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 **Nourhan Abdelrahman**

The public defense will take place on **Monday 1st December 2025 at 4 pm** in room **D.2.01** (Building D, VUB Main Campus)

To join the digital defense, please click here

# A NUMERICAL INVESTIGATION INTO THE LEACHING OF CORROSION INHIBITION PIGMENTS IN A PAINT DEFECT AND THEIR INFLUENCE ON THE ELECTROCHEMISTRY OF ALUMINUM ALLOY CORROSION

## BOARD OF EXAMINERS

**Prof. Herman Terryn**

**Prof. Lincy Pyl**

**Prof. Sebastian Eeltink**

**Prof. Robert G. Kelly**

**Prof. Caterina Zanella**

**Dr. Peter Visser**

## PROMOTORS

**Prof. Mesfin Haile Mamme**

**Dr. Mats Meeusen**

VRIJE UNIVERSITEIT BRUSSEL

# Abstract of the PhD research

Aluminum alloys are extensively used throughout industries. This is due to their favorable strength to weight ratio. As aluminum is a metal, corrosion is one of the main concerns associated with it. However, upon reacting with oxygen, a precipitate layer of aluminum oxide is formed, isolating the alloy surface from the external environment and protecting from the harmful effects of corrosion. However, this layer isn`t stable at all possible environmental conditions and upon removal, aluminum corrosion is intense and could cause damage to structures, loss of money, and even worse, lives.

There are many techniques utilized for corrosion protection. One that has proven effectiveness is the use of protective coatings. The usual coating system consists of multiple layers; each plays a role in the protection scheme. Through isolating the alloy surface from the environmental effects, passive protection is achieved. However, continuous coverage of the surface must be achieved to guarantee the desired result. This is a challenging condition due to the possible damage to the paint system during installation and service time. A potential mitigation strategy involves the incorporation of corrosion inhibiting particles into a designated layer of the coating system, thereby providing an additional protective mechanism. If the coating system is compromised during operation, these inhibitor particles are released towards the exposed aluminum surface to suppress the corrosive reactions occurring and thus restore the surface protection and extend the service life of the system.

To obtain a reliable corrosion inhibitor, extensive performance tests must be conducted in both in controlled laboratory environment and external service environment. This requires long time and high budget. Meanwhile, numerical models such as finite element models are a way to represent real life systems using physical equations and mathematical manipulations. Their use could provide an aiding insight while cutting down the design and testing time. An established numerical model could be used to predict the behavior of different inhibitors and their corrosion protection in different environments and operation conditions.

This PhD aims at developing a modeling tool capable of predicting corrosion protection provided by an active protection scheme including inhibitors. Finite modeling techniques are utilized to consider the processes of dissolution of the inhibitors, their diffusion, and the changes reflected in the electrochemical reactions near an aluminum alloy 2024-T3. Some perspective changes in the environmental conditions are included in the model's physics. This model accounts for the concentration and movement of the different ions and their chemical interactions through the different solution domains. Eventually, the model solves the overall operation of the coating system.