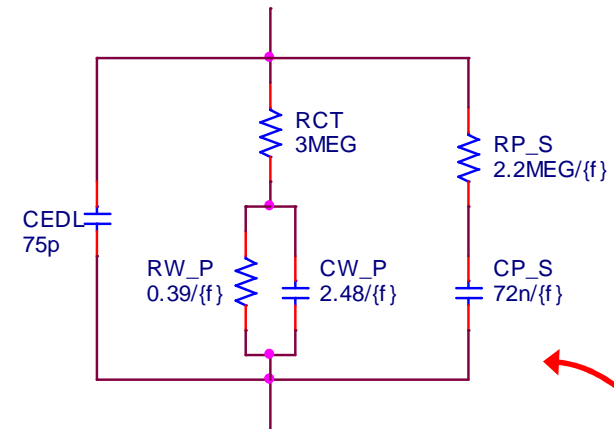
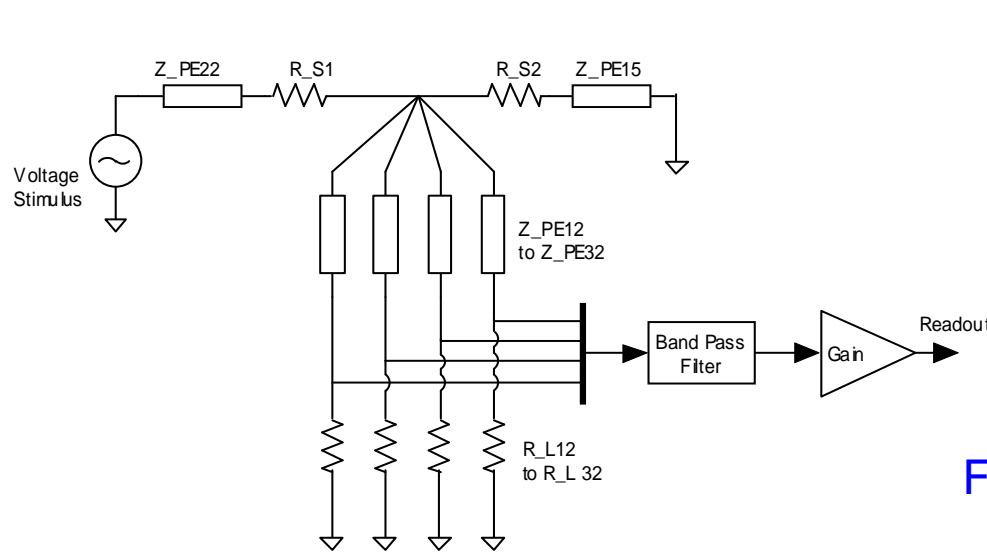
- BioDrop system – droplet transportation and contents sensing
- Micro-Electrode Array (MEA) – sensing cell signals in a bio-sensor system
- Frequently reported failure – electrode degradation, dissolved gas, insulation layer damage and etc.



- Checking the symmetrical properties of the surrounding electrodes



Preliminary evaluation

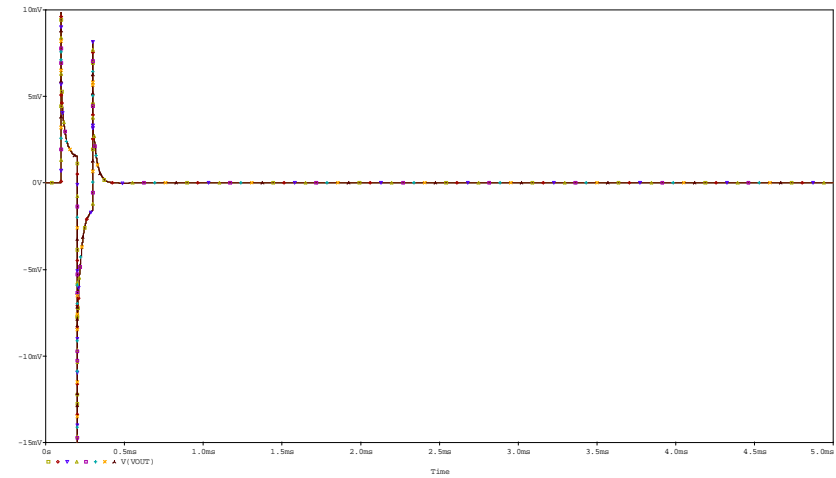
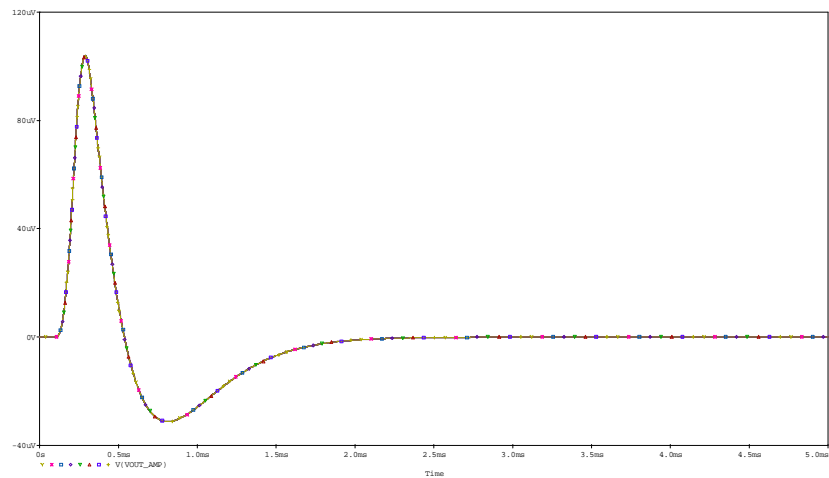


Frequency-dependent circuitry

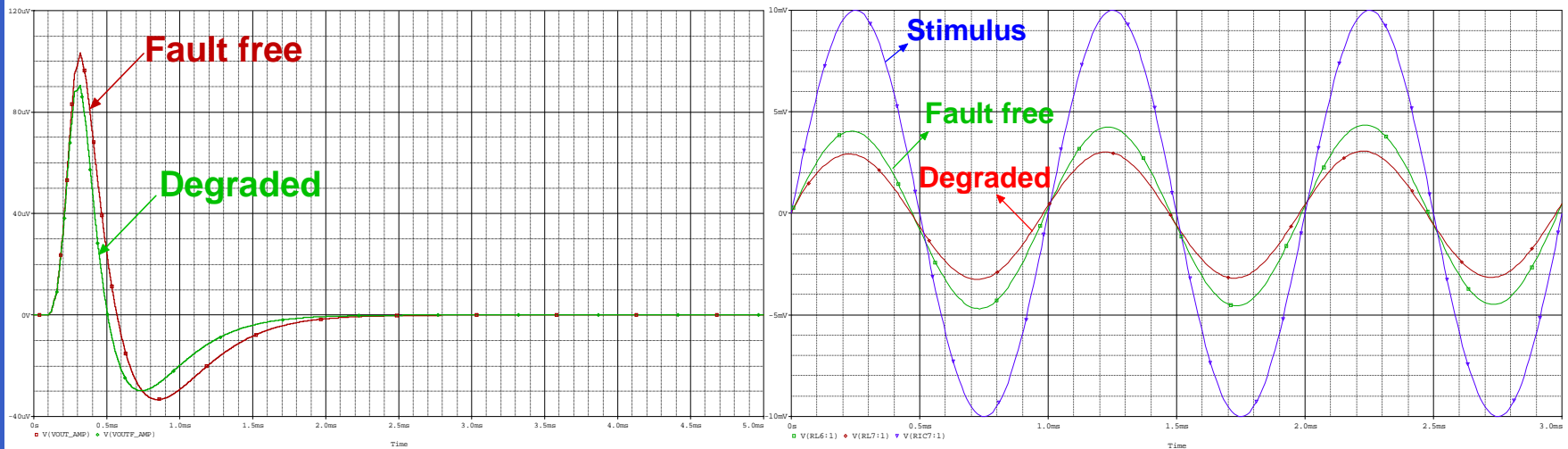
Z_PE	Electrode impedance
R_S	Electrolyte resistance
R_L	Load resistance

CEDL	Electrical Double Layer
RCT	Charge transfer
RW_P CW_P	Diffusion effect
RP_S + CP_S	Electrode porosity

DA Stenger and TM McKenna, Chapter 7 in 'Enabling Technologies for Cultured Neural Networks', Academic Press, 1994.
 Bard A.J. and Faulkner L.R., 'Electrochemical methods, Fundamentals and applications', 2nd Ed., Wiley, 2001.



- Similar responses for bi-phase pulse stimulus during frequency sweep: 10 0.1K 1K 3.8K 5K 10K 14K 20K
- † parameters are small
- † magnitude of low frequency components in bi-phase square-wave pulse is small



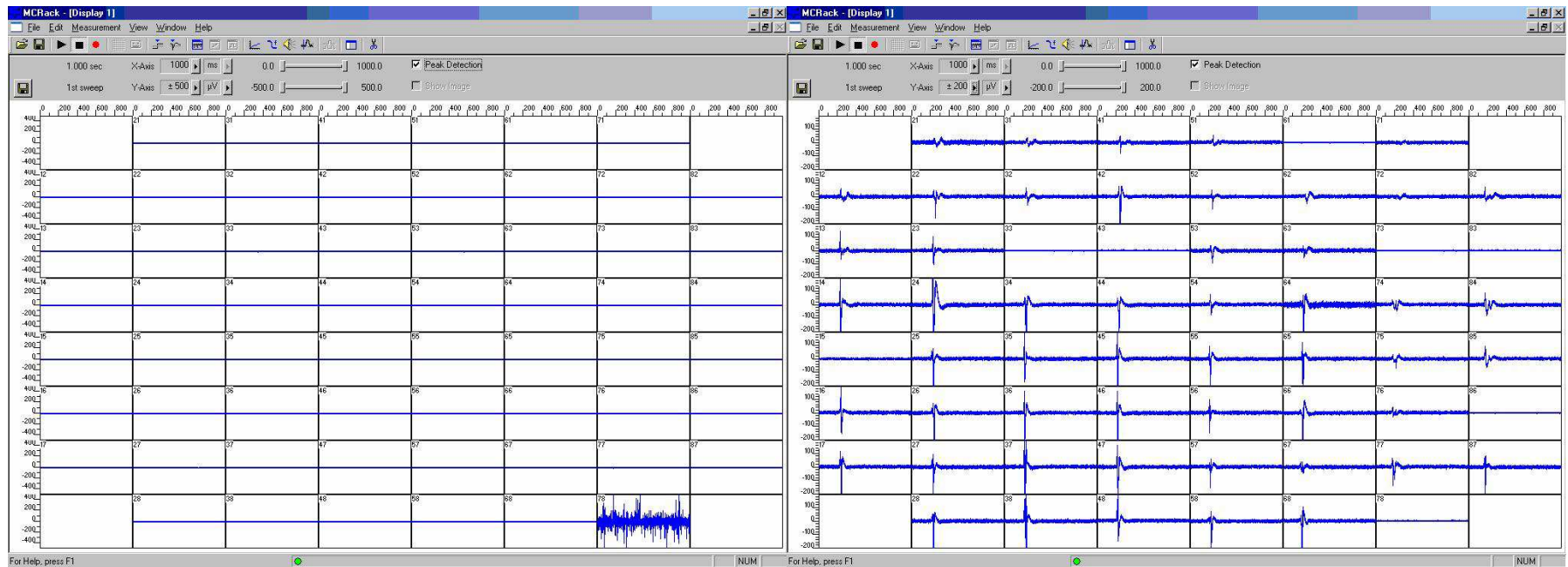
A square-wave pulse (0mV, 100 μ s; 10mV, 100 μ s; -10mV, 100 μ s; 0mV, 100 μ s)

A sine wave with a frequency 10KHz and amplitude 10mV

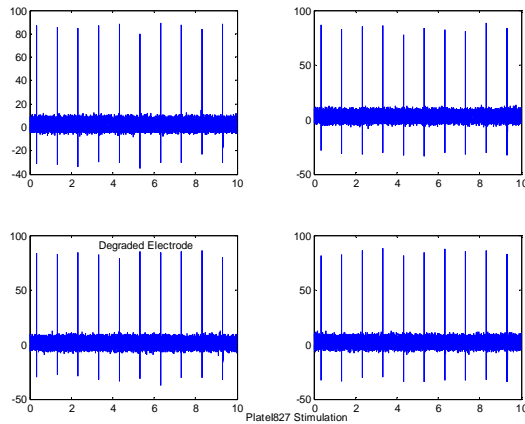
A clear difference of amplitude can be recognized between the fault-free waveform and the faulty one, which is ten times the nominal magnitude of RP_S in the simulation

- Assumption
 - † Only one of the four surrounding electrodes is degraded
 - † Or, all the degraded electrodes do not process in the same way or same rate
- This is reasonable and indeed observed by our project partners from QinetiQ's Winfrith

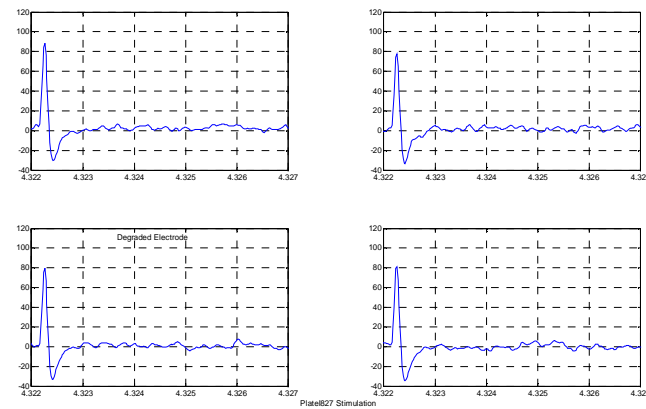
- three possibilities that can result in damage of micro electrodes:
 - † Electrode degradation due to damage during the cleaning and preparation of the MEAs
 - † Fouling of the electrodes by biological material that is not removed completely during cleaning
 - † Material loss of the electrode surface through ion loss into the surrounding liquid medium



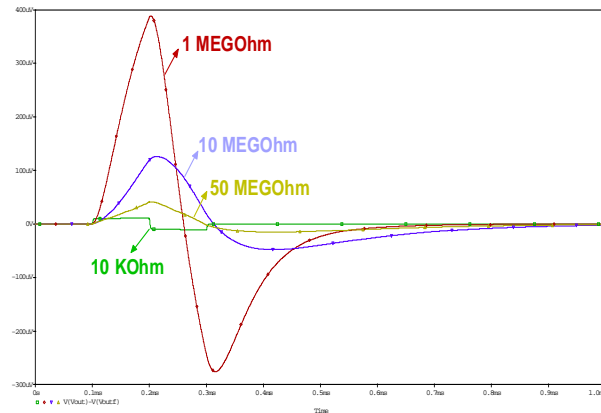
- One with no biological material present and a clear noisy electrode
- One with data from heart cells with varying baseline noise levels



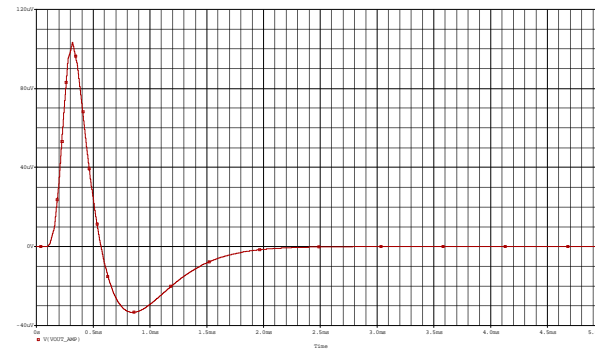
10 pulses



1 pulse – experiment



Load effect



1 pulse – simulation



- The feasibility of testing micro electrode degradation was proved by preliminary simulation results.
- The correctness of a developed equivalent electrical simulation model for MEA platform interface to the experiment electrolyte solution was certified by initial experiment data.
- The assumption was confirmed by professional expertise and the application experience of MEA platform from an end-user

- Fault mechanisms and modelling – based on experiment analysis
 - † electrode degradation
 - † insulating layer damage
 - † dissolved gas
- Validate and optimize the off-line test technique