About Impedance Spectroscopy

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by

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Justification

Spectroscopy

Phenomenological: in terms of latin/greek origin

spicere = to watch , skopein = to see

Conceptual:

Spectroscopy = search for resonances in a system

Justification

Conceptually: ”Spectrum” = statistical distribution of resonances of a system over a parameter space like ”energy” or ”frequency” etc.

Impedance Spectroscopy

Measurement of complex resistances with AC techniques.

Investigation of

- Surface / Interface-Properties

- Bulk-Properties of Materials

1. Surfaces (Processes on Electrodes)
    - Adsorption / Reaction Kinetics
    - Double Layer Capacity
2. Volume Properties
    - Conductivities (ionic, electronic)
    - Diffusion Constants

3. Interfaces

   - Size, Resistance and Capacitance of Grain Boundaries

Properties to 1., 2., and 3. are differently frequency dependant and can be separated in the range $10^{-5} \leq f \leq 10^{6}$ Hz.

Theory

Excite a system with AC voltage $U(\omega) = U_o e^{i\omega t}$

System responds with an AC current $I(\omega) = I_o e^{i\omega t + \delta}$

Generally there is a phase shift $\delta \neq 0$ between U and I.

Def.: Impedance $\mathcal{Z}(\omega) = \frac{dU(\omega)}{dI(\omega)} = Z_o\, e^{i\phi} = Z_o \cos\phi - i Z_o \sin\phi$

$Z_o \cos\phi = Z'$, $Z_o \sin\phi = Z''$

Theory

Try to describe a system

- based on parallel and series circuits
- in terms of Resistance, Capacitance, and Inductance
- applying Kirchhoff's laws; $Z_s = \sum_i Z_i$, and $\frac{1}{Z_p} = \sum_i \frac{1}{Z_i}$.

Examples

Studies on porous electrodes (electrochemistry)

Studies on the eigenfrequencies of piezo actuators (dielectric relaxation spectroscopy)

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