VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Meisam Dabiri Havigh**

The public defense will take place on **Thursday 3rd April 2025 at 5pm** in room the **Green Room** (U-Residence, VUB Main Campus)

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DEVELOPMENT OF OPERANDO ORP-EIS FOR MONITORING OF ONGOING ELECTROCHEMICAL PROCESSES

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Abstract of the PhD research

Electrochemistry is a must in modern society since it covers (directly or indirectly) many aspects of our daily needs ranging from energy storage and energy conversion devices (batteries and fuel cells), metal production, and corrosion and corrosion protection technology. Therefore, electrochemical processes are fundamental to many key technologies that drive society. Considering the key role of electrochemical processes in many applications, there is a crucial demand for monitoring and optimizing these systems to enhance their performance, efficiency, and durability. Understanding the dynamic behavior of electrochemical reactions at the electrode-electrolyte interface (where electrochemical reactions occur) is crucial for developing next-generation technologies. This has led to the growing importance of operando techniques, which allow researchers to study electrochemical processes in real time under actual operating conditions, providing deeper insights into material behavior.

Among other electrochemical techniques, electrochemical impedance spectroscopy (EIS) is a powerful technique because it is a frequency-based method that can capture slow and fast-evolving processes in one experiment. The electrochemical process under investigation should satisfy causality, stationarity, and linearity constraints to obtain valid impedance data. To meet these requirements, EIS is applied after occurrence of the electrochemical processes. For example, EIS is measured after anodizing, conversion, cycling of Li batteries, etc. So it is impossible to monitor ongoing electrochemical processes using the classical EIS methodology. To bridge the gap, the EIS methodology should be developed to measure the impedance of the electrochemical processes during their occurrence, not after.

The main goal of this PhD is to extend the application of electrochemical impedance spectroscopy to measure the impedance of electrochemical processes when they are occurring. This is done by developing operando odd random phase electrochemical impedance spectroscopy (ORP-EIS). Various electrochemical processes, including anodizing, conversion, and Li batteries, are investigated to reach the goal.

It has been revealed that the operando ORP-EIS can monitor and give real-time insight into ongoing electrochemical processes, which provides an opportunity to optimize and improve the efficiency of processes. Moreover, this technique is mature enough to move beyond the lab scale and enter industry to be applied in the R&D pilot plants.