Autolab Application Note EIS04

Electrochemical Impedance Spectroscopy (EIS)
Part 4 – Equivalent Circuit Models

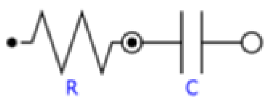
Keywords

Electrochemical impedance spectroscopy; frequency response analysis; Nyquist and Bode presentations; data fitting; equivalent circuit

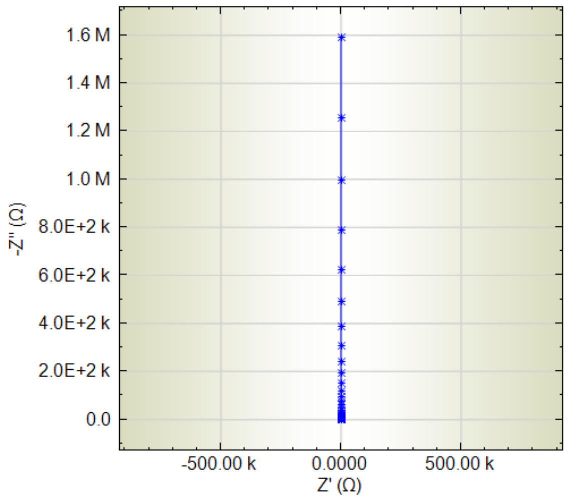
Summary

The passive circuit elements, described in the previous note on data analysis, can be combined in series and parallel to build equivalent circuit models, which can then be used to model the various phenomena going on at the interface. In this note the use of the circuit elements to build models is described.

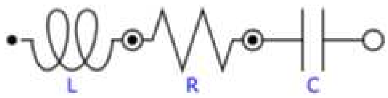
Model 1 – A resistance and capacitance in series



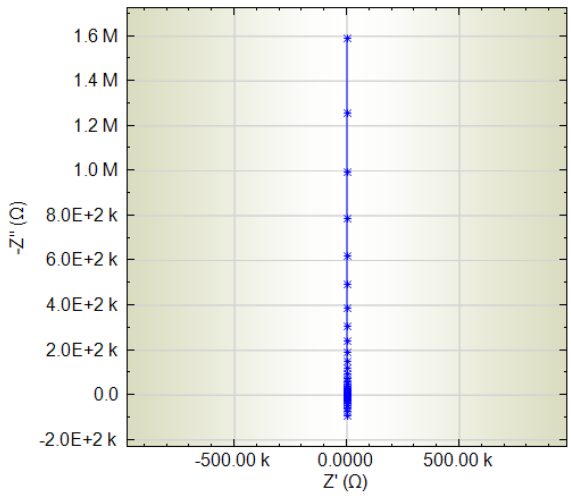
Model 1 can be used, for example, to model a metal with an undamaged high impedance coating.



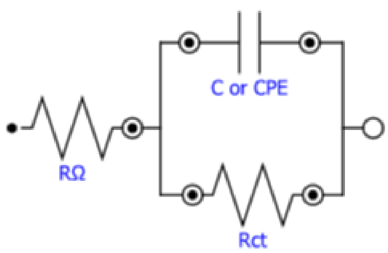
Model 2 – A resistance, a capacitance and an inductance in series



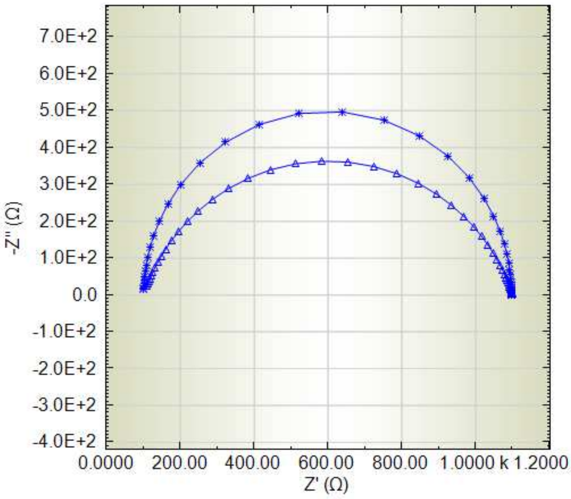
Model 2 can be used to model the response of a supercapacitor.



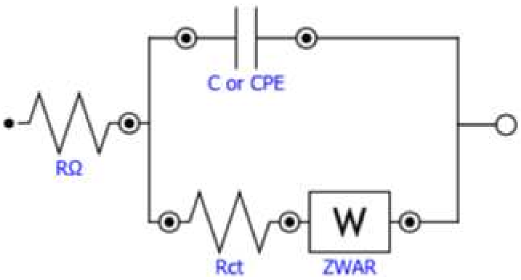
Model 3 – A resistance and a capacitance in parallel (Randles circuit)



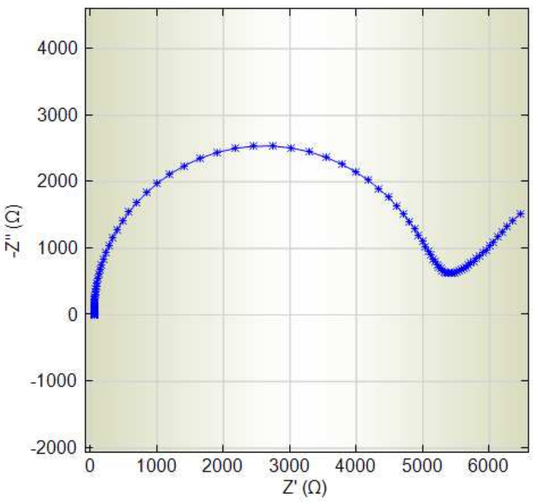
The Randles circuit is one of the simplest and most common cell models. It includes a solution resistance, a double layer capacitor or a CPE and a polarization resistance. It is used to model corrosion processes and is often the starting point for other more complex models.



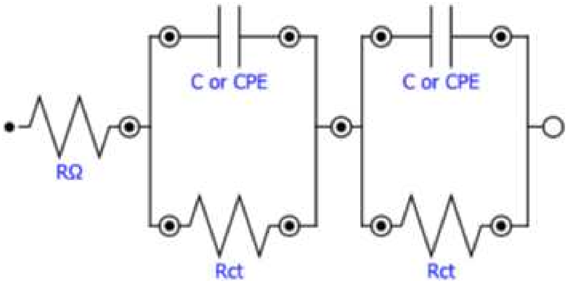
Model 4 – Mixed kinetic and diffusion control



Model 4 can be used to describe electrode processes when both kinetics and diffusion are important.

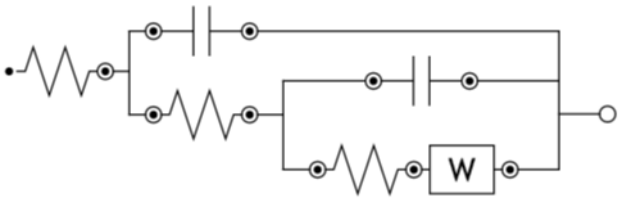


Model 5 – Two Randles circuits in series

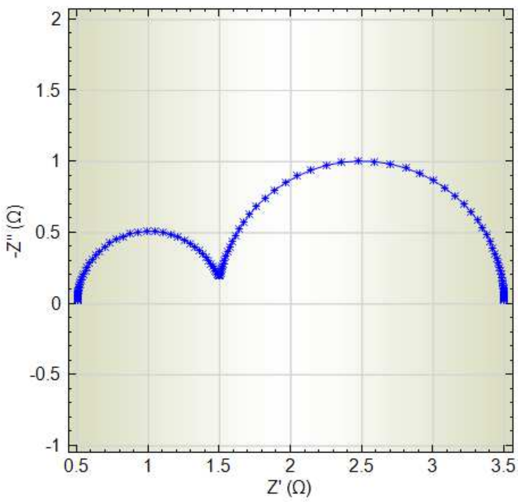


Model 5 can be used, for example, to model the response of batteries.

Model 6 – A complex circuit



Model 6 can be used, for example, to describe the impedance of an organic coating on a metal substrate in contact with an electrolyte.



Non uniqueness of models

It is important to keep in mind that the equivalent circuit modelling is a method that aims at matching a theoretical model of an electrochemical interface with an experimental set of data. Proper assignment of the circuit elements can only be performed when the sufficient information on the chemical and electrochemical phenomena taken place at the interface is available.

Moreover, it is important to keep in mind at all times that several arrangements of circuit elements are possible for a given set of data and that some equivalent circuits are mathematically identical (see application note #15).

Date

1 July 2011