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APPLICATION OF ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY FOR CHARACTERIZATION OF NANOPOROUS FILMS

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ABSTRACT

Electrochemical impedance spectroscopy is a non-destructive method for films characterization. Spectra of electrochemical impedance in encrypted way carry valuable information about thin film physical properties. Revealing this data is a non-routine problem which requires alliance of modeling, computing and careful experimental advances. This short communication provides a brief overview of EIS method with an emphasis of solving mentioned practical problems of thin film characterization.

Keywords: diffusion, electrochemical impedance spectroscopy, porous materials, Nyquist plot, Bode plot, electrochemical impedance

INTRODUCTION

In EIS, variable frequency potential is applied to an electrode covered with the studied sample. Impedance measurements are taken in the solution of an electrolyte. Collected data is presented in two types of graphs: Nyquist and Bode plots which are the imaginary part of impedance vs. real part of impedance, and impedance modulus vs. frequency logarithm, respectively.

Description of the method

EIS allows studying double electric layer at electrode/solution interface when no direct measurements are possible. Nyquist plot is shown in Fig 1. In the particular case shown in

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this figure, the plot consists of a part of semicircle, which is indicative to double electric layer or interphase, and part of a straight line. Equivalent circuits constructed by fitting EIS data contains passive circuit elements: resistor, capacitors, constant phase element and Warburg element. In the equivalent scheme shown in Fig. 2, resistor accounts for solution resistance; the capacitor for double electric layer capacitance, therefore indicating the interface; Warburg element (W.) shown in this figure is an empirical element, which does not have a simple analogue in electronics, It is responsible for diffusion.

W. element allows obtaining main characteristics of the diffusion. If real part of the impedance is plotted at abscises axes, and imaginary part is plotted at ordinate axes, line at 45 degrees at the right hand side of a semicircle is indicative for the diffusion. This line can be fitted by W [1] and establishes correlation between parameters of uniform diffusion and pore size. Solving practical problems, however, non-uniform diffusion frequently takes place. This is the diffusion through ensemble of pores of variable size conditionally varying by length and size. Theoretical basis for solving the mentioned problem suggests [2] with the equation:

$$Z\_0 = [(ZR)]\text{^}(1/2)\ \mathrm{cota}nh[(l] ,$$

where Z_0 measuring impedance, Z impedance of film/solution interface, R ohmic resistance of the interphase, l pore depth, ρ quantity reciprocal to so-called penetration length, which can be linked to diffusion coefficient.

Systematically varying characteristics of pores, electrolyte resistance in pores obtained by electrochemical methods (pore resistance) [3]) can be linked with the characteristics of the diffusion through studied structure and allows to establish correlation between measured characteristics of the diffusion with microscopic characteristic of a sample.

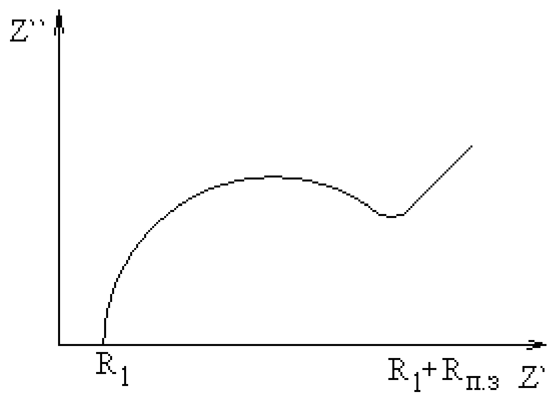

Figure 1. Typical Nyquist plot.

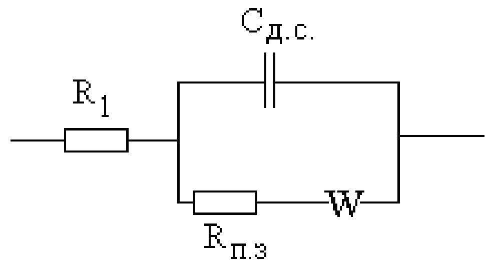

Figure 2. Electrical equivalent schematic fitting of Nyquist plot shown in Figure 1.

CONCLUSION

EIS data contains valuable information about characteristics of nanoporous films. Applying relevant experiment al methods and data analysis allows extracting data about the diffusion through nanoporous film, pore size distribution, diffusion through film different types of ions.

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