Date: 7/25/2022

Master Thesis

on

Mechanical resonance of neural interfaces

Analysis of the impact of electrical stimuli and electrode design on the material stability

From September 1, 2022 on

Targeting single and multiple neural signals for the therapy of neuronal disorders e.g. phantom pain, the restoration of lost body functions in neuroprostheses or neuromonitoring requires high spatial resolution and miniaturization of the individual electrode contacts of neural interfaces. The demands of state-of-the-art and future neuronal stimulations and recordings are met by using thin-film technology and MEMS processing to design ultra-thin structures on stiff or flexible substrates in the dimensions down to the nanometer range forming the interface between neurobiology and engineered technology. So far, a possible coupling between the mechanical and structural changes in thin films of neural interfaces under electrical current flow during neural stimulation is still unaddressed and missed in research. Evidence exists that a link between electro-chemical surface reactions and mechanical stress generation and the plastic deformation of thin films exists. Preliminary studies give evidence that faradaic surface reactions during the electrical stimulation of a neural interface electrode can cause -with dimensions in the range of surfaces themselves and preloaded with intrinsic stresses- structural changes and successive plastic deformation following membrane like behavior with resonance oscillations due to the transient of the current pulse.

These studies could pave the way to new electrode design and stimulation pattern solutions to fulfil the pursuit of chronical stability and reliability of neural interfaces in neuroprostheses.

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Aim of this project is the investigation of resonance behavior and its dependency of the mechanical deformation on the engineered design (geometry and topography) and stimulation pulse parameters of thin film electrodes for neural interfaces.

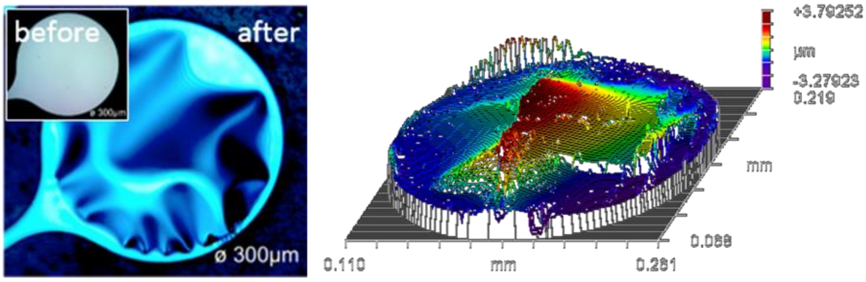

Figure 1: optical microscopy (left) and white-light interferometry (right) of deformed platinum thin-film electrodes through electrical stimulation and accelerated aging.

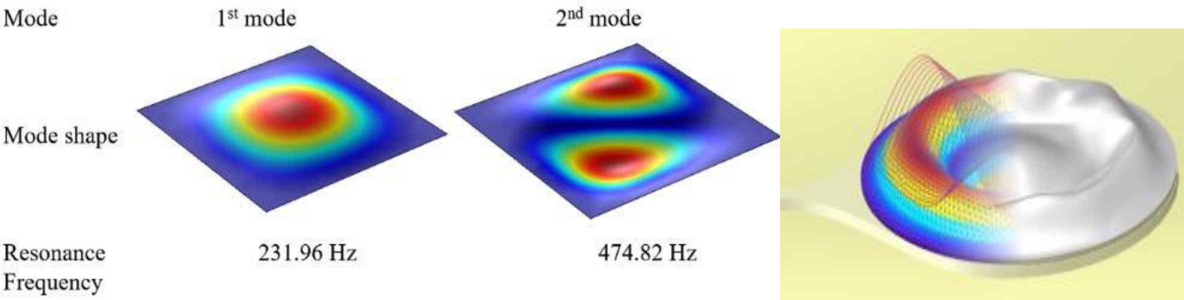

Figure 2: COMSOL simulation of deformation modes in a MEMS mirror at resonances [17] and simulated surface deformation of a thin-film electrode using SOLIDWORKS .

Different designs for electrodes shall be developed and the resonance behavior analyzed using a holographic microscope. A resonance analysis of different stimulation parameters shall give the most preferred pulse forms for material longevity in neural stimulation.

Finally, assumptions on redesign of next generation thin-film electrodes with strategies to compensate for mechanical stress will be developed to target chronical stability and reliability in neural interfaces**.**

The following aspects have to be addressed:

- Literature research in order to gain knowledge on the structure and residual state of stress in thin-films and basics in fundamental electrical stimulation. A special focus is set on to mechanical failure mechanisms (structural and compositional changes, stress corrosion and material fatigue of thin films) and mechanical oscillation resonance appearance depending on the geometric design and correlated to the electrical stimuli pattern (design-resonance-response).
    - Development of different electrode designs (using Autodesk® AutoCAD software).
- Analysis of the surface deformation and resonance behavior for different electrode thin-film designs and geometries in 4D microscopy.
- Analysis of the resonance behavior in 4D microscopy of electrode vibrations for different electrical stimulation parameters.

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