Corrosion study of the BR1 fuel in highly alkaline conditions

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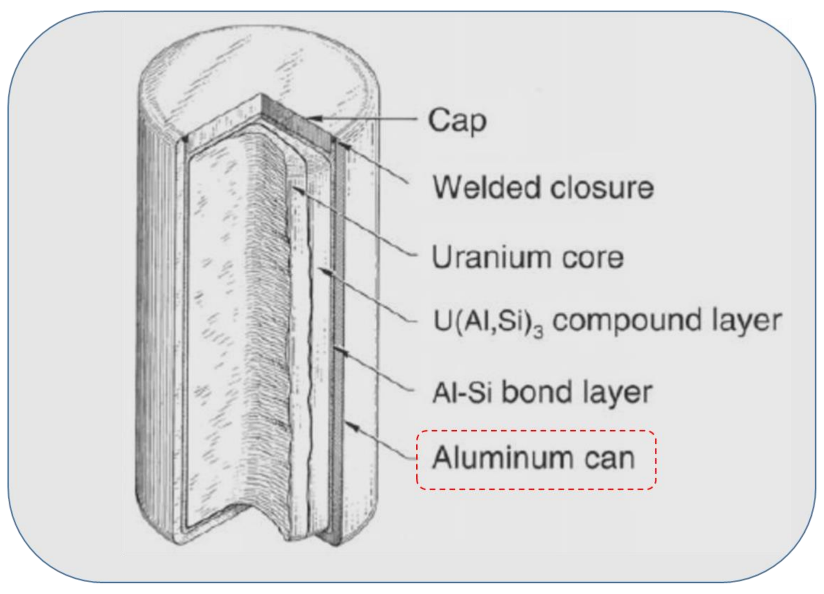
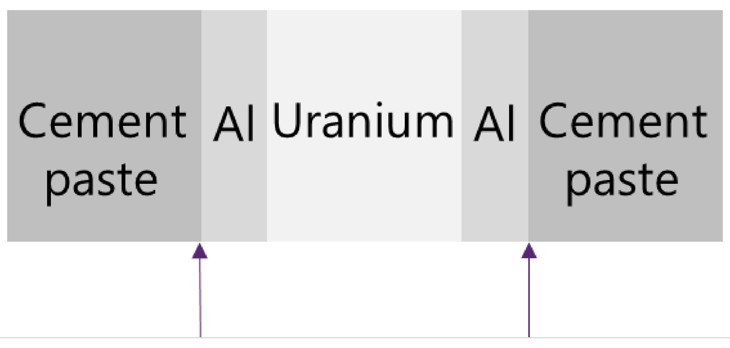
Introduction

Al-1100 is used as the fuel cladding material to separate the inner uranium fuel and outer coolant in the Belgian Reactor 1 (BR1). One feasible solution for the long-term management of BR1 fuels, which will eventually become waste, is the geological disposal, and one of the possible options could be a direct embedding of these spent fuels in a cement-based material.

BR1 fuel structure





The key problem: the corrosion of Al layer in the highly alkaline cementitious matrix

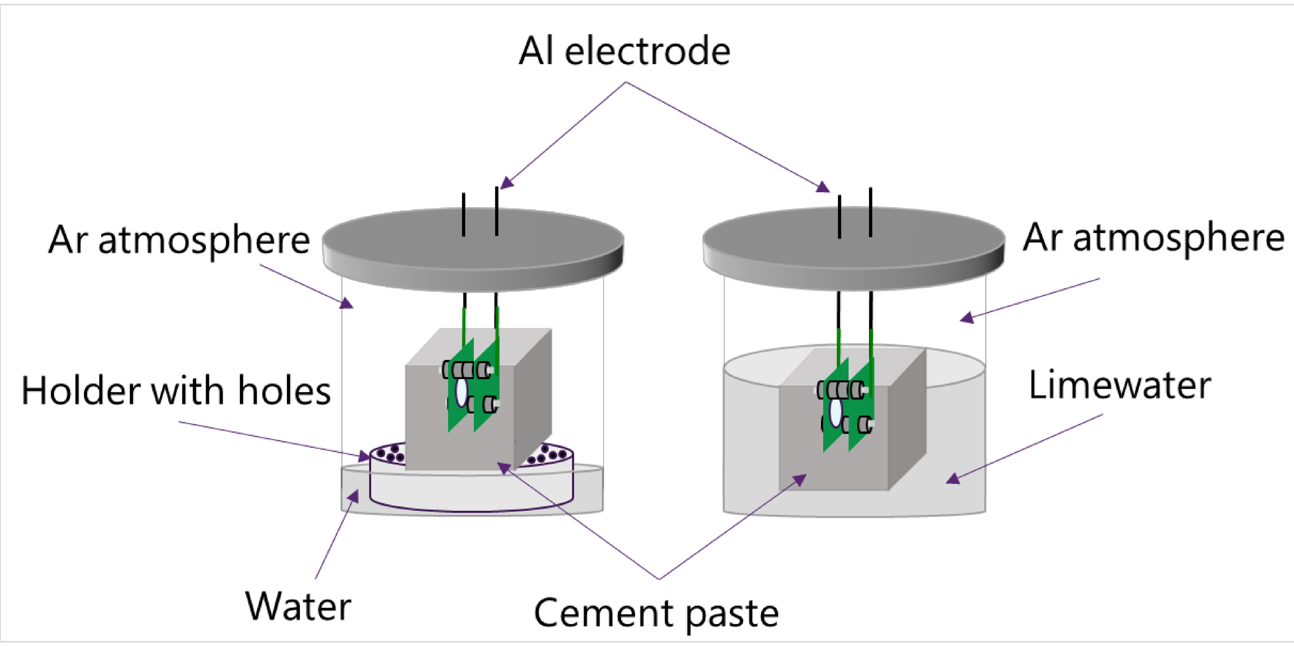
Al corrosion equation in highly alkaline conditions:

$$Al + 3H_2O + OH^- \rightarrow Al\,(OH)_4^- + \frac{3}{2}H_2\uparrow$$

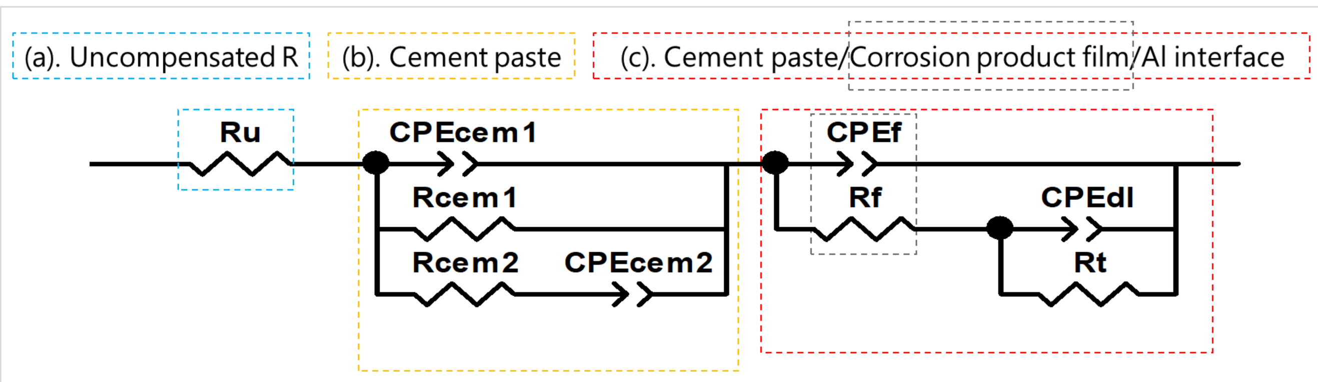
Methods

In this research, a combination of electrochemical techniques (EIS, Tafel plots) and GC, SEM and MIP were used to determine the corrosion rate of Al and to understand the physicochemical behaviour of the system.

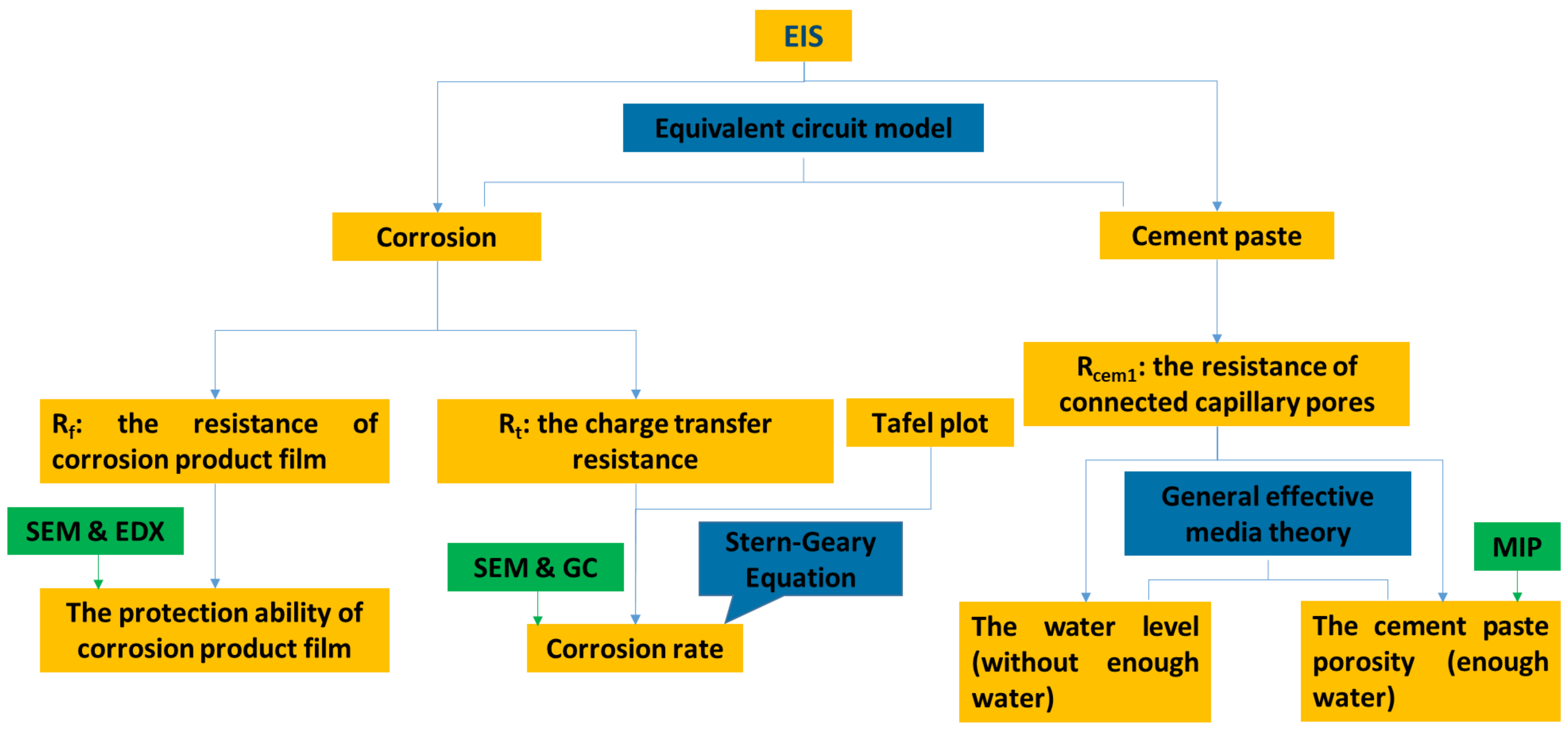
- Sample configurations and the curing environments



- Equivalent circuit model of EIS fitting



- Methodology in this project

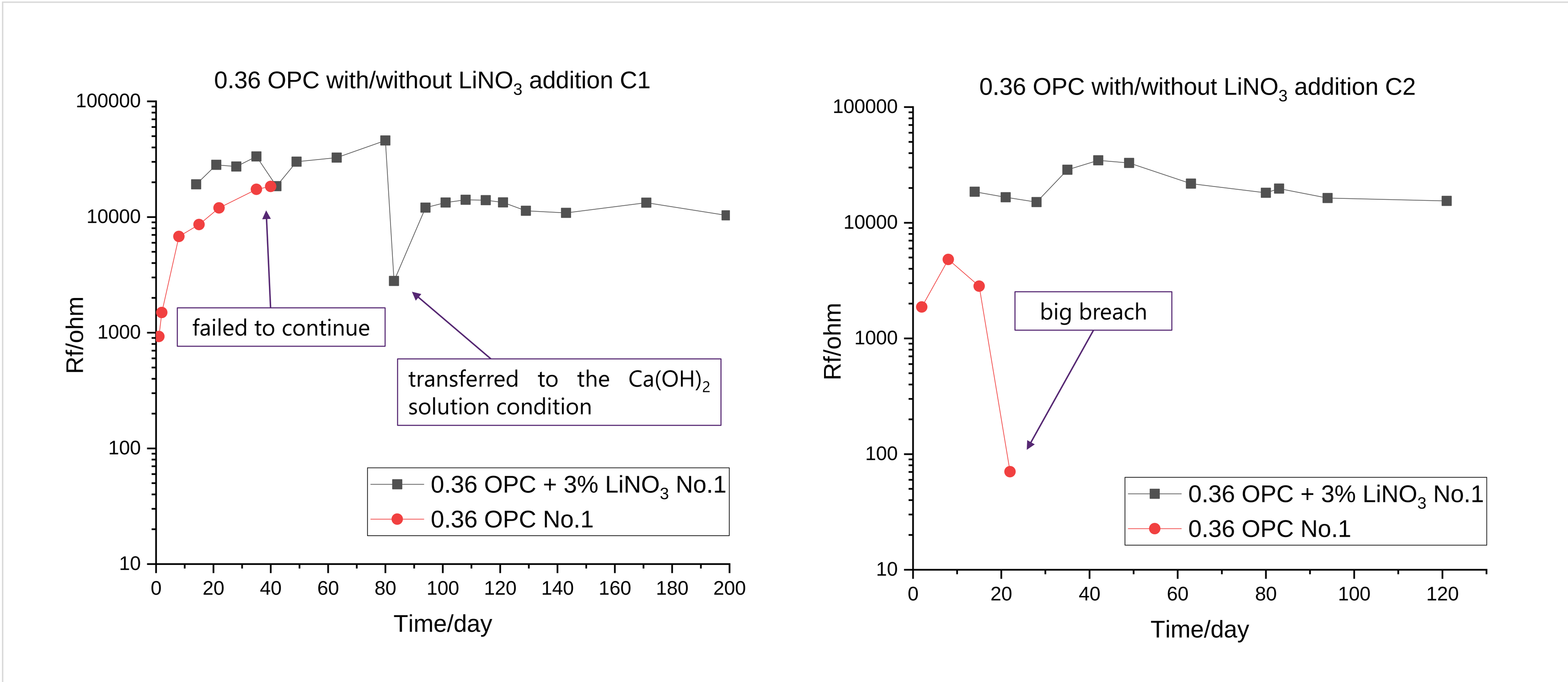


Conclusion

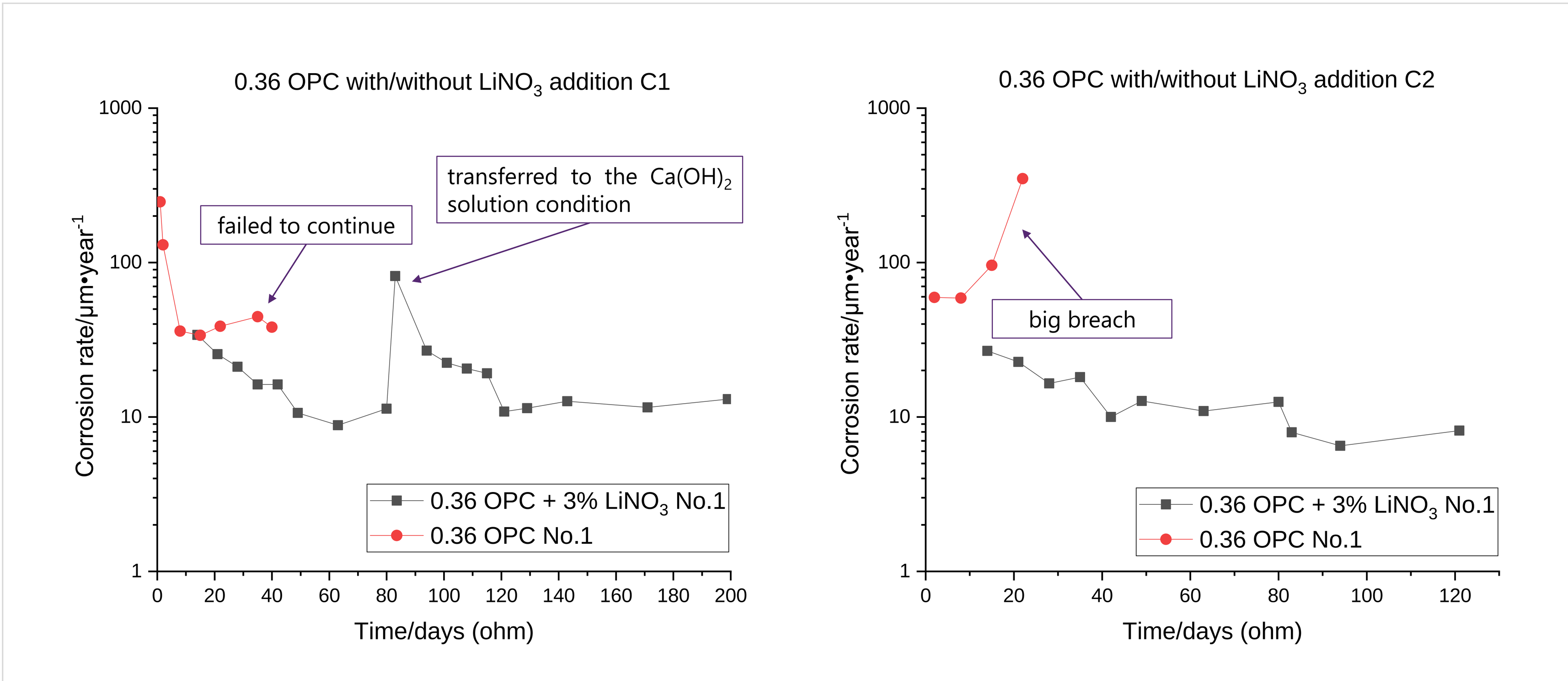
- $LiNO_3$ seems to be an adequate corrosion inhibitor for Al in OPC paste.
- After about 50 days, Al in 0.36 OPC+3% $LiNO_3$ cement paste reaches a steady state corrosion rate of about 15 μm·year^{-1}.
- The intrusion of underground water will lead to a sharp increase of the corrosion rate. However, the corrosion rate is found to quickly decrease to its original level.
- EIS seems to be a powerful tool that is capable to monitor both the corrosion rate and cement paste porosity simultaneously.

Results

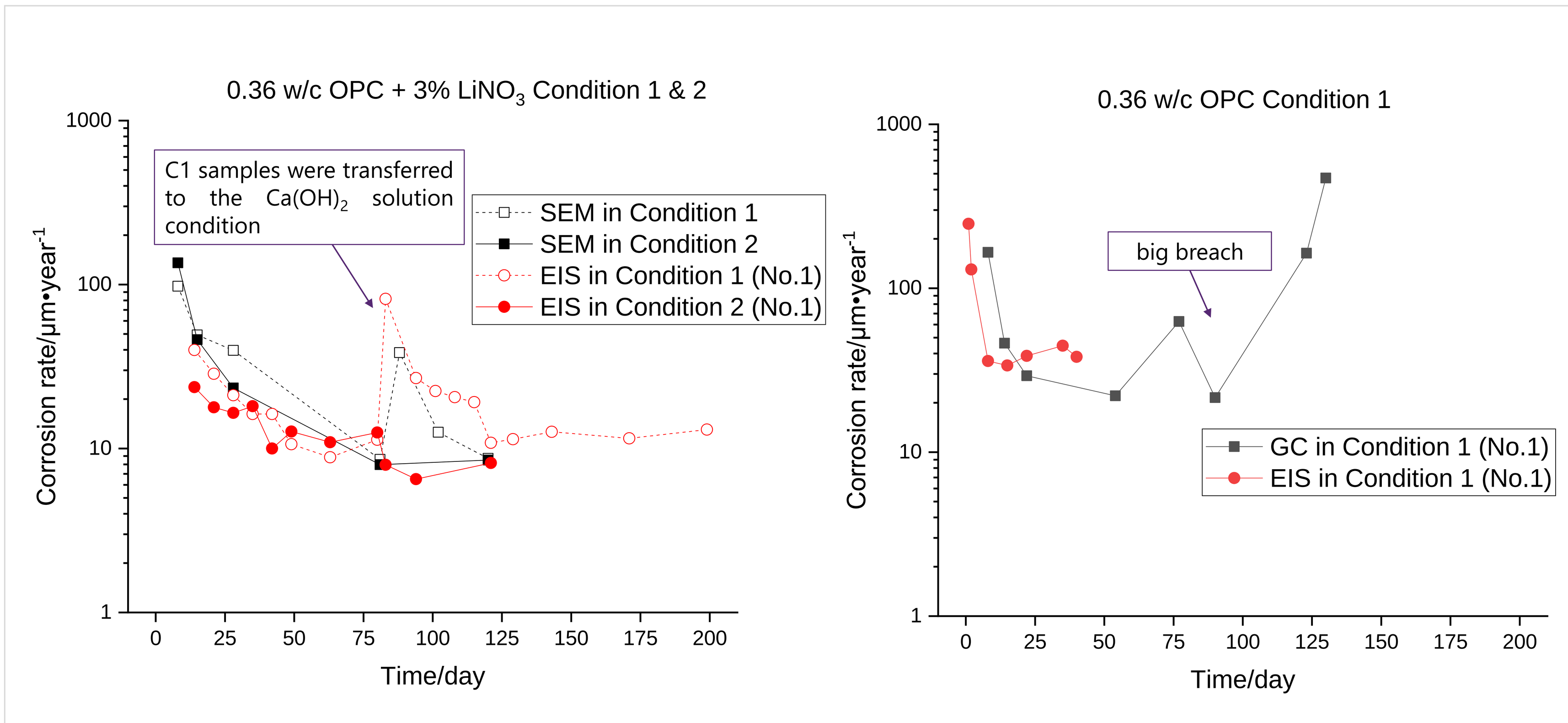
- Variation of R_f values (the resistance of corrosion product film) obtained from EIS fitting: it reveals the protection ability of the corrosion product film to some extent.



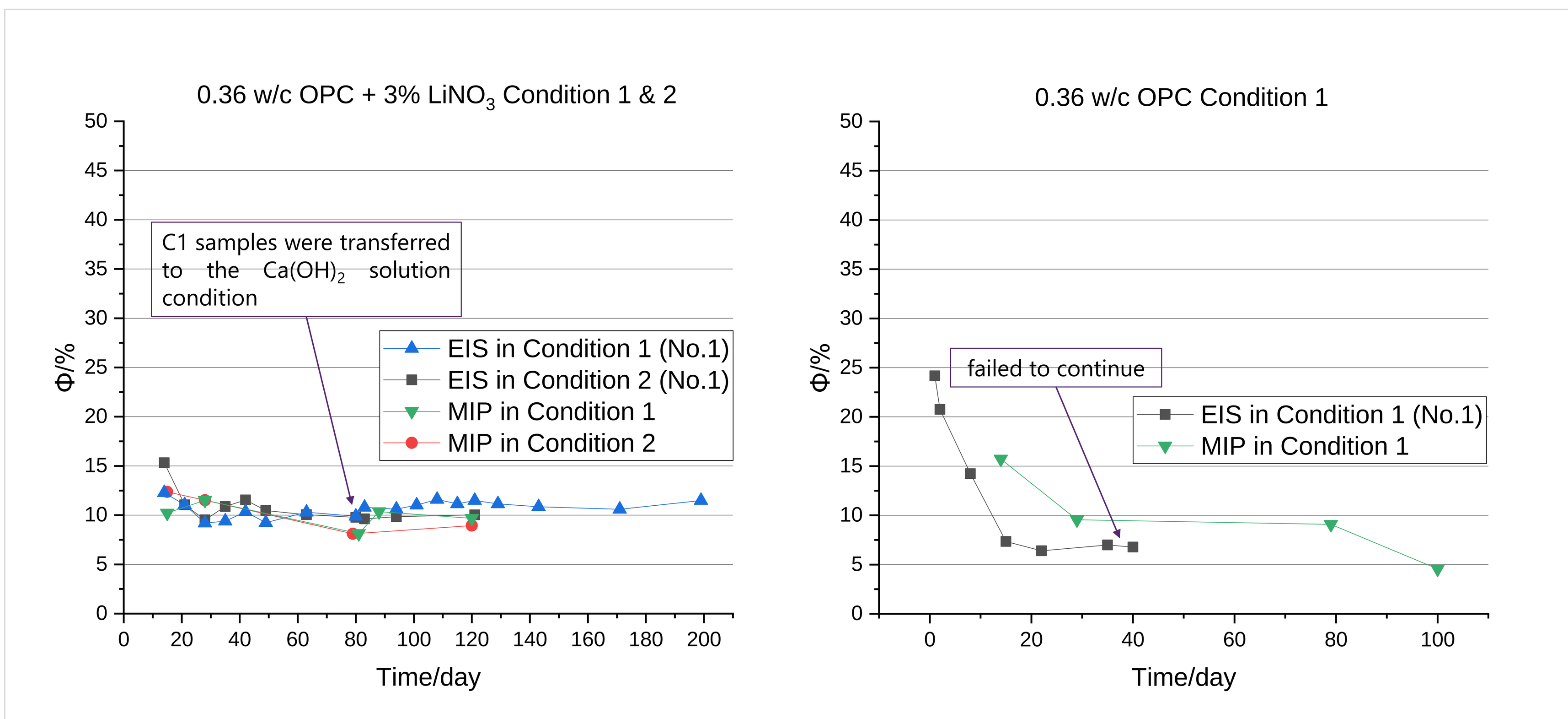
- Variation of the corrosion rate calculated from R_t values (obtained from EIS fitting): a quantitative indicator of the corrosion process



- Comparison of corrosion rate values obtained from EIS, SEM & GC: different techniques give similar corrosion results



- The comparison of cement paste porosity values obtained from EIS and MIP: the porosity results obtained from EIS is verified by MIP



(Note): The proposed approach and obtained results in no way entail a decision of O/N whatsoever on this approach as a solution for the long-term management of this waste.

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